

# Digestive Physiology of Pigs



**XII INTERNATIONAL SYMPOSIUM ON  
DIGESTIVE PHYSIOLOGY OF PIGS**

**PROGRAM AND  
BOOK OF ABSTRACTS**

**KEYSTONE RESORT AND CONFERENCE CENTER**

**KEYSTONE, CO, USA**

**MAY 29–JUNE 1, 2012**



The Chemical Company

## **BASF Animal Nutrition**

is proud to be the exclusive  
Diamond Sponsor of the  
*12<sup>th</sup> International Symposium  
Digestive Physiology of Pigs*

For more information on our products, visit

[www.animal-nutrition.basf.com](http://www.animal-nutrition.basf.com)

## CONTENTS

Preface.....	3
International Steering Committee.....	5
Local Organizing Committee.....	5
Acknowledgments.....	7
Meeting at a glance.....	9
Maps.....	11, 13
Program.....	15
List of Abstracts.....	21
Abstracts.....	37



Grilled Pork Chops  
with Basil-Garlic Rub



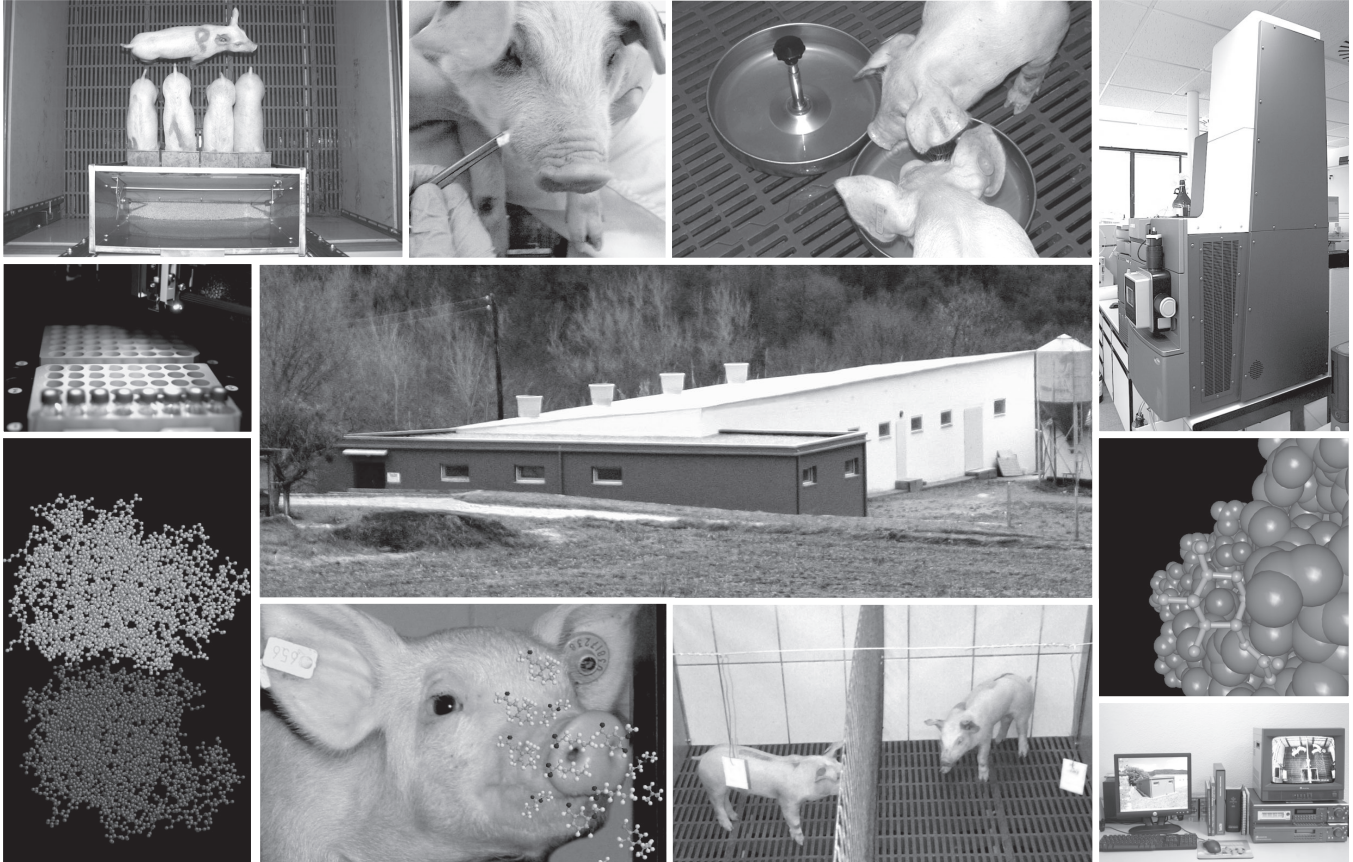
**Be inventive**

With pork chops, it's easy to go beyond the expected. These Grilled Pork Chops with Basil-Garlic Rub are tender, juicy, and deliciously different. Learn more about the versatile chop at [PorkBelInspired.com](http://PorkBelInspired.com)

**pork**  
**Be inspired**  
[PorkBelInspired.com](http://PorkBelInspired.com)

**pork checkoff** ©2012 National Pork Board, Des Moines, IA USA. This message funded by America's Pork Producers and the Pork Checkoff.

# The Key to Performance...



## ...is Research

Developing innovative solutions for optimal feed palatability and performance of young pigs in Lucta's Swine Research facilities

Proud sponsor of the 12th International Symposium on Digestive Physiology in Pigs and the Pre-Conference Symposium on "Gut Chemosensing"

<http://www.lucta.com>



Creating trust



## PREFACE

On behalf of the Local Organizing Committee, we are happy to welcome you to the beautiful venue of Keystone, Colorado, USA, for the 12th International Symposium on Digestive Physiology of Pigs (DPP 2012). This event has grown to become the premier event where discussions focus specifically on various aspects of digestive physiology in the pig. Your involvement in this symposium testifies to the value of the information that will be presented and discussed as well as builds the impact of the meeting for future scientists.

More than thirty years ago, in 1979, Dr. R. Braude organized the first International Symposium on Digestive Physiology of Pigs in Shinfield, Reading (UK). Subsequently, symposia have been held triennially in France, Denmark, Poland, The Netherlands, Germany, France, Sweden, Canada, Denmark, and Spain. The number of participants and of scientific reports has increased substantially during this time. This symposium is now globally considered one of the most important. Although it started as a European symposium, it has clearly gained importance beyond European boundaries to a worldwide dimension, as shown by the increasing number of presenting and attending scientists from both academia and industry in many non-European countries. We have 251 abstracts being presented at this symposium from 19 countries and 373 attendees from 29 countries.

The Symposium this year will consist of five plenary sessions with the following themes: (1) gut microbiome and the host response, (2) nutrient digestion and absorption, (3) mucosal immunity and pathogenesis, (4) neonatal development of digestive and absorptive capacity, and (5) long-term effects of pre- and early-postnatal nutrition/environment. Each session will be introduced by an invited speaker and followed by selected oral communications, selected from over 250 submitted papers. Our invited speakers represent 6 countries, and the oral communications represent 11 countries. In addition, two theme areas (Methodologies and Application, and Manipulation of Digestion) will be highlighted with concurrent poster discussion sessions wherein a discussion leader will guide discussion of key posters. The symposium this year will actually start on May 29 with a pre-conference symposium on "Gut chemosensing: Integrating nutrition, gut function, and metabolism in pigs" that is sponsored by Lucta S.A. Thus, we have a focused symposium from a diversity of research groups and disciplines.

The organizing committee hopes that as you participate with us and our international colleagues, you find DPP 2012 to be useful and productive professionally while also being enjoyable personally.

Merlin Lindemann and John Patience  
Co-Chairs

**It's about you.  
It's about  
your business.**



## The power of *Full Value Pigs*™

**It's about working together to find you more profit.**

*Full Value Pigs* is more than a metric or a tool. It's a set of beliefs that together, we can make your business better. It's about taking a holistic approach to disease management and herd health. It's about feed optimization and getting the most out of your biggest input. It's about marketing your pigs at the right weight and at the right time, giving you a precision harvest. It's about access and the assurance that you'll be able to sell your products to your preferred buyer. It's about feeding the world. But most of all, *Full Value Pigs* is about growing your business.

© 2011 Elanco Animal Health. All rights reserved. Elanco®, *Full Value Pigs*™ and the diagonal color bar are trademarks of Eli Lilly and Company.  
GMS 0031

**Elanco**

## INTERNATIONAL STEERING COMMITTEE

Prof. M. D. Lindemann, University of Kentucky, USA  
Dr. K. E. Bach Knudsen, Aarhus University, Denmark  
Dr. R. Ball, University of Alberta, Canada  
Dr. J. Brufau de Barbera, IRTA-Mas de Bover, Spain  
Dr. C. F. M. De Lange, University of Guelph, Canada  
Dr. N. Dierick, Ghent University, Belgium  
Dr. J. Freire, Instituto Superior de Agronomia, Portugal  
Dr. A. J. M. Jansman, Wageningen UR, The Netherlands  
Dr. P. Leterme, Cargill, Belgium  
Prof. J. E. Lindberg, Swedish University of Agricultural Science, Sweden  
Dr. C. H. Malbert, INRA Rennes, France  
Dr. R. Mosenthin, University of Hohenheim, Germany  
Prof. A. Piva, University of Bologna, Italy  
Dr. J. Pluske, Murdoch University, Australia  
Dr. R. Zabielski, Warsaw University of Life Sciences, Poland

## LOCAL ORGANIZING COMMITTEE

Dr. Merlin D. Lindemann, University of Kentucky, USA (Co-chair)  
Dr. John F. Patience, Iowa State University, USA (Co-chair)  
Dr. Layi Adeola, Purdue University, USA  
Dr. Diego Braña, National Research Institute for Forestry, Agriculture and Livestock, Mexico  
Dr. Doug Burrin, Baylor College of Medicine, USA  
Dr. Tom Burkey, University of Nebraska, USA  
Dr. Nick Gabler, Iowa State University, USA  
Dr. Brian Kerr, ARS, USDA, USA  
Dr. Kees de Lange, University of Guelph, Canada  
Dr. Gerardo Mariscal-Landin, National Research Institute for Forestry, Agriculture and Livestock, Mexico  
Dr. Rob Payne, Evonik, USA  
Dr. Chad Risley, Lucta, USA  
Dr. Hans Stein, University of Illinois, USA  
Dr. Andrew Van Kessel, University of Saskatchewan, Canada  
Dr. Ruurd Zijlstra, University of Alberta, Canada



Pancosma  
just makes sense

*Discover our ranges of additives  
dedicated to animal nutrition on  
[www.pancosma.com](http://www.pancosma.com)*



## ACKNOWLEDGMENTS

We would like to express our appreciation to all those who contributed to the success of this Symposium. The Local Steering Committee provided tremendous assistance in everything from fundraising to program development to publications/editorial review to registration; their commitment of time and energy was essential to the success of this conference and will be reflected throughout the next three days.

We want to acknowledge the essential role of the Federation of Animal Science Societies (FASS) in the development and maintenance of the website, registration, accounting, receiving and processing of abstracts and papers and printing of this program booklet. Conference Direct provided efficient and professional assistance in venue selection and on-site management, including serving as a liaison between Keystone and attendees, planning all menus and the gala and general overall logistics. We also want to acknowledge the support of the American Society of Animal Science for its encouragement of our initial hosting of the meeting and for publishing the papers in a special e-supplement of their journal. We could not have been successful without these three organizations lending their expertise to the excellence of our conference.

Thank you especially to all of our sponsors for their generous financial support. Without them, the registration fee would have been much, much higher and the quality of the program much lower.

Finally, we truly appreciate how accommodating the staff at Keystone Resort and Conference Center has been throughout the planning and organization of this event.

Merlin Lindemann and John Patience  
Co-Chairs



Elanco would like to extend two welcomes: First, **to all the participants and guests** at this year's symposium. We'd also like to welcome **our newest partner, ChemGen**, to Elanco.

ChemGen is a bioscience company specializing in feed enzyme products that improve efficiency in swine production. When it comes to improving the health and performance of swine, Elanco and ChemGen have both been active industry leaders. ChemGen's products support Elanco's goal of using innovation to meet the world's growing demand for food. We're energized about the future of animal health and performance. We hope you are, too.



**ChemGen**

Elanco®, ChemGen® and the diagonal bar are trademarks owned or licensed by Eli Lilly and Company, its subsidiaries or affiliates.

© 2012 Elanco Animal Health. All rights reserved.

USSBUN0N00165

## MEETING AT A GLANCE

Day/Time	Tuesday May 29	Wednesday May 30	Thursday May 31	Friday June 1
8:00 am		Welcome		Concurrent poster discussion sessions 1 & 2
9:00 am		Session I Columbine Ballroom	Session III Columbine Ballroom	Columbine Ballroom/ Colorado Rockies Ballroom
10:00 am		Poster Session I with authors Viewable 8 am - 6 pm Quandry Peak	Poster Session III with authors Viewable 8 am - 6 pm Quandry Peak	Session V Columbine Ballroom
11:00 am		Session I cont'd	Session III cont'd	Poster Session V with authors Viewable 8 am - 2 pm Quandry Peak
12:00 pm		Lunch Shavano Foyer and Terrace	Lunch Shavano Foyer and Terrace	Lunch Shavano Foyer and Terrace
1:00 pm	Pre-Conference Symposium Columbine Ballroom	Session II Columbine Ballroom	Session IV Columbine Ballroom	Session V cont'd
2:00 pm				Concluding Remarks
3:00 pm		Poster Session II with authors Viewable 8 am - 6 pm Quandry Peak	Poster Session IV with authors Viewable 8 am - 6 pm Quandry Peak	
4:00 pm		Session II cont'd	International Steering Committee Meeting	
5:00 pm				
6:00 pm	Reception Shavano Foyer and Terrace			
7:00 pm		Dinner Keystone Lodge Ball- room, Third Floor	Gala Dinner Keystone Stables	
8:00 pm				
9:00 pm				

**THE NEXT  
HALF-CENTURY  
OF PROGRESS  
STARTS HERE.**

**PIC  
50**

**Years**

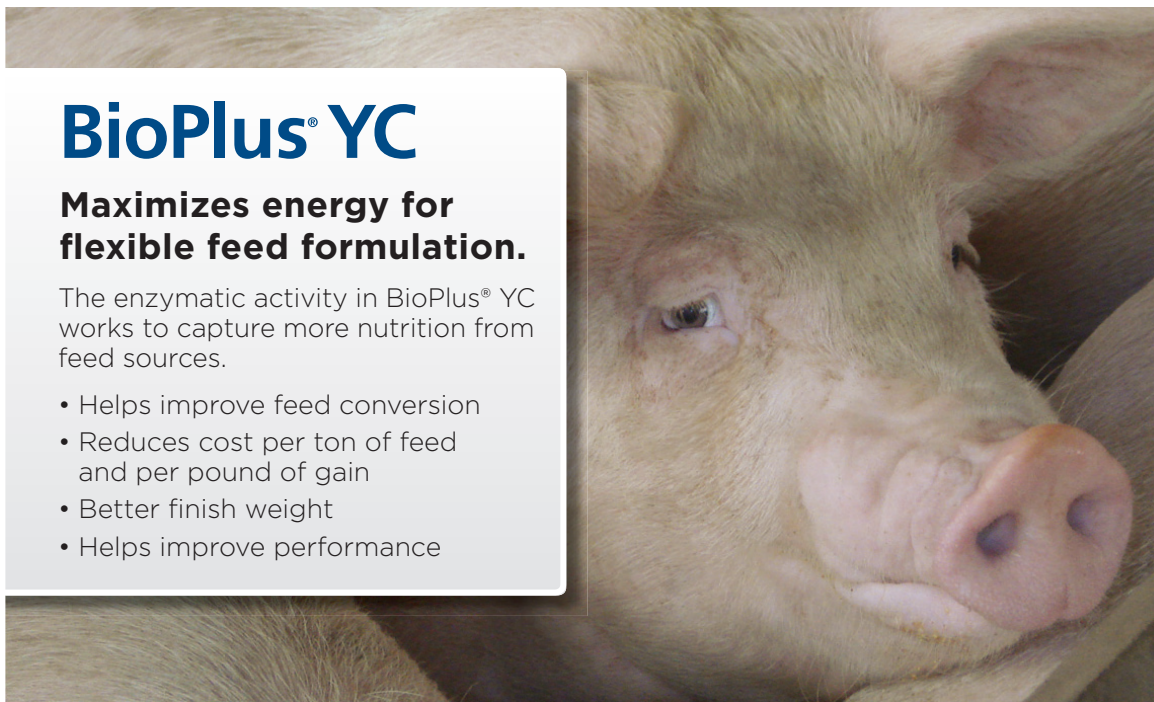
**1962-2012**

## **BioPlus® YC**

**Maximizes energy for  
flexible feed formulation.**

The enzymatic activity in BioPlus® YC works to capture more nutrition from feed sources.

- Helps improve feed conversion
- Reduces cost per ton of feed and per pound of gain
- Better finish weight
- Helps improve performance



**CHR HANSEN**

*Improving food & health*

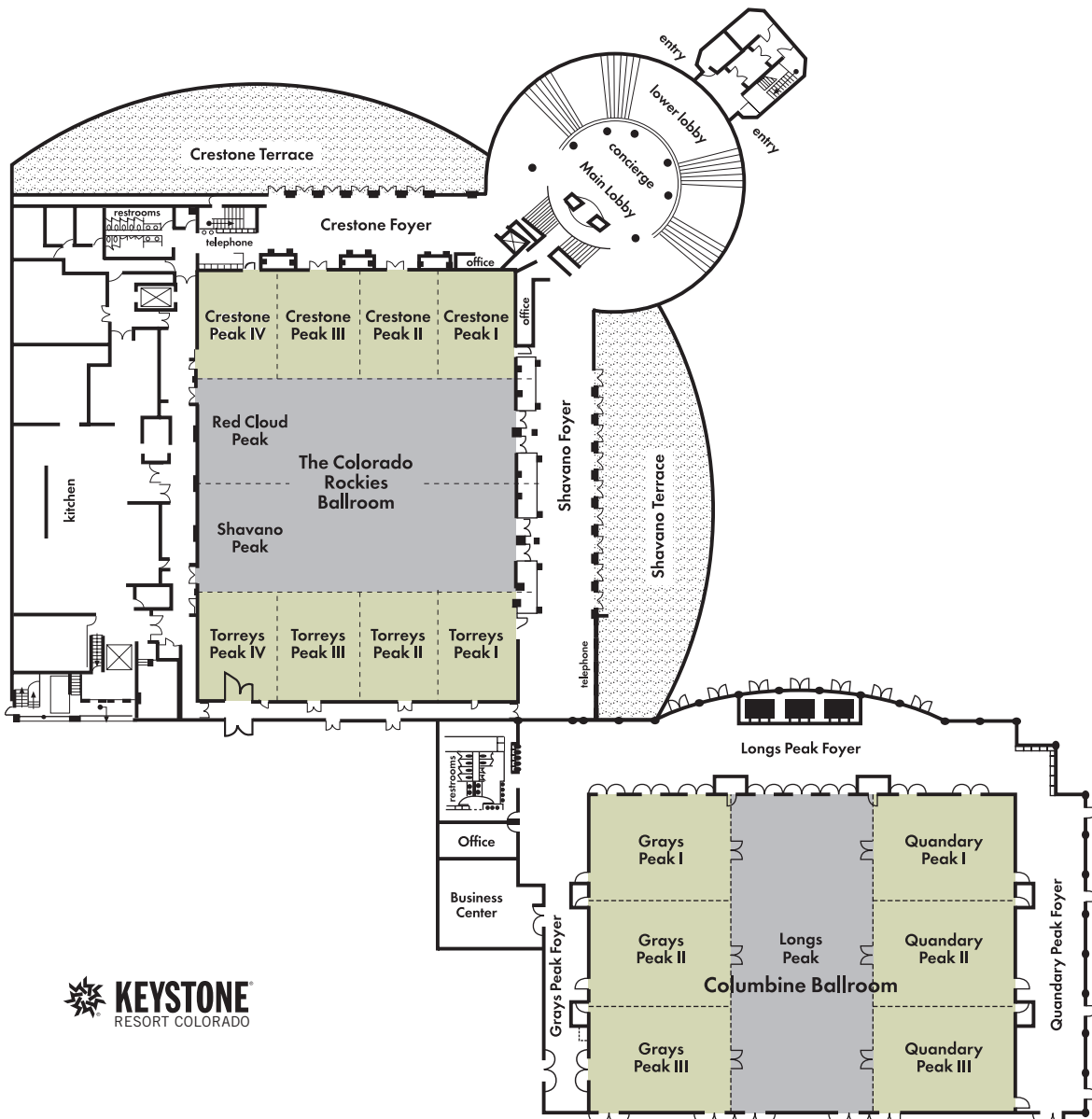
[www.chr-hansen.com/animal-health](http://www.chr-hansen.com/animal-health)





# MAPS

## FIRST FLOOR CONFERENCE MEETING ROOMS AND BALLROOMS

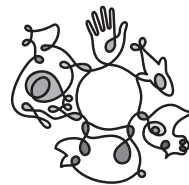




## ADM is a proud sponsor of Digestive Physiology of Pigs 2012.

For more than a century, the people of Archer Daniels Midland Company (NYSE: ADM) have transformed crops into products that serve vital needs. Today, 30,000 ADM employees around the globe convert oilseeds, corn, wheat and cocoa into products for food, animal feed, industrial and energy uses.

With more than 265 processing plants, 400 crop procurement facilities, and the world's premier crop transportation network, ADM helps connect the harvest to the home in more than 160 countries. For more information about ADM and its products, visit [www.adm.com](http://www.adm.com).

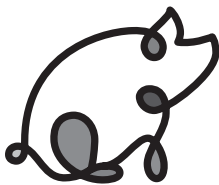


**Jefo**  
Species-specific additives

### **PORCINAT+™ | Organic Acids + Essential Oils**

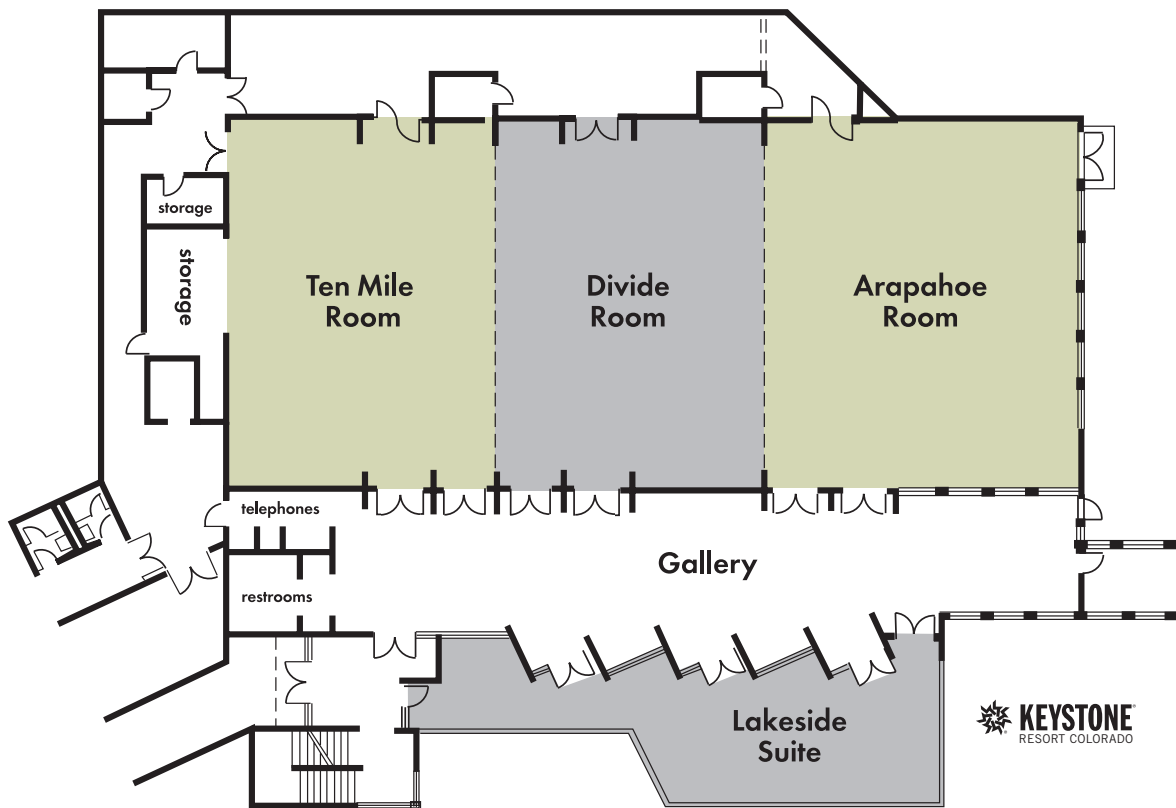
**Jefo** is an industry leader in non-medicated high-performance additives, committed to the livestock feed industry since 1982.

In the last 30 years, our involvement in research has resulted in innovation; our products have been designed specifically for each species and have shown that they **make a significant difference on farms.**



[jefo.com](http://jefo.com)

THIRD FLOOR MEETING ROOMS



**AJINOMOTO®**

**AJINOMOTO HEARTLAND, INC.**

**Proud Sponsor of DPP 2012**



**EVONIK**  
**INDUSTRIES**

**Proud Sponsor of DPP 2012**



## PROGRAM

**2012 Digestive Physiology of Pigs Conference**  
**Keystone Resort, Keystone, CO, USA**  
**May 29 to June 1, 2012**

### Tuesday, May 29

- 1:00 pm to 6:00 pm Pre-Conference Symposium  
(Columbine Ballroom)
- 6:00 pm Reception  
(Shavano Foyer and Terrace)

### Wednesday, May 30

- 8:30 am **Welcome**  
*Dr. Merlin Lindemann, University of Kentucky, Co-Chair, Organizing Committee*  
(Columbine Ballroom)
- Session I: Gut Microbiome and Host Response**
- Session Chair:** Dr. Andrew van Kessel, *University of Saskatchewan*  
(Columbine Ballroom)
- 8:45 am to 9:30 am **Keynote Speaker: Microbiomics of monogastric farm animals.**  
*Dr. Hauke Smidt, Wageningen University, Wageningen, The Netherlands*
- 9:30 am to 9:45 am Discussion
- 9:45 am to 10:00 am **Influence of diets high in fermentable carbohydrates or protein on large intestinal microbial ecology, mucosal response, and urinary metabolomic profiles in piglets.**  
*R. Pieper\*<sup>1</sup>, K. Neumann<sup>2</sup>, S. Kroeger<sup>1</sup>, J. F. Richter<sup>3</sup>, J. Wang<sup>4</sup>, L. Martin<sup>1</sup>, J. Bindelle<sup>5</sup>, J. K. Htoo<sup>6</sup>, W. Vahjen<sup>1</sup>, J. Zentek<sup>1</sup>, and A. G. Van Kessel<sup>4</sup>, <sup>1</sup>Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany, <sup>2</sup>Department of Biometry and Clinical Epidemiology, Charité, Berlin, Germany, <sup>3</sup>Institute of Clinical Physiology, Charité, Berlin, Germany, <sup>4</sup>Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, <sup>5</sup>University of Liège, Gembloux Agro-Bio Tech, Animal Science Unit, Gembloux, Belgium, <sup>6</sup>Evonik Industries, Hanau-Wolfgang, Germany.*
- 10:00 am to 10:05 am Discussion
- 10:05 am to 10:20 am **Differences in core microbiota between P1 and P3 dams and their progeny.**  
*E. E. Hinkle\*, S. Ferando, and T. E. Burkey, University of Nebraska-Lincoln, Lincoln, NE, USA.*
- 10:20 am to 10:25 am Discussion
- 10:25 am to 11:10 am Break  
(Quandry Peak) *Abstract authors present at posters for discussions during break (Abstract section #1)*

- 11:10 am to 11:25 am **EGF-expressing *Lactococcus lactis* enhances growth performance of early-weaned pigs fed diets devoid of blood plasma.**  
*A. Bedford*<sup>\*1</sup>, *Z. Li*<sup>2</sup>, *M. Li*<sup>2</sup>, *S. Ji*<sup>2</sup>, *C. F. M. de Lange*<sup>1</sup>, and *J. Li*<sup>1</sup>, <sup>1</sup>*Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada,* <sup>2</sup>*INVE, Shenzhen, China.*
- 11:25 am to 11:30 am Discussion
- 11:30 am to 11:45 am **An *Escherichia coli* F18 challenge model in newborn pigs.**  
*M. L. Jensen, M. S. Cillieborg*<sup>\*</sup>, *M. V. Østergaard, S. B. Bering, and P. T. Sangild, Department of Human Nutrition, University of Copenhagen, DK-1958 Frederiksberg C, Denmark.*
- 11:45 am to 11:50 am Discussion
- 11:50 am to 12:05 pm **Dietary zinc oxide leads to short- and long-term modifications in the intestinal microbiota of piglets.**  
*I. Starke*<sup>\*</sup>, *W. Vahjen, and J. Zentek, Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany.*
- 12:05 pm to 12:10 pm Discussion
- 12:10 pm to 1:30 pm Lunch  
(Shavano Foyer/Terrace)
- Session II: Nutrient Digestion and Absorption**
- Session Chair:** Dr. H. C. Rainer Mosenthin, *University of Hohenheim Institute of Animal Nutrition*  
(Columbine Ballroom)
- 1:30 pm to 2:15 pm **Keynote Speaker: Starch and fiber properties affect their kinetics of digestion and thereby digestive physiology in pigs.**  
*Dr. Ruurd Zijlstra, University of Alberta, Edmonton, Canada*
- 2:15 pm to 2:30 pm Discussion
- 2:30 pm to 2:45 pm **Modeling the digestibility of dietary phosphorus: Model logic and concepts.**  
*V. Symeou*<sup>\*</sup>, *I. Leinonen, S. Edwards, and I. Kyriazakis, School of Agriculture, Food and Rural Development, Newcastle University, United Kingdom.*
- 2:45 pm to 2:50 pm Discussion
- 2:50 pm to 3:05 pm **Segment-specific glucose transport characteristics in the porcine small intestine.**  
*J. Herrmann*<sup>\*</sup>, *B. Schroeder, and G. Breves, University of Veterinary Medicine Hannover, Foundation, Department of Physiology, Hannover, Germany.*
- 3:05 pm to 3:10 pm Discussion
- 3:10 pm to 3:55 pm Break  
(Quandry Peak) *Abstract authors present at posters for discussions during break (Abstract section #2)*
- 3:55 pm to 4:10 pm **The impact of lower gut nitrogen supply on nitrogen balance and urea kinetics in growing pigs.**  
*D. Columbus*<sup>\*1</sup>, *H. Lapiere*<sup>3</sup>, *M. F. Fuller*<sup>2</sup>, and *C. F. M. de Lange*<sup>1</sup>, <sup>1</sup>*Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada,* <sup>2</sup>*Department of Surgery, State University of New York, Stony Brook, New York, USA,* <sup>3</sup>*Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, Sherbrooke, Quebec, Canada.*

- 4:10 pm to 4:15 pm Discussion
- 4:15 pm to 4:30 pm **Molecular weight distribution of soluble fibre fractions and short-chain fatty acids in ileal digesta of growing pigs.**  
*E. Ivarsson<sup>\*1</sup>, R. Andersson<sup>2</sup>, and J. E. Lindberg<sup>1</sup>, <sup>1</sup>Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden, <sup>2</sup>Department of Food Science, Swedish University of Agricultural Sciences, Uppsala, Sweden.*
- 4:30 pm to 4:35 pm Discussion
- 4:35 pm to 4:50 pm **Porcine periweaning failure to thrive syndrome is driven by poor appetite and nutrient digestibility, but not ileal morphology or absorptive capacity.**  
*C. K. Jones\*, N. K. Gabler, and J. F. Patience, Iowa State University, Ames, IA, USA.*
- 4:50 pm to 4:55 pm Discussion
- 5:15 pm to 6:15 pm Speakers' Reception (Restricted Admission)  
(Keystone Lodge Ballroom, Third Floor)
- 7:00 pm Dinner  
(Keystone Lodge Ballroom, Third Floor)

**Thursday, May 31**

**Session III: Mucosal Immunity and Pathogenesis**

**Session Chair:** Dr. Romuald Zabielski, *Warsaw University of Life Sciences (Columbine Ballroom)*

- 8:30 am to 9:15 am **Keynote Speaker: Promoting mucosal immunity-developing new efficacious probiotics.**  
*Dr. Denise Kelly, Rowett Research Institute, Aberdeen, Scotland*
- 9:15 am to 9:30 am Discussion
- 9:30 am to 9:45 am **Effects of capsicum and turmeric oleoresins on performance, diarrhea, gut morphology, immune and inflammatory status of weaned pigs infected with a pathogenic *E. coli*.**  
*Y. Liu<sup>1</sup>, M. Song<sup>1</sup>, J. A. Soares<sup>1</sup>, D. Bravo<sup>2</sup>, C. M. Maddox<sup>1</sup>, J. E. Pettigrew<sup>1</sup>, and C. Oguey<sup>\*2</sup>, <sup>1</sup>University of Illinois, Urbana, IL, USA, <sup>2</sup>Pancosma SA, Geneva, Switzerland.*
- 9:45 am to 9:50 am Discussion
- 9:50 am to 10:05 am **Influence of the feed physical form (grinding intensity/compaction) on the incidence of immune cells, the mannose content in the mucus, and the in vitro adhesion of *Salmonella* Typhimurium in the porcine intestine.**  
*J. Sander<sup>\*1</sup>, A. Callies<sup>1</sup>, A. Beineke<sup>2</sup>, J. Verspohl<sup>1</sup>, and J. Kamphues<sup>1</sup>, <sup>1</sup>Institute for Animal Nutrition, University of Veterinary Medicine, Hannover, Germany, <sup>2</sup>Institute for Pathology, University of Veterinary Medicine, Hannover, Germany.*
- 10:05 am to 10:10 am Discussion
- 10:10 am to 10:55 am Break  
(Quandry Peak) *Abstract authors present at posters for discussions during break (Abstract section #3)*

- 10:55 am to 11:10 am **Heat stress reduces barrier function and alters intestinal metabolism in growing pigs.**  
S. C. Pearce<sup>\*1</sup>, V. Mani<sup>1</sup>, R. L. Boddicker<sup>1</sup>, J. S. Johnson<sup>1</sup>, T. E. Weber<sup>1,2</sup>, J. W. Ross<sup>1</sup>, L. H. Baumgard<sup>1</sup>, and N. K. Gabler<sup>1</sup>, <sup>1</sup>Department of Animal Science, Iowa State University, Ames, IA, USA, <sup>2</sup>USDA-ARS, Ames, IA, USA.
- 11:10 am to 11:15 am Discussion
- 11:15 am to 11:30 am **Effects of supplementation with *Laminara hyperborea*, *Laminara digitata*, and *Saccharomyces cerevisiae* on the IL17 pathway in the porcine colon.**  
M. T. Ryan<sup>1</sup>, C. J. O'Shea<sup>\*</sup>, C. B. Collins<sup>1</sup>, J. V. O'Doerty<sup>2</sup>, and T. Sweeney<sup>1</sup>, <sup>1</sup>School of Veterinary Medicine, College of Life Sciences, University College Dublin, Belfield, Dublin 4, Ireland, <sup>2</sup>School of Agriculture and Food Science, College of Life Sciences, University College Dublin, Belfield, Dublin 4, Ireland.
- 11:30 am to 11:35 am Discussion
- 11:35 am to 11:50 am **The influence of dietary locust bean gum and live yeast on some digestive immunological parameters of piglets experimentally challenged with *Escherichia coli*.**  
R. Badia<sup>1,2</sup>, R. Lizardo<sup>1</sup>, P. Martinez<sup>2</sup>, I. Badiola<sup>3</sup>, and J. Brufau<sup>\*1</sup>, <sup>1</sup>IRTA - Institut de Recerca i Tecnologia Agroalimentaries, Constantí, Tarragona, Spain, <sup>2</sup>IBB - UAB Institut de Biotecnologia i Biomedicina – Universidad Autònoma de Barcelona, Bellaterra, Barcelona, Spain, <sup>3</sup>CReSA - Centre de Recerca en Sanitat Animal, Bellaterra, Barcelona, Spain.
- 11:50 am to 11:55 am Discussion
- 12:00 pm to 1:30 pm Lunch  
(Shavano Foyer/Terrace)
- Session IV: Neonatal Development of Digestive and Absorptive Capacity**
- Session Chair:** Dr. D. G. Burrin, ARS Children's Nutrition Research Center, Baylor College of Medicine (Columbine Ballroom)
- 1:30 pm to 2:15 pm **Keynote Speakers: The preterm pig as a model for studying gastrointestinal development.**  
Dr. Per Sangild, University of Copenhagen, Copenhagen, Denmark, and Dr. Randy Buddington, University of Memphis, Memphis, TN, USA
- 2:15 pm to 2:30 pm Discussion
- 2:30 pm to 2:45 pm **Potential new approaches to stimulate GLP-2 secretion and intestinal adaptation in weanling piglets.**  
I. R. Ipharraguerre<sup>\*1</sup>, D. G. Burrin<sup>2</sup>, A. Mereu<sup>1</sup>, D. Menoyo<sup>3</sup>, J. J. Holst<sup>4</sup>, and G. Tedó<sup>1</sup>, <sup>1</sup>Feed Additive Division, Lucta S.A., Montornés del Vallés, Spain, <sup>2</sup>USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas, <sup>3</sup>Departamento de Producción Animal, Universidad Politécnica de Madrid, ETS Ingenieros Agrónomos, Madrid, Spain, <sup>4</sup>Department of Biomedical Sciences, University of Copenhagen, Copenhagen, Denmark.
- 2:45 pm to 2:50 pm Discussion



- 2:50 pm to 3:05 pm **Effect of feeding immunoglobulin (IgG) on gastrointestinal structure in newborn pigs.**  
*J. Wolinski<sup>\*1</sup>, M. Słupecka<sup>1</sup>, P. Ochniewicz<sup>1</sup>, O. Fedkiv<sup>2</sup>, O. Prykhodko<sup>2</sup>, G. Ushakova<sup>3</sup>, G. Skibo<sup>4</sup>, T. Kovalenko<sup>4</sup>, I. Osadchenko<sup>4</sup>, K. Goncharova<sup>4</sup>, K. Szwiec<sup>2</sup>, B. Weström<sup>2</sup>, and S. G. Pierzynowski<sup>2,5,1</sup>* *The Kielanowski Institute of Animal Physiology and Nutrition, Jablonna, Poland, <sup>2</sup>Department of Biology, Lund University, Lund, Sweden, <sup>3</sup>Department of Biochemistry and Biophysics, Dnepropetrovsk National University, Dnepropetrovsk, Ukraine, <sup>4</sup>Bogomoletz Institute of Physiology, Kiev, Ukraine, <sup>5</sup>Department of Medical Biology, Institute of Rural Health, Lublin, Poland.*
- 3:05 pm to 3:10 pm Discussion
- 3:10 pm to 3:55 pm Break  
(Quandry Peak) *Abstract authors present at posters for discussions during break (Abstract section #4)*
- 4:00 pm to 5:00 pm International Steering Committee meeting  
(Room TBD)
- 3:10 pm to 7:00 pm Recreation activities: Free time to enjoy the many Keystone offerings
- 7:00 pm to 10:00 pm Gala Dinner: Barn Dance and Barbecue with Live Country and Western Entertainment  
(Keystone Stables)

### **Friday, June 1**

- 8:30 am to 10:00 am **Concurrent poster discussion session #1**  
**Manipulation of Digestion**  
*Dr. N. K. Gabler, Iowa State University and Dr. John Pluske, Animal Research Institute, Murdoch University*  
(Columbine Ballroom)
- Concurrent poster discussion session #2**  
**Methodologies and Application**  
*Dr. C. F. M. De Lange, Department of Animal and Poultry Science, University of Guelph and Dr. A. J. M. Jansman, Wageningen UR Livestock Research Center*  
(Colorado Rockies Ballroom)
- Session V: Long-Term Effects of Pre and Early Postnatal Nutrition/ Environment**
- Session Chair:** Dr. Layi Adeola, *Purdue University*  
(Columbine Ballroom)
- 10:00 am to 10:45 am **Keynote Speaker: Long-term effects of pre- and early-postnatal nutrition and environment on the gut.**  
*Jean-Paul Lallès, Institut National de la Recherche Agronomique (INRA), Saint-Gilles, France*
- 10:45 am to 11:00 am Discussion
- 11:00 am to 11:45 am Break  
(Quandry Peak) *Abstract authors present at posters for discussion during break (Abstract sections #5, 6, and 7)*

- 11:45 am to 12:00 pm **Long-term impact of piglet weaning age on intestinal epithelial barrier function and stress responsiveness.**  
*A. J. Moeser\**, *E. L. Overman*, *S. M. D'Costa*, and *J. Xu*, *North Carolina State University, College of Veterinary Medicine, Raleigh, NC, USA.*
- 12:00 pm to 12:05 pm Discussion
- 12:00 pm to 1:30 pm Lunch  
(Shavano Foyer/Terrace)
- 1:30 pm to 1:45 pm **Butyrate supplementation to gestating sows and piglets induces muscle and adipose tissue oxidative genes and improves growth performance.**  
*H. Lu* and *K. Ajuwon\**, *Purdue University, West Lafayette, IN, USA.*
- 1:45 pm to 1:50 pm Discussion
- 1:50 pm to 2:05 pm **Effects of early management on the long-term development of intestinal immunity in growing pigs.**  
*M. A. Smits*<sup>\*1,2</sup>, *D. Schokker*<sup>1</sup>, and *A. J. M. Rebel*<sup>2</sup>, <sup>1</sup>*Wageningen UR Livestock Research, Lelystad, The Netherlands*, <sup>2</sup>*Central Veterinary Institute, Lelystad, The Netherlands.*
- 2:05 pm to 2:10 pm Discussion
- 2:10 pm to 2:25 pm **The perinatal development of the gut is delayed in intrauterine growth-retarded piglets.**  
*M. Mickiewicz*<sup>1,2</sup>, *R. Zabielski*<sup>\*2</sup>, *B. Grenier*<sup>3</sup>, *L. Le Normand*<sup>2</sup>, *G. Savary*<sup>2</sup>, *J. J. Holst*<sup>4</sup>, *I. P. Oswald*<sup>3</sup>, *C. C. Metges*<sup>5</sup>, and *P. Guilloteau*<sup>2</sup>, <sup>1</sup>*UR 1341, Alimentation Adaptations Digestives, Nerveuses et Comportementales (ADNC), Institut National de la Recherche Agronomique (INRA), Saint Gilles, France*, <sup>2</sup>*Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences, Warsaw, Poland*, <sup>3</sup>*INRA URPT, Unité de Recherche Pharmacologie-Toxicologie Toulouse 180 Chemin de Tournefeuille 31931, St-Martin-du-Touch, France*, <sup>4</sup>*Department of Medical Physiology, University of Copenhagen, Copenhagen, Denmark*, <sup>5</sup>*Research Unit Nutritional Physiology, Leibniz Institute for Farm Animal Biology (FBN), Dummerstorf, Germany.*
- 2:25 pm to 2:30 pm Discussion
- 2:30 pm to 2:45 pm **Effects of a simple or a complex starter microbiota on intestinal microbiota composition in caesarean-derived piglets.**  
*A. J. M. Jansman*<sup>\*1</sup>, *J. Zhang*<sup>2</sup>, *S. J. Koopmans*<sup>1</sup>, *R. A. Dekker*<sup>1</sup>, and *H. Smidt*<sup>2</sup>, <sup>1</sup>*Wageningen UR Livestock Research, Lelystad, The Netherlands*, <sup>2</sup>*Wageningen University, Laboratory of Microbiology, Wageningen, The Netherlands.*
- 2:45 pm to 2:50 pm Discussion
- 2:50 pm **Concluding Remarks**  
*Dr. Merlin Lindemann*, *University of Kentucky, Co-Chair, Local Organizing Committee, DPP 2012*

## LIST OF ABSTRACTS

Wednesday, May 30, 2012

### SYMPOSIA AND ORAL SESSIONS

<b>SESSION I:</b>		<b>Gut Microbiome and Host Response</b>	
		Chair: Dr. Andrew van Kessel, University of Saskatchewan, Columbine Ballroom .....	37
8:45 am	1000	Invited review: Microbiomics of monogastric farm animals. H. Smidt .....	38
9:45 am	1001	Influence of diets high in fermentable carbohydrates or protein on large intestinal microbial ecology, mucosal response and urinary metabolomic profiles in piglets. R. Pieper*, K. Neumann, S. Kroeger, J. F. Richter, J. Wang, L. Martin, J. Bindelle, J. K. Htoo, W. Vahjen, J. Zentek, and A. G. Van Kessel .....	38
10:05 am	1002	Differences in core microbiota between P1 and P3 dams and their progeny. E. E. Hinkle*, S. Ferando, and T. E. Burkey .....	38
10:25 am		Break.	
11:10 am	1003	EGF-expressing <i>Lactococcus lactis</i> enhances growth performance of early-weaned pigs fed diets devoid of blood plasma. A. Bedford*, Z. Li, M. Li, S. Ji, C. F. M. de Lange, and J. Li.....	39
11:30 am	1004	An <i>Escherichia coli</i> F18 challenge model in newborn pigs. M. L. Jensen, M. S. Cilieborg*, M. V. Østergaard, S. B. Bering, and P. T. Sangild .....	39
11:50 am	1005	Dietary zinc oxide leads to short- and long term modifications in the intestinal microbiota of piglets. I. Starke*, W. Vahjen, and J. Zentek .....	39

### POSTER PRESENTATIONS

<b>SESSION I:</b>		<b>Gut Microbiome and Host Response</b>	
		Quandry Peak, with authors present from 10:25 am to 11:10 am, viewable from 8:00 am to 6:00 pm.....	40
	1006	High throughput sequence-based analysis of the intestinal microbiota of weanling pigs fed genetically modified Bt MON810 maize for 31 days. S. G. Buzoianu, M. C. Walsh, M. C. Rea, O. O'Sullivan, P. D. Cotter, R. P. Ross, G. E. Gardiner, and P. G. Lawlor .....	40
	1007	Effects of dietary supplementation with chitooligosaccharide on growth performance, biochemical parameters and intestinal flora in Huanjiang mini-piglets. G. Q. Lian, X. L. Zhou, X. F. Kong, Z. M. Feng, and Y. L. Yin.....	40
	1008	Soybean oligosaccharides alter short-chain fatty acid production and microbial population of colon in vitro. X. L. Zhou, X. F. Kong, and Y. L. Yin.....	41
	1009	Effect of a bacterial endo-1,4- $\beta$ -xylanase on ammonia emission in pigs. R. Mombaerts, A. Goderis, and R. Geers .....	41
	1010	The influence of grinding intensity and compaction of diets on the microbial community in the gastrointestinal tract of young pigs. J. Bullermann, S. J. Sander, M. Arlinghaus, J. Verspohl, and J. Kamphues.....	41
	1011	Effect of feeding level on the composition of the intestinal microbiota in weaned piglets. V. T. S. Rist, M. Eklund, E. Bauer, N. Sauer, and R. Mosenthin .....	42
	1012	Interactions of <i>S. cerevisiae</i> fermentation product and in-feed antibiotic on gastrointestinal and immunological responses in piglets challenged with <i>E. coli</i> K88+. E. Kiarie, M. Scott, D. O. Krause, H. Khazanehei, E. Khafipour, and C. M. Nyachoti .....	42

1013	Expression of heat shock protein 27 in gut tissue of growing pigs fed diets without and with inclusion of chicory fiber. H. Y. Liu, T. Lundh, J. Dicksved, and J. E. Lindberg .....	43
1014	Effect of pea protein-alginate encapsulation on viability of freeze-dried <i>Bifidobacterium adolescentis</i> during storage. J. Wang, M. Nickerson, N. Low, T. Scott, and A. Van Kessel.....	43
1015	Effect of wheat DDGS or sugar beet pulp on prevalence of <i>Salmonella enteric</i> Typhimurium in weaned pigs. L. W. Thomson, R. Pieper, J. K. Marshall, and A. G. Van Kessel.....	43
1016	Comparison of fecal methanogenic Archaea between Erhualian and Landrace pigs by using denaturing gradient gel electrophoresis and real-time PCR analysis. Y. Su, Y. Luo, L. Zhang, H. Smidt, and W. Zhu .....	44
1017	Effects of supplementation with $\beta$ -glucans on cytokine gene expression in the porcine liver. M. T. Ryan, C. B. Collins, J. V. O. Doherty, and T. Sweeney .....	44
1018	Effect of a bacillary probiotic on health and performance of sows and piglets. T. Marubashi, S. K. Kritas, G. Filioussis, G. Christodoulopoulos, E. Petridou, A. R. Burriel, E. Papadopoulos, A. Tzivara, and E. McCartney.....	44
1019	G protein-coupled receptor120 (GPR120) transcription in intestinal epithelial cells are significantly affected by bacteria belonging to the Bacteroides, Proteobacteria, and Firmicutes phyla. M. Fredborg, P. K. Theil, B. B. Jensen, and S. Purup.....	45
1020	Intestinal delivery of probiotics bacteria protected with succinylated $\beta$ -lactoglobulin tablets and their effects on pig intestinal microbiota. I. Paquette, J.-P. Brousseau, G. Talbot, M. Lessard, R. Caillard, and M. Subirade.....	45
1021	Dietary supplementation with alkaline phosphatase affects intestinal microbial populations of nursery pigs. M. H. Rostagno, J. Ferrel, J. S. Radcliffe, and B. T. Richert.....	45
1022	Medium chain fatty acids and organic acid based feed additives improve animal performance and reduce bacterial overgrowth in the small intestine of weaning piglets. A. Awati, C. H. Smits, and H. M. Timmerman .....	46
1023	Barcoded pyrosequencing reveals a decrease in microbial diversity in small intestine after weaning of piglets irrespective of rearing conditions. A. Awati, C. H. Smits, and H. M. Timmerman .....	46
1024	Increasing amylose content of starch shifts bacterial populations in the cecum and colon of weaned pigs. J. M. Fohse, M. G. Gänzle, P. R. Regmi, T. A. T. G. van Kempen, and R. T. Zijlstra .....	47
1025	Comparison between the effects of spray dried and wet dietary supplementation of laminarin and fucoidan on microbiology and inflammatory cytokine gene expression in the pig gut. A. Mukhopadhyaya, J. V. O'Doherty, A. Smith, B. Bahar, and T. Sweeney .....	47
1026	Effect of feeding different extruded and non-extruded cereals on the gut mucosa and gut microbiota of piglets during the first week post-weaning. D. Torrallardona, N. Andrés-Elias, S. López, I. Badiola, and M. Cerdà-Cuéllar .....	47
1027	Effect of feeding different cereal-based diets on the performance and gut health of weaned piglets with or without previous access to creep feed during lactation. D. Torrallardona, N. Andrés-Elias, S. López, I. Badiola, and M. Cerdà-Cuéllar.....	48
1028	Improved growth performance of weaned piglets by dietary supplementation of plant material from Caucasian wingnut ( <i>Pterokarya fraxinifolia</i> ). O. Hojberg, R. M. Engberg, B. B. Jensen, and R. J. Wallace.....	48
1029	Supplementation of a sow's diet with oat promotes improved indices of health in their offspings. R. Minor, T. Dortch, L. Kloc, L. Williams, and A. Woldeghebriel .....	48
1030	Assessment of RNA integrity in the post-mortem pig colonic tissue ex-vivo. B. Bahar, J. O'Doherty, and T. Sweeney.....	49

1031	Extracts of brown seaweeds can attenuate the bacterial lipopolysaccharide (LPS) induced pro-inflammatory response in the porcine colon ex vivo. B. Bahar, J. O'Doherty, M. Hayes, and T. Sweeney .....	49
1032	The addition of a <i>Bacillus licheniformis</i> CECT 4536 probiotic to piglet diets improves animal intestinal microbiota and performance parameters. J. J. Mallo, M. Oficialdeguí, M. I. Gracia, M. Gutierrez, and P. Honrubia .....	50
1033	Influence of antibiotic treatment of sows on intestinal microbiota in their offsprings. J. Zhang, O. Pérez, J. P. Lallès, and H. Smidt.....	50
1034	Effects of yeast-dried milk (YDM) product in creep and Phase-1 nursery diets on circulating IgA and fecal microbiota of nursing and nursery pigs. H. Tran, J. W. Bundy, E. E. Hinkle, J. Walter, P. S. Miller, and T. E. Burkey .....	50
1035	Evaluation of the growth performance and fecal microbiota profile in developing gilts fed high-fiber diets. W. Burger, H. Tran, J. W. Bundy, E. E. Hinkle, R. K. Johnson, P. S. Miller, and T. E. Burkey .....	51

## SYMPOSIA AND ORAL SESSIONS

### **SESSION II:**

#### **Nutrient Digestion and Absorption**

Chair: Dr. H. C. Rainer Mosenthin, University of Hohenheim, Institute of Animal Nutrition, Columbine Ballroom .....

		53
1:30 pm	1036 Invited review: Starch and fiber properties affect their kinetics of digestion and thereby digestive physiology in pigs. R. T. Zijlstra*, R. Jha, A. D. Woodward, J. Fohuse, and T. A. T. G. van Kempen.....	54
2:30 pm	1037 Modelling the digestibility of dietary phosphorus: Model logic and concepts. V. Symeou*, I. Leinonen, S. Edwards, and I. Kyriazakis .....	54
2:50 pm	1038 Segment-specific glucose transport characteristics in the porcine small intestine. J. Herrmann*, B. Schroeder, and G. Breves.....	54
3:10 pm	Break	
3:55 pm	1039 The impact of lower gut nitrogen supply on nitrogen balance and urea kinetics in growing pigs. D. Columbus*, H. Lapierre, M. F. Fuller, and C. F. M. de Lange.....	55
4:15 pm	1040 Molecular weight distribution of soluble fiber fractions and short-chain fatty acids in ileal digesta of growing pigs. E. Ivarsson*, R. Andersson, and J. E. Lindberg.....	55
4:35 pm	1041 Porcine periweaning failure to thrive syndrome is driven by poor appetite and nutrient digestibility, but not ileal morphology or absorptive capacity. C. K. Jones*, N. K. Gabler, and J. F. Patience.....	55

## POSTER PRESENTATIONS

### **SESSION II:**

#### **Nutrient Digestion and Absorption**

Quandry Peak, with authors present from 3:10 pm to 3:55 pm,  
viewable from 8:00 am to 6:00 pm.....

		56
1042	The contribution of portal-drained viscera to circadian homocysteinemia in pigs. J. J. Matte, F. Guay, and C. L. Girard .....	56
1043	Dietary energy density affects the preference for protein or carbohydrate solutions and piglet performance after weaning. S. A. Guzmán-Pino, D. Solà-Oriol, J. Figueroa, E. Borda, and J. F. Pérez.....	56
1044	Supplementation of barley-based diets with $\beta$ -glucanase for pigs: Energy and amino acid digestibility responses. C. Kong and O. Adeola .....	57



1045	Effect of L-valine supplementation to a wheat diet with Leu excess on performance, gene expression and serum concentration of amino acids. H. García, A. Morales, A. B. Araiza, J. K. Htoo, M. Cota, and M. Cervantes .....	57
1046	Growth performance and nutrient digestibilities in nursery pigs receiving varying doses of xylanase and $\beta$ -glucanase blend in pelleted wheat and barley-based diets. A. Owusu-Asiedu, E. Kiarie, A. Péron, T. A. Woyengo, and C. M. Nyachoti .....	57
1047	Total-tract phosphorus digestibility of monocalcium phosphate in 15-kg pigs. H. Zhai and O. Adeola .....	58
1048	Ileal digestibility of amino acids in co-products of corn processing into ethanol for pigs. O. Adeola .....	58
1049	Total tract digestibility of nitrogen in pigs exposed to high environmental temperatures. M. Brestenský, S. Nitrayová, P. Patráš, and J. Heger .....	58
1050	The supplementation of low-P diets with microbial 6 phytase from <i>Aspergillus oryzae</i> improves P and Ca digestibility in growing pigs. D. Torrallardona, R. Salvadó, and J. Broz .....	59
1051	The supplementation of low-P diets with microbial 6 phytase from <i>Aspergillus oryzae</i> improves P digestibility in sows. D. Torrallardona, L. Llauradó, and J. Broz .....	59
1052	Differences in portal appearance of lysine, threonine and methionine in Iberian and Landrace pigs fed diets differing in protein content. L. Gonzalez-Valero, J. M. Rodriguez-Lopez, M. Lachica, and I. Fernandez-Figares .....	59
1053	Lower gut nitrogen supply has no effect on apparent ileal digestibility of nitrogen or amino acids in growing pigs. D. Columbus, M. F. Fuller, and C. F. M. de Lange .....	60
1054	The effect of supplementing a xylanase to nursery diets on growth performance of 9 to 36 kg BW pigs. E. Fruge, E. Hansen, R. Cabrera, and J. Foss .....	60
1055	The effects of supplementation of a novel bacterial 6-phytase on mineral digestibility and plasma minerals in lactating sows. Z. Nasir, J. Broz, and R. T. Zijlstra .....	60
1056	Effects of particle size and heat treatment of soybean meal on standardized ileal digestibility of amino acids in growing pigs. U. Messerschmidt, M. Eklund, V. T. S. Rist, P. Rosenfelder, H. K. Spindler, J. K. Htoo, and R. Mosenthin .....	61
1057	Prececal digestibility of various sources of starch (wheat, rice, potato, maize, pea) in minipigs with or without experimentally induced lack of exocrine pancreatic function. A. Moessler, N. Kramer, C. Becker, P. C. Gregory, and J. Kamphues .....	61
1058	Endogenous nitrogen losses (prececal and total) in pigs with exocrine pancreatic insufficiency (experimentally induced by pancreatic duct ligation). A. Moessler, H. Looock, J. Classen, P. C. Gregory, and J. Kamphues .....	61
1059	Effect of highly insoluble, low fermentable fiber on energy, fiber, and amino acid digestibility and on hindgut fermentation of fiber in growing pigs. N. A. Gutierrez, B. J. Kerr, and J. F. Patience .....	62
1060	Lactose in diet influences the degradation of mixed linked $\beta$ -D-glucan in the small intestine of pigs. K. E. B. Knudsen .....	62
1061	Assessment of the presence of chemosensing receptors based on bitter and fat taste in the gastro-intestinal tract of young pig. M. Colombo, P. Trevisi, G. Gandolfi, and P. Bosi .....	63
1062	Ileal and total tract digestibility of wet and dried wheat distillers grain products in growing pigs. K. Lyberg, J. Borling, and J. E. Lindberg .....	63
1063	Meta-analysis of the effect of microbial phytase on the digestibility and bioavailability of copper and zinc in growing pigs. P. Bikker, A. W. Jongbloed, and J. T. N. M. Thissen .....	63

1064	Modelling the retention and excretion of digestible phosphorus for different genotypes. V. Symeou, I. Leinonen, S. Edwards, and I. Kyriazakis.....	64
1065	Prediction of apparent, standardized and true ileal digestible total and reactive lysine contents in heat-treated soybean meal samples. J. C. Kim, B. P. Mullan, and J. R. Pluske.....	64
1066	Digestible and metabolizable energy concentrations in copra meal, palm kernel meal, and cassava root fed to growing pigs. A. R. Son, S. Y. Ji, and B. G. Kim.....	64
1067	Comparison of standardized ileal amino acid digestibilities in protein supplements and cereal grains for weaned pigs. N. Sauer, M. Eklund, S. Hoerner, M. Rademacher, and R. Mosenthin.....	65
1068	Performance and fecal phosphorus and calcium digestibility in grower-finisher pigs fed diets with and without phytase. I. Kühn and K. Männer.....	65
1069	Effects of $\beta$ -hydroxy $\beta$ -methyl butyrate supplementation to sows in late gestation on absorption and hepatic metabolism of glucose and amino acids during transition. C. Flummer, H. Lyby, K. S. Storli, V. Bjerre-Harpøth, B. M. Nielsen, M. Krämer, B. A. Røjen, N. B. Kristensen, and P. K. Theil.....	65
1070	The degradation of arabinoxylan rich cell walls in digesta obtained from piglets fed on wheat-based diets by exogenous xylanases and auxiliary enzymes. N. R. Pedersen, D. M. Le, P. Fojan, E. Azem, J. Broz, P. Guggenbuhl, and D. Pettersson....	66
1071	Effects of dietary supplementation with a protease on the apparent ileal digestibility of the weaned piglet. P. Guggenbuhl, Y. Wache, and J. Wilson.....	66
1072	Nutritional characteristics of byproducts originating from a Central European ethanol fuel industry for pigs. S. Nitrayová, M. Brestenský, P. Patráš, and J. Heger.....	67
1073	Effect of dietary fiber concentration on retention and redistribution of nitrogen in pigs. P. Patráš, S. Nitrayová, M. Brestenský, and J. Heger.....	67
1074	Evaluation of optimal supplementation level of emulsifier (lysophospholipids) in low energy diets for growing pigs. J. H. Cho, J. W. Hong, and I. H. Kim.....	67
1075	Effects of molasses supplementation on growth performance, nutrient digestibility, blood characteristics, fecal moisture, fecal noxious gas emission, and meat quality in finishing pigs. S. M. Hong, J. Li, J. H. Cho, and I. H. Kim.....	68
1076	Effects of phytase with different calcium and phosphorous density diet on growth performance, nutrient digestibility, blood profiles, fecal noxious gas emission, and meat quality in finishing pigs. L. Yan, Z. F. Zhang, J. P. Wang, J. H. Cho, and I. H. Kim.....	68
1077	Effects of sericite supplementation on apparent total tract digestibility, blood profiles, and odor gas emission from manure in growing pigs. P. Y. Zhao, J. H. Jung, J. H. Cho, and I. H. Kim.....	68
1078	Effects of faba beans and faba bean hulls on the expression of selected genes in the small intestine of piglets. A. J. M. Jansman, J. van Baal, H. C. A. Widjaja, J. van der Meulen, and M. A. Smits.....	69
1079	Improved nutrient digestibility and retention partially explains feed efficiency gains in pigs selected for low residual feed intake. A. J. Harris, J. F. Patience, S. M. Lonergan, J. C. M. Dekkers, and N. K. Gabler.....	69
1080	Dietary protein content does not influence calcium and phosphorus absorption and retention in the Iberian pig growing from 50 to 100 kg body-weight. R. Nieto, A. Haro, C. Delgado-Andrade, I. Seiquer, and J. F. Aguilera.....	69
1081	Nutrient digestibilities of degermed dehulled corn, citrus pulp and soy protein concentrate by barrows. U. S. Ruiz, M. C. Tomaz, L. A. F. Pascoal, P. H. Watanabe, A. B. Amorim, G. M. P. Melo, and E. Daniel.....	70

1082	Microscopic matrix and in vitro degradation and fermentation characteristics of wheat co-products from flour milling in the pig intestine. R. Jha, A. Owusu-Asiedu, P. H. Simmins, A. Pharazyn, and R. T. Zijlstra .....	70
1083	Net energy of Canadian feedstuffs in growing finishing pigs. S. Moehn, R. T. Zijlstra, and R. O. Ball .....	71
1084	Slowly-digestible starch influences mRNA abundance of glucose and short chain fatty acid (SCFA) transporters in the porcine distal intestinal tract. A. D. Woodward, P. R. Regmi, M. G. Gänzle, T. A. T. G. van Kempen, and R. T. Zijlstra .....	71
1085	Net energy of Canadian feedstuffs in pregnant sows. S. Moehn, R. T. Zijlstra, and R. O. Ball .....	71
1086	Effect of a supra-phytase level on post-weaning growth and stool firmness of pigs fed low or high soybean meal diets. C. E. Zier-Rush, S. Smith, R. Palan, J. Steckel, P. Wilcock, and R. D. Boyd .....	72
1087	Effect of palm kernel meal with $\beta$ -mannanase supplementation in gestating sows' diet on nutrient digestibility. D. H. Kim, Y. D. Jang, P. S. Heo, Y. H. Kim, I. C. Kim, and Y. Y. Kim .....	72
1088	Determination of metabolizable energy contents in copra and palm kernel meal for growing pigs. P. S. Heo, Y. D. Jang, D. H. Kim, S. D. Lee, J. C. Park, and Y. Y. Kim .....	72
1089	High vs. low amylose starch increases methane and volatile fatty acid production and reduces energy retention in pigs. J. L. Yanez, S. Moehn, R. O. Ball, T. A. T.G. van Kempen, and R. T. Zijlstra .....	73
1090	Influence on the ileal and fecal digestibility of forage inclusion in the diet. H. Jørgensen, D. Carlson, and H. N. Lærke .....	73
1091	Digestive utilization of diets with low or high level of fibers in pigs divergently selected for residual feed intake. L. Montagne, M. Le Gall, and H. Gilbert .....	73
1092	Short-term effect of dietary yeast nucleotide supplementation on total and diurnal variation of small intestinal enzyme activities in piglets. N. Sauer, M. Eklund, S. Hoerner, E. Bauer, D. Jezierny, and R. Mosenthin .....	74
1093	Comparative effects of five phytases on the phosphorus and calcium utilisation in the weaned piglet. P. Guggenbuhl, Y. Wache, C. Simoes-Nunes, and F. Fru .....	74
1094	Effects of a new 6-phytase on the apparent ileal digestibility of minerals and amino acids in ileo-rectal anastomozed pigs fed on a corn-soybean meal-barley diet. P. Guggenbuhl, Y. Wache, C. Simoes Nunes, and F. Fru .....	75
1095	Bioavailability of zinc from different sources in pigs. S. Nitrayova, W. Windisch, E. von Heimendahl, A. Müller, and J. Bartelt .....	75
1096	Effect of soybean meal origin on standardized ileal amino acid digestibilities in piglets. M. Eklund, N. Sauer, F. Rink, M. Rademacher, and R. Mosenthin .....	75
1097	Comparative evaluation of standardized ileal amino acid digestibilities in protein supplements for piglets. M. Eklund, N. Sauer, S. Hörner, M. Rademacher, and R. Mosenthin .....	76
1098	Endogenous losses and true ileal digestibility of amino acids in piglets as influenced by feed and protein intake. M. Eklund, N. Sauer, D. Jezierny, M. Goerke, M. Rademacher, and R. Mosenthin .....	76
1099	An increased ratio of dietary tryptophan to lysine post weaning improves feed conversion efficiency and elevates plasma tryptophan and kynurenine in the absence of antimicrobials and regardless of infection with enterotoxigenic <i>E. coli</i> . M. M. Capozzalo, J. C. Kim, J. K. Htoo, C. F. M. de Lange, B. P. Mullan, J. W. Resink, P. A. Stumbles, and J. R. Pluske .....	76
1100	Phytase improves apparent fecal P and Ca digestibility of piglet diets with adequate or reduced P content. I. Kühn and K. Partanen .....	77

1101	Phytase inclusion in pig diets improves zinc status but its effect on copper availability is inconsistent. P. Bikker and A. W. Jongbloed.....	77
1102	Copper induced reductions in cellular proliferation and changes in membrane integrity in porcine epithelial intestinal cells (IPEC-J2) and mouse macrophage cells (RAW264.7). B. E. Aldridge, Y. Liu, J. S. Radcliffe, and Y. Wang.....	78
1103	Metabolic profiling of plasma from sows before parturition and during lactation. M. S. Hedemann, C. Flummer, N. B. Kristensen, and P. K. Theil.....	78
1104	Influence of high levels of dietary zinc oxide on performance and small intestinal gene expression in weaned piglets. L. Martin, R. Pieper, W. Vahjen, and J. Zentek.....	78
1105	Pharmacological levels of zinc oxide change the expression of zinc transport proteins ZIP4 and ZnT1 and metallothionein but not DMT 1 and ZnT2 in the jejunum of weaned piglets. R. Pieper, L. Martin, W. Vahjen, and J. Zentek.....	79
1106	Ileal digestibility of soybean meal, sunflower meal, pea, rape seed cake and lupine in pigs. J. V. Nørgaard, J. A. Fernández, and H. Jørgensen.....	79
1107	Effect of microbial phytase on phosphorus digestibility in non-heat-treated and heat-treated wheat-barley pig diets. K. Blaabjerg, J. V. Nørgaard, and H. D. Poulsen.....	79
1108	Environmental consequences of feeding high fiber diet to growing pigs. A. Woldeghebriel, S. Smith, T. Barios, B. Pope, and S. Gebrelul.....	80
1109	The effect of live yeast utilization and dietary fibre on growth performance, nutrient utilization and gut microbiology in the weaning pig. R. Lizardo, A. Perez-Vendrell, I. Badiola, R. D’Inca, E. Auclair, and J. Brufau.....	80
1110	Histamine and PGE <sub>2</sub> -induced chloride secretion and the epithelial catabolism of histamine in the colon of piglets is influenced by diets high in fermentable protein. S. Kroeger, R. Pieper, H. G. Schwelberger, J. Wang, J. F. Richter, J. R. Aschenbach, A. G. Van Kessel, and J. Zentek.....	81
1111	Digestible energy values of feed ingredients with or without addition of enzymes complex in growing pigs. P. Cozannet, A. Preynat, and J. Noblet.....	81
1112	Effects of fibers with different fermentation characteristics on feeding motivation in adult pigs. C. Souza Da Silva, J. E. Bolhuis, W. J. J. Gerrits, B. Kemp, and J. J. G. C. van den Borne..	81
1113	Effects of formic acid and phytase supplementation on digestibility and utilization of phosphorus and zinc in growing pigs. R. Blank, M. Naatjes, P. Ader, U. Roser, and A. Susenbeth.....	82
1114	Effect of supplementing alternating ratios of laminarin and fucoidan in the diet of the weanling piglet on performance, nutrient digestibility and selected faecal microbial populations and volatile fatty acid concentrations. A. M. Walsh, T. Sweeney, C. J. O’Shea, D. N. Doyle, B. Flynn, and J. V. O’Doherty.....	82
1115	Digestibility of canola meal from 2 species ( <i>Brassica juncea</i> and <i>Brassica napus</i> ) fed to ileal-cannulated grower pigs. M. H. A. Le, A. D. G. Buchet, E. Beltranena, W. J. J. Gerrits, and R. T. Zijlstra.....	82
1116	Prediction of gross energy and digestible energy in copra meal, palm kernel meal, and cassava root fed to pigs. C. S. Park, A. R. Son, and B. G. Kim.....	83
1117	Effect of singular or combined consumption of dietary seaweed extracts and zinc oxide on growth performance and selected faecal microbial populations of weaned piglets. P. O. McAlpine, C. J. O’Shea, P. F. Varley, B. Flynn, and J. V. O’Doherty.....	83
1118	Evaluation of different protections of butyric acid aiming for release in the last part of the GIT of piglets. J. J. Mallo, A. Balfagon, M. I. Gracia, M. Puyalto, and P. Honrubia.....	83

1119	Artificial sweeteners do not all increase glucose absorption at the same level in piglets. A. Moran, D. Batchelor, S. Shirazi-Beechey, D. Bravo, and C. Oguey .....	84
1120	Expression of the small intestinal Na-neutral amino acid co-transporter B0AT1 (SLC6A19) in early-weaned pigs. Z. Wang, C. Yang, T. Archbold, M. Hayhoe, K. Lien, and M. Fan .....	84
1121	Cocoa husks in diets of Italian heavy pigs. D. Magistrelli, L. Malagutti, G. Galassi, and F. Rosi.....	85
1122	Microscopic matrix and in vitro pig model fermentation of wheat and corn distillers dried grains with solubles with supplemental carbohydrases and protease. R. Jha, J. Li, M. R. Bedford, C. R. Christensen, T. Vasanthan, and R. T. Zijlstra.....	85
1123	Microbial fermentation in the hindgut—Energy contribution to sows fed diets differing in dietary fibre source with and without addition of a live yeast. N. Canibe, E. C. Soto, H. Jørgensen, K. E. Bach Knudsen, and B. B. Jensen .....	85
1124	Effect of immune system stimulation and divergent selection for residual feed intake on digestive capacity of the small intestine in growing pigs. A. Rakhshandeh, T. E. Weber, J. C. M. Dekkers, B. J. Kerr, J. English, and N. K. Gabler .....	86
1125	Post-weaning evolution of plasma levels of zinc from different sources and doses in a commercial farm. R. Davin, E. G. Manzanilla, S. Durosoy, and J. F. Perez .....	86
1126	Dynamic changes in digestive capability may contribute to compensatory growth following a nutritional insult in newly weaned pigs. C. L. Levesque, L. Skinner, J. Zhu, and C. F. M. de Lange .....	86
1127	Standardized ileal amino acid digestibility in egg from hyperimmunized-hens fed to nursery pigs. J. M. Heo, E. Kiarie, R. Kahindi, T. A. Woyengo, and C. M. Nyachoti .....	87
1128	High-moisture airtight storage of barley and wheat improves nutrient digestibility. H. D. Poulsen, J. V. Nørgaard, and K. Blaabjerg.....	87
1129	Dose response of a new phytase on dry matter, calcium and phosphorus digestibility in weaned piglets. M. H. L. Bento, C. Pedersen, P. W. Plumstead, L. Salmon, C. M. Nyachoti, and P. Bikker ....	87
1130	Hypophosphatemia during refeeding with corn-soy-blends is prevented by addition of milk or permeate. A. Hother, M. Lykke, T. Martinussen, C. Mølgaard, P. T. Sangild, C. F. Hansen, H. Friis, K. F. Michaelsen, and T. Thymann .....	88
1131	Severe acute malnutrition (SAM) in early life reduces gut function and structure. M. Lykke, A. Hother, P. T. Sangild, K. F. Michaelsen, H. Friis, C. F. Mølgaard, and T. Thymann .....	88
1132	Evolution of zinc, iron, and copper concentrations along the gastrointestinal tract of pigs weaned with or without in-feed high doses of zinc oxide compared to unweaned littermates. R. Davin, E. G. Manzanilla, K. C. Klasing, and J. F. Perez.....	89
1133	Characterization of digestion discrepancy between in vitro and in vivo for co-products using spectroscopy. L. F. Wang, M. L. Swift, and R. T. Zijlstra .....	89
1134	The effect of alkaline phosphatase in nursery pig diets containing dried distillers grains with solubles on performance and active intestinal glucose and phosphate absorption. J. S. Radcliffe, Z. Rambo, B. E. Aldridge, J. Ferrel, D. Anderson, D. Kelly, and B. T. Richert .....	89
1135	The effects of $\beta$ -mannanase and $\beta$ -glucanase on nursery pig growth performance, intestinal morphology and active nutrient absorption. Z. Rambo, B. E. Aldridge, B. T. Richert, J. Ferrel, D. Anderson, and J. S. Radcliffe.....	90
1136	Effects of dietary true digestible Ca to P ratio on growth performance and efficiency of Ca and P utilization in growing pigs. M. Fan, C. de Lange, and T. Archbold .....	90



**Thursday, May 31, 2012**  
**SYMPOSIA AND ORAL SESSIONS**

**SESSION III: Mucosal Immunity and Pathogenesis**  
Chair: Dr. Romuald Zabielski, Warsaw University of Life Sciences,  
Columbine Ballroom .....

			91
8:30 am	2000	Invited review: Promoting mucosal immunity—Developing new efficacious probiotics. D. Kelly .....	92
9:30 am	2001	Effects of capsicum and turmeric oleoresins on performance, diarrhea, gut morphology, immune and inflammatory status of weaned pigs infected with a pathogenic <i>E. coli</i> . Y. Liu, M. Song, JA Soares, D. Bravo, C. M. Maddox, J. E. Pettigrew, and C. Oguey* .....	92
9:50 am	2002	Influence of the feed physical form (grinding intensity/compaction) on the incidence of immune cells, the mannose content in the mucus and the in vitro adhesion of <i>Salmonella</i> <i>Typhimurium</i> in the porcine intestine. S. J. Sander*, A. Callies, A. Beineke, J. Verspohl, and J. Kamphues.....	92
10:10 am		Break	
10:55 am	2003	Heat stress reduces barrier function and alters intestinal metabolism in growing pigs. S. C. Pearce*, V. Mani, R. L. Boddicker, J. S. Johnson, T. E. Weber, J. W. Ross, L. H. Baumgard, and N. K. Gabler.....	93
11:15 am	2004	Effects of supplementation with <i>Laminara hyperborea</i> , <i>Laminara digitata</i> and <i>Saccharomyces cerevisiae</i> on the IL17 pathway in the porcine colon. M. T. Ryan, C. J. O'Shea, C. B. Collins, J. V. O'Doerty, and T. Sweeney* .....	93
11:35 pm	2005	The influence of dietary locust bean gum and live yeast on some digestive immunological parameters of piglets experimentally challenged with <i>Escherichia coli</i> . R. Badia, R. Lizardo, P. Martinez, I. Badiola, and J. Brufau* .....	93

**POSTER PRESENTATIONS**

**SESSION III: Mucosal Immunity and Pathogenesis**  
Quandry Peak with authors present from 3:10 pm to 3:55 pm on Thursday, May 31<sup>st</sup>.  
Viewable from 8:00 am to 6:00 pm on Thursday, May 31<sup>st</sup> and from 8:00 am to 2:00 pm on  
Friday, June 1<sup>st</sup>.....

			94
	2006	Effects of feeding capsicum oleoresin, garlison, or turmeric oleoresin on gene expression of ileal mucosa of pigs experimentally infected with a pathogenic <i>E. coli</i> . Y. Liu, M. Song, T. M. Che, J. A. Soares-Almeida, J. J. Lee, D. Bravo, C. W. Maddox, and J. E. Pettigrew .....	94
	2007	Butyrate relieves weaning diarrhea by promoting repair of pig intestinal barrier. X. Ma, S. Hu, and D. Li .....	94
	2008	Influence of grain type (wheat/barley), grinding intensity (coarse/fine) and fibre content on the incidence of epithelial alterations of the gastric pars oesophagea in fattening pigs. S. J. Sander, M. Wintermann, A. Moessler, C. Schulze Langenhorst, G. Stalljohann, and J. Kamphues.....	95
	2009	The effect of yeast cell walls on performance and innate immunity of weaned piglets. R. Gerritsen, G. Klaassen, G. Schuttert, S. Rouwers, and H. K. Parmentier .....	95
	2010	Dietary oxidative stress-induced yellow fat and lipofuscin accumulation in the digestive tract of swine. J. J. Dibner, C. D. Knight, M. Vazquez-Anon, T. Lu, M. L. Kitchell, and J. Zhao.....	95
	2011	Effects of an <i>Allium</i> botanical on performance, diarrhea, gut morphology, immune and inflammatory status of weaned pigs infected with a pathogenic <i>E. coli</i> . Y. Liu, M. Song, T. M. Che, J. A. Soares, D. Bravo, C. M. Maddox, J. E. Pettigrew, and C. Oguey.....	96

2012	in vitro test on the ability of a yeast cell wall product to inhibit the <i>Escherichia coli</i> F4ac adhesion on the brush border of porcine intestinal villi. P. Trevisi, D. Priori, G. Gandolfi, M. Colombo, T. Goossens, and P. Bosi.....	96
2013	Diarrhea-like condition and intestinal mucosal responses in susceptible homozygous and heterozygous F4R+ pigs under challenge. S. Sugiharto, M. Hedemann, B. Jensen, and C. Lauridsen.....	96
2014	Impact of <i>Bacillus cereus</i> var. Toyoi on the infection with <i>Salmonella</i> Typhimurium DT104 in weaned piglets. L. Scharek-Tedin, R. Pieper, W. Vahjen, S. Kinzinger, A. Mueller, and J. Zentek.....	97
2015	Effect of $\beta$ -glucans on net fluid absorption in enterotoxigenic <i>E. coli</i> -infected small intestinal segments of weaned piglets. J. van der Meulen, A. J. M. Jansman, J. J. Mes, I. M. van der Meer, and M. M. Hulst.....	97
2016	Impact of plant extracts on the adhesion of enterotoxigenic <i>Escherichia coli</i> on the porcine intestinal epithelial cell line IPEC-J2. A. Mader, W. Vahjen, and J. Zentek.....	98
2017	Lipopolysaccharide and n-3 fatty acids alter intestinal toll-like receptor 4 (TLR4) recruitment and function. V. Mani, J. D. Spencer, J. Hollis, T. E. Weber, and N. K. Gabler.....	98
2018	Effect of milk fractions on functional properties and inflammatory response in human and porcine intestinal epithelial cells. M. Blais, M. Fortier, Y. Pouliot, S. Gauthier, Y. Boutin, G. Robitaille, and M. Lessard.....	98
2019	Serocolostrum modulates gene expression in porcine intestinal epithelial cells IPEC J2. M. Blais, Y. Pouliot, S. Gauthier, Y. Boutin, and M. Lessard.....	99
2020	Influence of a phytogetic feed additive on digestive, microbiological and immunological measurements in weaned piglets. J. Zentek, S. Gaertner, L. Scharek-Tedin, A. Mader, K. R. Wendler, and W. Vahjen.....	99
2021	Deoxynivalenol and lipopolysaccharides affect porcine small intestinal integrity along the proximo-distal axis. J. Kluess, L. R. Klunker, N. Walk, C. Nossol, S. Kahlert, B. Brosig, S. Döll, S. Dänicke, and H. J. Rothkötter.....	100
2022	Effects of supplementing dietary laminarin and fucoidan in the weaned pig on intestinal morphology and volatile fatty acid concentrations. A. M. Walsh, T. Sweeney, C. J. O'Shea, D. N. Doyle, B. Flynn, and J. V. O'Doherty.....	100
2023	Porcine-derived mixed bacterial culture induces an innate immune response in gnotobiotic piglets. R. B. Harvey, K. J. Genovese, H. He, and D. J. Nisbet.....	100
2024	The effects of immune stressors on porcine intestinal epithelial cell integrity and inflammation. V. Mani, S. C. Pearce, A. J. Harris, T. E. Weber, and N. K. Gabler.....	101
2025	The effects of zinc on the adaptive T cell immune response in weaning piglets. S. Kreuzer, J. Schulte, J. Assmus, and G. A. Brockmann.....	101
2026	The effects of dam parity on microbial diversity in milk, and the in vitro effects of digested milk on immunoglobulin transport and neonatal Fc receptor expression in IPEC-J2 cells. S. E. Tangeman, E. E. Hinkle, H. Tran, and T. E. Burkey.....	101
2027	Consumption of guar gum and retrograded resistant cornstarch increases interleukin-10 abundance without affecting pro-inflammatory cytokines in the colon of pigs fed a high-fat diet. M. Fan, T. Archbold, D. Lackeyram, Q. Liu, Y. Mine, and G. Paliyath.....	102
2028	The small intestinal apical hydrolase activities are decreased in the piglet with bowel inflammation induced by dextran sodium sulfate. D. Lackeyram, Y. Mine, T. Archbold, and M. Fan.....	102

- 2029 The effect of potential immunomodulating milk components on mucosal immune responses and metabolomic plasma profile of ETEC-infected weaned piglets.  
S. Sugiharto, M. S. Hedemann, B. B. Jensen, and C. Lauridsen ..... 103

### SYMPOSIA AND ORAL SESSIONS

- SESSION IV: Neonatal Development of Digestive and Absorptive Capacity**  
Chair: Dr. D. G. Burrin, ARS Children's Nutrition Research Center,  
Baylor College of Medicine, Columbine Ballroom..... 105
- 1:30 pm 2030 Invited review: The preterm pig as a model for studying gastrointestinal development after preterm birth.  
R. Buddington\*, K. Buddington, D. Black, B. Hance, S. Grimes, S. Chattopadhyay, E. Huang, and P. T. Sangild ..... 106
- 2031 Invited review: The preterm pig as a model for necrotizing enterocolitis and intestinal resection.  
P. T. Sangild\*, L. Aunsholt, T. Thymann, A. Vegge, S. Bering, M. Cileborg, M. Ladegaard, M. Lykke, Y. Li, N. Quist, D. Burrin, and R. Buddington..... 106
- 2:30 pm 2032 Potential new approaches to stimulate GLP-2 secretion and intestinal adaptation in weanling piglets.  
I. R. Ipharraguerre\*, D. G. Burrin, A. Mereu, D. Menoyo, J. J. Holst, and G. Tedó..... 106
- 2:50 pm 2033 Effect of feeding immunoglobulin (IgG) on gastrointestinal structure in newborn pigs.  
J. Wolinski\*, M. Slupecka, P. Ochniewicz, O. Fedkiv, O. Prykhodko, G. Ushakova, G. Skibo, T. Kovalenko, I. Osadchenko, K. Goncharova, K. Szwiec, B. Weström, and S. G. Pierzynowski..... 107

### POSTER PRESENTATIONS

- SESSION IV: Neonatal Development of Digestive and Absorptive Capacity**  
Quandry Peak with authors present from 3:10 pm to 3:55 pm on Thursday, May 31<sup>st</sup>.  
Viewable from 8:00 am to 6:00 pm on Thursday, May 31<sup>st</sup> and from 8:00 am to 2:00 pm on Friday, June 1<sup>st</sup>..... 107
- 2034 Chenodeoxycholic acid improves intestinal permeability in piglets.  
Y. van der Meer, W. J. J. Gerrits, M. van den Bosch, J. J. Holst, W. Kulik, and T. A. T. G. van Kempen ..... 107
- 2035 Evaluation of immunoglobulin absorption from colostrum supplements gavaged to newborn piglets.  
J. Campbell, S. Jacobi, Y. Liu, K. Hard Robertson, J. Drayton, I. Medina, J. Polo, J. Crenshaw, and J. Odle ..... 107
- 2036 Small intestinal development of very early-weaned piglets fed milk replacer.  
M. De Vos, V. Huygelen, S. Willemen, B. Tambuyzer, C. Casteleyn, S. Van Cruchten, and C. Van Ginneken..... 108
- 2037 Half-life of porcine antibodies absorbed from a colostrum supplement containing porcine immunoglobulins.  
J. Polo, J. Campbell, J. Crenshaw, C. Rodríguez, N. Pujol, N. Navarro, and J. Pujols ..... 108
- 2038 Expression of mRNA for arginine succinate synthase and spermidine/spermine-N-acetyltransferase enzymes involved in the synthesis of polyamines by the enterocytes of recently weaned pigs.  
N. Arce, A. Morales, M. Cervantes, D. Pérez, E. Yocupicio, and A. Araiza..... 109
- 2039 Low birth weight is not related to higher intestinal distribution or increased serum levels of 5-hydroxytryptamine.  
S. Willemen, L. Che, M. De Vos, V. Huygelen, C. Casteleyn, S. Van Cruchten, and C. Van Ginneken..... 109

2040	Permeability changes in the small intestine of neonatal piglets fed formula. V. Huygelen, M. De Vos, S. Willemen, B. Tambuyzer, C. Casteleyn, D. Knapen, S. Van Cruchten, and C. Van Ginneken .....	109
2041	Insoluble nonstarch polysaccharides (iNSP) in diets for weaned piglets. R. Gerritsen and P. van der Aar .....	110
2042	The juvenile pig as a model for exocrine pancreatic insufficiency (EPI) in children: How to achieve sufficient vitamin A and vitamin E supply in EPI-patients? A. Moessler, T. Schwarzmaier, J. Grunemann, PC Gregory, and J. Kamphues.....	110
2043	Kidney bean lectin extract induces gut maturation resembling weaning. R. Zabielski, M. M. Godlewski, P. Matyba, J. L. Valverde Piedra, B. Westrom, and S. G. Pierzynowski.....	110
2044	Feed supplementation with pancreatic-like enzymes improve growth of exocrine pancreatic insufficient (EPI) pigs. S. G. Pierzynowski, K. Szwiec, J. Valverde Piedra, D. Gruijc, O. Prykhodko, O. Fedkiv, G. Skibo, G. Ushakova, T. Kovalenko, I. Osadchenko, D. Kruszewska, S. Szymanczyk, P. Swieboda, R. Filip, and B. Westrom .....	111
2045	Feeding pancreatic-like enzymes increases gut barrier function in pre-weaned piglets. O. Prykhodko, J. Wolinski, M. Slupecka, P. Ochniewicz, K. Szwiec, O. Lozinski, L. Lozinska, O. Fedkiv, D. Gruijc, S. Pierzynowski, and B. Weström .....	111
2046	Stimulating effect of pancreatic-like enzymes on the development of the gastrointestinal tract (GIT) in piglets. M. Slupecka, J. Wolinski, O. Prykhodko, P. Ochniewicz, D. Gruijc, O. Fedkiv, B. Weström, and S. G. Pierzynowski.....	112
2047	Development of intestinal carbohydrates sensing, digestion and absorption mechanisms in piglets. M. Al-Rammahi, A. Moran, D. Batchelor, P. Sangild, D. Bravo, S. Shirazi-Beechey, and C. Oguey.....	112
2048	Growth performance of early-weaned pigs is enhanced by feeding epidermal growth factor-expressing <i>Lactococcus lactis</i> fermentation product. A. Bedford, E. Huynh, M. Fu, J. Zhu, D. Wey, C. F. M. De Lange, and J. Li.....	112
2049	Early weaning decreases sodium-dependent acidic ileal excitatory amino acid carrier-1 (EAAC1) gene expression in pigs. Q. J. Wang, C. Yang, X. Teng, L. Xu, D. Lackeyram, K. Lien, and M. Fan .....	113
2050	Early weaning up-regulates jejunal neutral amino acid exchanger (ASCT2) gene expression in pigs. X. Teng, Q. J. Wang, C. Yang, and M. Fan.....	113

## Friday, June 1, 2012

### SYMPOSIA AND ORAL SESSIONS

<b>SESSION V:</b>		<b>Long-Term Effects of Pre and Early Postnatal Nutrition/Environment</b>	
		Chair: Dr. Layi Adeola, Purdue University, Columbine Ballroom .....	115
10:00 am	3000	Invited review: Long-term effects of pre and early postnatal nutrition and environment on the gut. J. P. Lallès.....	116
11:00 am		Break	
11:45 am	3001	Long-term impact of piglet weaning age on intestinal epithelial barrier function and stress responsiveness. A. J. Moeser*, E. L. Overman, S. M. D'Costa, and J. Xu.....	116
12:00 pm		Lunch	
1:30 pm	3002	Butyrate supplementation to gestating sows and piglets induces muscle and adipose tissue oxidative genes and improves growth performance. H. Lu and K. Ajuwon* .....	116

1:50 pm	3003	Effects of early management on the long-term development of intestinal immunity in growing pigs. M. A. Smits*, D. Schokker, and A. J. M. Rebel .....	117
2:10 pm	3004	The perinatal development of the gut is delayed in intrauterine growth retarded piglets. M. Mickiewicz, R. Zabielski*, B. Grenier, L. Le Normand, G. Savary, J. J. Holst, I. P. Oswald, C. C. Metges, and P. Guilloteau .....	117
2:30 pm	3005	Effects of a simple or a complex starter microbiota on intestinal microbiota composition in caesarean derived piglets. A. J. M. Jansman*, J. Zhang, S. J. Koopmans, R. A. Dekker, and H. Smidt .....	117

## POSTER PRESENTATIONS

### **SESSION V:**

#### **Long-Term Effects of Pre- and Early Postnatal Nutrition/Environment**

Quandry Peak with authors present from 11:00 am to 11:45 am on Friday, June 1<sup>st</sup>. Viewable from 8:00 am to 6:00 pm on Thursday, May 31<sup>st</sup> and from 8:00 am to 2:00 pm on Friday, June 1<sup>st</sup>... 118

3006	The influence of yeast extract in end gestation and lactation diets on piglets performance. J. M. R. Pupa, M. I. Hannas, C. M. C. Pereira, and F. Catunda .....	118
3007	Impact of <i>Pichia guilliermondii</i> (Pg) on weaned pig immune performance. B. Bass, V. Perez, H. Yang, T. Tsai, D. Holzgraefe, J. Chewing, and C. Maxwell .....	118
3008	Effect of age and of maternal antibiotic treatment on offspring gastric expression of the receptor for umami taste (TAS1R1) and of $\alpha$ -transducin, a taste receptor signaling messenger. P. Trevisi, S. Messori, D. Priori, M. Mazzoni, J.-P. Lalles, and P. Bosi.....	118
3009	Effects of supplemental zinc amino acid complex on intestinal integrity in heat-stressed pigs. M. V. Sanz-Fernandez, S. C. Pearce, V. Mani, N. K. Gabler, J. F. Patience, M. E. Wilson, M. T. Socha, R. P. Rhoads, and L. H. Baumgard.....	119
3010	The effect of feeding genetically modified Bt MON810 maize to sows during first gestation and lactation on maternal and offspring health. M. C. Walsh, S. G. Buzoianu, G. E. Gardiner, M. C. Rea, O. O'Donovan, R. P. Ross, and P. G. Lawlor.....	119
3011	Zinc oxide at low supplementation level improves productive performance and health status of piglets. J. Morales, G. Cordero, C. Pineiro, and S. Durosoy.....	120
3012	Brain development is dependent on colostrum intake in newborn piglets. G. Skibo, T. Kovalenko, I. Osadchenko, K. Goncharova, G. Ushakova, J. Wolinski, P. Ochniewicz, M. Slupecka, K. Szwiec, O. Prykhodko, O. Fedkiv, D. Grujic, B. Westrom, and S. G. Pierzynowski.....	120
3013	Behavioral changes in response to feeding pancreatic-like enzymes to exocrine pancreatic insufficient (EPI) pigs. S. G. Pierzynowski, P. Swieboda, K. Szwiec, D. Grujic, J. Botermans, J. Svendsen, J. L. Valverde Piedra, O. Prykhodko, G. Skibo, T. Kovalenko, K. Goncharova, G. Ushakova, D. Kruszewska, R. Filip, and B. Westrom .....	120
3014	Feed intake, rather than digestion is the growth-limiting factor in poor performing piglets. S. P. Paredes, A. Awati, A. J. M. Jansman, H. M. J. van Hees, M. W. A. Verstegen, and W. J. J. Gerrits .....	121
3015	Efficacy of prebiotics on lactose digestibility, whole body protein metabolic status and growth performance in replacing antibiotics in weanling pigs fed corn, soybean meal and dried-whey powder based diets. M. Hayhoe, T. Archbold, Q. Wang, X. Yang, and M. Fan.....	121
3016	Relationship between gut-derived endotoxin and postpartum dysgalaxia syndrome in sows. D. Guillou, V. Demey, F. Chaucheyras-Durand, and Y. Le Treut.....	122



3017	Short- and long-term effects of maternal antibiotic treatment around parturition on gut defence function. M. E. Arnal, J. Zhang, S. Mroz, S. Messori, and O. Perez-Gutierrez.....	122
3018	Body composition of piglets from sows fed the leucine metabolite $\beta$ -hydroxy $\beta$ -methyl butyrate (HMB) in late gestation. C. Flummer, N. B. Kristensen, and P. K. Theil .....	122
3019	Environmental control of early bacterial succession affects growth rate and postweaning gene expression in the pig. D. Petri and A. G. Van Kessel.....	123
3020	Endotoxin transfer through colostrum from the dam to the piglet. D. Guillou, S. Isinger, F. Chaucheyras-Durand, and Y. Le Treut.....	123
3021	Impact of maternal dietary fat supplementation during gestation upon neonatal offspring liver and muscle development and fatty acid metabolism. A. Mostyn, H. P. Fainberg, K. L. Almond, D. Li, C. Rauch, M. E. Symonds, and P. Bikker...	123
3022	Impact of <i>Pichia guilliermondii</i> (Pg) on lipopolysaccharide (LPS)-induced acute phase protein and cytokine response in the weaned pig. B. Bass, V. Perez, H. Yang, T. Tsai, D. Holzgraeffe, J. Chewning, and C. Maxwell .....	124
3023	Impact of <i>Pichia guilliermondii</i> (Pg) on sow and litter immune parameters. B. Bass, V. Perez, H. Yang, T. Tsai, D. Holzgraeffe, J. Chewning, and C. Maxwell .....	124
3024	Ileal mucosa-associated, but not ileal digesta, bacterial profiles in grower pigs are influenced by nutrition and use of antibiotics for starter pigs. C. L. Levesque, H. Yu, and C. F. M. de Lange .....	125

## POSTER PRESENTATIONS

### **SESSION VI: Methodologies and Their Application**

Quandry Peak with authors present from 11:00 am to 11:45 am on Friday, June 1<sup>st</sup>. Viewable from 8:00 am to 6:00 pm on Thursday, May 31<sup>st</sup> and from 8:00 am to 2:00 pm on Friday, June 1<sup>st</sup>. 127

3025	Gene expression profiles of peripheral blood mononuclear cell (PBMC) from young pigs fed high level of zinc oxide. S. Y. Ji, B. H. Choi, B. G. Kim, and C. H. Yun.....	128
3026	Comparison of three intestinal permeability methods. Y. van der Meer, W. J. J. Gerrits, M. van den Bosch, M. Moretó, W. A. Buurman, and T. A. T. G. van Kempen .....	128
3027	Flavor preferences conditioned by post-ingestive effect of sucrose and porcine digestive peptides (PDP) in post-weaning pigs. J. Figueroa, D. Solà-Oriol, E. Borda, S. A. Guzmán-Pino, and J. F. Pérez.....	128
3028	Evaluation of two external markers for measurement of ileal and fecal digestibility of humanized diets. H. N. Lærke, M. M. Kasprzak, and K. E. Bach Knudsen .....	129
3029	Use of medium without reducing agent for in vitro fermentation studies by bacteria isolated from pig intestine. C. Poelaert, C. Boudry, D. Portetelle, A. Théwis, and J. Bindelle .....	129
3030	Direct and regression methods do not give different estimates of digestible and metabolizable energy of wheat for pigs. O. A. Bolarinwa and O. Adeola .....	129
3031	Cell line IPEC-J2 develops properties of porcine jejunum if cultured under optimized conditions. S. S. Zakrzewski, J. F. Richter, J. D. Schulzke, M. Fromm, and D. Günzel.....	130
3032	An in vitro technique to model digestive behavior of feeds containing soluble fibers. B. A. Williams, K. Shelat, J. Hanan, S. Dhital, and M. J. Gidley .....	130

3033	Discrepancies in microbiota composition along the pig gastro-intestinal tract between in vivo observations and an in vitro batch fermentation model. C. Boudry, C. Poelaert, D. Portetelle, A. Thewis, and J. Bindelle .....	131
3034	Comparison of three internal markers in flow and recovery of feed enzymes in pigs. H. Jørgensen, L. Salmon, H. N. Lærke, and K. E. B. Knudsen .....	131
3035	Ex vivo model for investigating the bacterial association to the gut epithelium of pigs. S. Sugiharto, B. Jensen, and C. Lauridsen.....	131
3036	Porcine gut microbial metagenomic library for mining novel cellulases established from grower pigs fed cellulose-supplemented high-fat diets. W. Wang, T. Archbold, M. Kimber, J. Li, J. Lam, and M. Fan.....	132
3037	Effect of milk hydrolysates on inflammation markers and drug-induced transcriptional alterations in cell-based models. D. S. G. Nielsen, P. K. Theil, L. B. Larsen, and S. Purup .....	132
3038	Growth performance and preference studies to evaluate solvent-extracted <i>Brassica napus</i> or <i>Brassica juncea</i> canola meal fed to weaned pigs. J. L. Landero, E. Beltranena, and R. T. Zijlstra .....	132
3039	Redox potential of cecum content of growing pigs and its relation with pH and VFA concentration. R. Lizardo, N. Tous, M. A. Calvo, C. Sampsonis, R. D'Inca, and J. Brufau .....	133
3040	Blood sampling and hemolysis affect concentrations of plasma nutrients. P. K. Theil, L. J. Pedersen, M. B. Jensen, C. C. Yde, and K. E. Bach Knudsen.....	133
3041	Development and validation of a spectroscopy method to predict protein digestibility. L. F. Wang, M. L. Swift, and R. T. Zijlstra .....	134
3042	The in vivo infusion of hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> ) induces oxidative stress in piglets and differentially affects the activities of small intestinal carbohydrate digesting enzymes in pigs. D. Lackeyram, Y. Mine, T. Archbold, and M. Fan.....	134

## POSTER PRESENTATIONS

### **SESSION VII: Manipulation of Digestion**

Quandry Peak with authors present from 11:00 am to 11:45 am on Friday, June 1<sup>st</sup>. Viewable from 8:00 am to 6:00 pm on Thursday, May 31<sup>st</sup> and from 8:00 am to 2:00 pm on Friday, June 1<sup>st</sup>. 135

3043	Effects of processing technologies and cell wall degrading enzymes on in vitro degradability of barley. S. de Vries, A. M. Pustjens, H. A. Schols, W. H. Hendriks, and W. J. J. Gerrits .....	136
3044	Inhibitory action of analytical grade and of a new potentiated form of zinc oxide on the ex vivo growth of porcine small intestine bacteria. W. Vahjen, J. Zentek, and S. Durosoy .....	136
3045	Effects of oral supplementation with glutamate or combination of glutamate and N-carbamylglutamate on intestinal mucosa morphology and epithelium cell proliferation in weanling piglets. X. Wu and Y. Yin .....	136
3046	Dietary CLA modify gene expression in liver, muscles and fat tissues of fattening pigs. N. Tous, P. K. Theil, C. Lauridsen, R. Lizardo, B. Vilá, and E. Esteve-Garcia.....	137
3047	Does the dry matter content of the diet (fed dry or liquid) affects the intragastric milieu of pigs fed diets differing in grinding intensity and diets' physical form? A. Moessler, M. Wintermann, S. Sander, and J. Kamphues.....	137
3048	The effects of supplementations with two potassium formate sources on performance of 8 to 22 kg pigs. J. K. Htoo and J. Morales .....	138
3049	Reduced small intestinal $\alpha$ -amylase activity in the presence of soluble fibre arabinoxylan. A. M. Pluschke, M. J. Gidley, and B. A. Williams .....	138

3050	Comparison of four commercial feed proteases for improvement of nutritive value of poultry feather meal. M. B. Pedersen, S. Yu, P. Plumstead, and S. Dalsgaard.....	138
3051	Use of COSITEC in vitro model of the pig colon to assess the effect of probiotic yeast on fermentation parameters and microbiota. E. Pinloche, M. Williams, R. D’Inca, E. Auclair, and C. J. Newbold .....	139
3052	Responses of dietary ileal amino acid digestibility to consumption of different cultivars of potatoes and conventional fibers in pigs fed a high-fat basal diet. Q. Wang, X. Yang, S. Leonard, T. Archbold, A. Sullivan, B. Bizimungu, A. Murphy, A. Duncan, D. Ma, J. Htoo, and M. Fan .....	139
3053	Changes in the pig small intestinal mucosal glutathione system after weaning. J. Degroote, J. Michiels, E. Claeys, A. Ovy, and S. De Smet .....	139
3054	Whole body protein deposition and plasma amino acid profiles in growing/finishing pigs fed different levels of sulfur amino acids with and without <i>E. coli</i> -lipopolysaccharide challenge. J. C. Kim, B. P. Mullan, B. Frey, H. G. Payne, and J. R. Pluske .....	140
3055	Colostrum and milk production of sows is affected by dietary conjugated linoleic acid. U. Krogh, C. Flummer, S. K. Jensen, and P. K. Theil .....	140
3056	Enteral formula feeding has limited effects on gut adaptation in newborn pigs just after intestinal resection. L. B. Aunsholt, B. Stoll, A. Vegge, N. Qvist, T. Eriksen, D. G. Burrin, P. T. Sangild, and T. Thymann .....	141
3057	Effects of processing technologies combined with cell wall degrading enzymes on in vitro degradability of DDGS. S. de Vries, A. M. Pustjens, H. A. Schols, M. A. Kabel, and W. J. J. Gerrits .....	141
3058	Wet distillers grains and liquid condensed solubles for growing pigs - digestibility and the impact of pre-fermentation. N. Canibe, K. E. Bach Knudsen, B. B. Jensen, and H. Jørgensen.....	142
3059	The effect of protease and non-starch polysaccharide enzymes on manure odor and ammonia emissions in finisher pigs. P. O. Mc Alpine, C. J. O’Shea, P. F. Varley, P. Solan, T. Curran, and J. V. O’Doherty.....	142
3060	Improving the nutritional value of rapeseed cake—Enzyme addition during liquid fermentation. G. V. Jakobsen, B. B. Jensen, K. E. Bach Knudsen, and N. Canibe.....	142
3061	Effect of HMB supplementation of sows in late gestation and lactation on sow production of colostrum and milk and piglet performance. C. Flummer and P. K. Theil .....	143
3062	The effect of protease and carbohydrase enzymes on growth performance and nutrient digestibility in finisher pigs. J. McAlpine, C. J. O’Shea, P. F. Varley, B. Flynn, and J. V. O’Doherty .....	143
3063	Addition of casein to a whey-based formula has limited effects on gut function in preterm pigs. T. Thymann, A. C. F. Støy, S. B. Bering, L. Mølbak, and P. T. Sangild.....	143
3064	Dietary inclusion of a microencapsulated blend of organic acids and pure botanicals impacts intestinal health in weaned pigs. E. Grilli, B. Tugnoli, B. S. Seabold, A. J. Moeser, A. Piva, and C. H. Stahl .....	144

## **Session I: Gut Microbiome and Host Response**

**1000 Invited review: Microbiomics of monogastric farm animals.** H. Smidt,\* *Wageningen University, Wageningen, the Netherlands.*

Soon after birth the gastrointestinal tract (GI) of humans, pigs and other monogastric animals is colonized by a myriad of microbes, generally referred to as GI tract microbiota. This microbiota plays an important role in the host's health and nutrition and is characterized by its wide phylogenetic and functional diversity. Despite all efforts in improving the cultivation of novel GI tract microbes, the use of culture-independent approaches is crucial to provide a comprehensive picture of the GI tract microbial functioning. Since the introduction of culture-independent approaches, mainly those based on 16S ribosomal RNA (rRNA) and its encoding gene, GI tract ecology has experienced a revival. These culture-independent approaches gave insight into the temporal, spatial and inter-individual microbial diversity in the GI tract of humans and animals. In the past years, major developments have been made in high throughput methodologies to characterize microbial communities. Novel technologies, such as barcoded pyrosequencing of 16S rRNA genes, as well as phylogenetic fingerprinting using DNA microarrays such as the Human, Pig and Poultry Intestinal Tract Chips have recently been described. Since multiple samples can be analyzed in detail in a rather short time, these approaches offer great potential in finding significant correlations between the GI tract microbiota compositional signatures and the health status of the host. In addition, several meta-omics studies have been developed which allow studying the genetic potential and functional properties of the GI tract microbiota. The application of these approaches to understanding the interplay of intestinal microbiota and production animal health, also in response to the production environment as well as dietary additives, can provide the necessary knowledge for the development of innovative nutritional strategies toward more sustainable animal production. Examples will be provided from current research on the pig, and an overview of the current state of the art of microbiomics research will be given.

**Key Words:** microbiomics, host microbe interaction, colonization

**1001 Influence of diets high in fermentable carbohydrates or protein on large intestinal microbial ecology, mucosal response and urinary metabolomic profiles in piglets.** R. Pieper\*<sup>1</sup>, K. Neumann<sup>2</sup>, S. Kroeger<sup>1</sup>, J. F. Richter<sup>3</sup>, J. Wang<sup>4</sup>, L. Martin<sup>1</sup>, J. Bindelle<sup>5</sup>, J. K. Htoo<sup>6</sup>, W. Vahjen<sup>1</sup>, J. Zentek<sup>1</sup>, and A. G. Van Kessel<sup>4</sup>, <sup>1</sup>*Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany*, <sup>2</sup>*Department of Biometry and Clinical Epidemiology, Charité, Berlin, Germany*, <sup>3</sup>*Institute of Clinical Physiology, Charité, Berlin, Germany*, <sup>4</sup>*Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada*, <sup>5</sup>*University of Liège, Gembloux Agro-Bio Tech, Animal Science Unit, Gembloux, Belgium*, <sup>6</sup>*Evonik Industries, Hanau-Wolfgang, Germany.*

Dietary inclusion of fermentable carbohydrates (fCHO) can reduce large intestinal formation of putatively toxic metabolites derived from fermentable proteins (fCP).

However, the influence of diets high in fCP concentration on epithelial response and interaction with fCHO is still unclear. Thirty-two weaned piglets were fed 4 diets in a 2 × 2 factorial arrangement with low fCP/low fCHO, low fCP/high fCHO, high fCP/ low fCHO and high fCP/high fCHO. After 21–23 d, pigs were euthanized and colon digesta, urine and tissue samples analyzed for indices of microbial ecology, tissue expression of genes for immune response and oxidative stress indices. Colon and urine metabolite profiles were obtained on an Agilent 6210 ESI-TOF mass spectrometer and metabolites were annotated into KEGG pathways. Fermentable CP increased ( $P < 0.05$ ) Clostridium leptum group 16S rRNA gene count, increased total short and branched chain fatty acids, ammonia, putrescine, histamine and spermidine concentrations, whereas high fCHO increased ( $P < 0.05$ ) clostridia in the C. leptum and C. coccoides groups 16 S rRNA gene count, shifted the acetate to propionate ratio toward acetate and reduced ammonia and putrescine. High dietary fCP increased expression of PCNA, IL1 $\beta$ , IL10, TGF $\beta$ , MUC1, MUC2 and MUC20, irrespective of fCHO concentration. The ratio of glutathione to glutathione disulfide was reduced ( $P < 0.05$ ) by fCP. Metabolite identification and annotation from colon contents revealed increased abundance of metabolites associated with arachidonic acid metabolism in groups receiving high concentration of fCP. Urinary metabolites did not show as clear patterns Fermentable fiber ameliorates fermentable protein-induced changes in most measures of luminal microbial ecology, but not the mucosal response in the large intestine of pigs. Whether metabolite profiling might be an effective tool for biomarker identification of intestinal microbial ecology needs further elucidation.

**Key Words:** fermentable protein, cytokines, metabolomics

**1002 Differences in core microbiota between P1 and P3 dams and their progeny.** E. E. Hinkle,\* S. Ferando, and T. E. Burkey, *University of Nebraska-Lincoln, Lincoln, NE, USA.*

Gut microbiota impact host physiology and health. The objective was to evaluate fecal microbiota of pigs from different dam (D) parities (P) (birth through nursery). Fecal samples were collected directly from P1 and P3 sows ( $n = 6/P$ ; d 7 postfarrowing) and 1 pig/litter on d 7 and 14 (PrW; preweaning), and d 7 and 42 (PoW; postweaning). Total DNA was extracted, 16s V1-V3 region of the 16s rRNA gene amplified, and pyrosequenced. Quality controlled, chimera checked sequences were taxonomically assigned to operational taxonomic units (OTU) and species richness determined. Diversity among samples were estimated (UniFrac). Bacterial strains were identified from individual OTU using a 97% cutoff value. Pigs (PrW) had decreased ( $P < 0.01$ ) Firmicutes compared with D and PoW piglets. Day affected ( $P < 0.01$ ) phyla Bacteroidetes as D and PoW pigs had lower percentages than PrW pigs. In D, Clostridiaceae (33%; Clost) were most abundant. Pigs at d 7 PrW had comparable percentages of Bacteroidaceae (14%; Bact), Clost (11%), Lachnospiraceae (16%; Lachno), and Lactobacillaceae (19%). Pigs at d 14 PrW had high populations of Bact (13%), Lachno (16%). On d7 PoW Lactobacillus (31%) was the most dominant followed by



Lachno (13%). On d 42 PoW as Streptococcaceae (25%) were most abundant. Shifts were seen in UniFrac analysis as communities clustered by day. Core OTU were selected if present in 66% of pigs/P for PrW pigs and D. Individual OTU with significant  $P \times$  day interactions were aligned with most related type strains. Pigs on d 7 and 14 (PrW) had more core variation within individual populations compared with D ( $P < 0.01$ ). Parity affected ( $P = 0.02$ ) species richness as P1 D and pigs were more diverse than P3 D and pigs. Also, D had greater diversity than pigs on d 7 and 14 PrW. Two strains of *B. boum* were greater in P1 pigs than all D and pigs. Parity 3 D had greater *C. baratii* than P1 D and pigs from both P. More unclassified Lactobacillus species were found in P1 pigs on d 7 than P1 pigs on d 14, P3 pigs at all time points and D of both P. Dam parity had a limited effect on microbiota, but knowledge of gut microbial establishment may lead to understanding of host-microbial interactions in health and disease.

**Key Words:** gut microbiota, microbial establishment, parity

**1003 EGF-expressing *Lactococcus lactis* enhances growth performance of early-weaned pigs fed diets devoid of blood plasma.** A. Bedford<sup>\*1</sup>, Z. Li<sup>2</sup>, M. Li<sup>2</sup>, S. Ji<sup>2</sup>, C. F. M. de Lange<sup>1</sup>, and J. Li<sup>1</sup>, <sup>1</sup>*Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada*, <sup>2</sup>*INVE, Shenzhen, China*.

Stress and incomplete gastrointestinal development in early-weaned pigs represent significant challenges in commercial pork production. Largely because of food safety concerns, there is a trend to limit animal-derived ingredients in pig feeds. Therefore, alternative methods should be developed to stimulate intestinal development and provide disease resistance. Previously we have shown that feeding early-weaned piglets *Lactococcus lactis* that was engineered to express epidermal growth factor (EGF-LL) improves mean villous height in the intestine. In this study, we examined the effect of supplementing EGF-LL to early-weaned pigs that were fed diets with typical levels of blood plasma (5%; high complexity) or diets without blood plasma (blood plasma was substituted with soybean meal and fish meal, based on amino acid supply; low complexity). A total of 108 newly weaned piglets (19–26 d of age, mean BW 6.58 kg; 9 pigs per pen) were fed ad libitum according to a 2-phase feeding program without growth promoters. Three pens were assigned to each of 4 treatments: 1) high complexity diet with blank bacterial growth medium (HiCon), 2) high complexity diet with fermented EGF-LL (HiEGF), 3) low complexity diet with blank bacterial growth medium (LoCon), and 4) low complexity diet with fermented EGF-LL (LoEGF). The amount of EGF was determined in the fermentation product and pigs were allotted 60  $\mu$ g EGF/kg/d during the first 3 weeks post-weaning. There were no differences ( $P > 0.10$ ) in growth performance between HiCon and HiEGF pigs and no differences ( $P > 0.10$ ) in total growth performance between HiCon and HiEGF pigs. LoEGF pigs showed increased daily body weight gain (410 vs. 260 g/d;  $P < 0.01$ ) and Gain:Feed (0.67 vs 0.58;  $P < 0.05$ ) compared with LoCon pigs in the third week of treatment; this was comparable to the HiCon group (400 g/d and 0.64). These results indicated that supplementation

with EGF-LL can be effective in enhancing the performance of early-weaned piglets fed a low complexity diet, and reduces the need for feeding high-quality animal proteins and antibiotics.

**Key Words:** epidermal growth factor, probiotics, growth performance

**1004 An *Escherichia coli* F18 challenge model in newborn pigs.** M. L. Jensen, M. S. Cilieborg,<sup>\*</sup> M. V. Østergaard, S. B. Bering, and P. T. Sangild, *Department of Human Nutrition, University of Copenhagen, DK-1958 Frederiksberg C, Denmark*.

*Escherichia coli* F18 is a common porcine enteric pathogen causing diarrhea and edema in weaned pigs. An essential step in the pathogenesis of enteric colibacillosis is fimbria-receptor interaction facilitating colonization of the small intestine. Studies indicate that the FUT1 enzyme, required for F18 epithelial receptor binding, is not active until weaning at 3–5 weeks. This could be due to age effects or change of diet from milk to solid food. We hypothesized that artificially-reared piglets, deprived of sow's milk, would show neonatal F18 susceptibility in age-dependent manner. Initially, we verified the intestinal expression of FUT1 in preterm, term and weaned pigs by qPCR. Then age-related F18 susceptibility was evaluated in 3, 10 and 20 d-old pigs after inoculation of 10<sup>10</sup> cfu of *Escherichia coli* F18 for 12 d and compared with unchallenged control animals (each  $n = 4$ ). All pigs were fed with a milk replacer and scores of diarrhea was monitored twice daily. Finally, F18 susceptibility was evaluated in caesarean-derived 0 to 7 d-old piglets inoculated daily with F18 as above ( $n = 8$ ). For all piglets, their sows were genotyped to ensure that all piglets would express the FUT1 enzyme. Expression of FUT1 was detected in the proximal and distal intestine with no apparent differences in levels among preterm, term, and weaned pigs. No consistent differences were found in the prevalence of diarrhea among 3 to 20 d-old pigs, except that there was a tendency ( $P < 0.15$ ) to more days of F18-induced diarrhea, in the 3 d-old pigs compared with 10 and 20 d-old (17, 0, 8% respectively). In contrast, the newborn caesarean-delivered pigs, showed a high prevalence of diarrhea of 51% for the F18 inoculated piglets vs. 22% for the control piglets ( $P < 0.001$ ). We conclude that caesarean-delivered piglets deprived of sow's milk are highly susceptible to diarrhea induced by *E. coli* F18. Lack of the protective effects of birth colonization and sow's milk may explain the high sensitivity. The newborn pig may be used as a model to investigate the factors in milk that protect against F18 diarrhea.

**Key Words:** FUT1, *E. coli*, intestine

**1005 Dietary zinc oxide leads to short- and long term modifications in the intestinal microbiota of piglets.** I. Starke,<sup>\*</sup> W. Vahjen, and J. Zentek, *Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany*.

Zinc oxide is used as feed additive in piglets with well documented effects on performance and animal health. A

proposed mode of action is the modification of the intestinal microbiota. This study investigated the effects of ZnO (57 (low) vs. 2425 (high) mg zinc/kg diet), supplied as analytical grade ZnO on the intestinal microbiota of weaned piglets (n = 8 per group and sampling day) by assessing bacterial cell numbers (qPCR) and metabolites (volatile fatty acids, lactate, ammonia) in stomach, small intestinal and hind gut samples at different times after weaning (28, 42, 49, 56 d). Significant differences (*t*-test;  $P < 0.05$ ) were observed one week after weaning. Pronounced reductions of bacterial cell numbers and metabolites were observed for some bacterial groups throughout the intestinal tract in the high dietary ZnO group. The influence of ZnO diminished with increasing age. Only a few long-term modifications were found 4 weeks after weaning. In general, differences in bacterial metabolites were far less pronounced than cell numbers. Only lactate was shown to be significantly reduced in the small intestine. Of the 5 *Lactobacillus* species tested, 3 species showed significant reductions throughout the trial in the small intestine (*L. acidophilus*, *L. amylovorus*, *L. mucosae*). *L. johnsonii* and *L. reuteri* were not influenced by high concentrations of dietary ZnO. Likewise, *bifidobacteria* were not influenced throughout the trial. Furthermore, of 3 clostridial clusters studied (cluster I, IV, XIVa), only the clostridial cluster IV showed a numeric decrease in cell numbers, while clusters I and XIVa even increased at certain sampling sites. Cell numbers of total enterobacteria and of the *E.coli/Hafnia/Shigella* group were only reduced in cell number during the first 2 weeks after weaning. Thereafter, no influence of dietary ZnO was visible. This study showed that distinct differences in bacterial composition occur during the application of dietary zinc. As the most marked modifications took place during the early period, the beneficial action of ZnO against intestinal bacteria may be restricted to the early post weaning period.

**Key Words:** zinc oxide, *Lactobacillus*, qPCR

**1006 High throughput sequence-based analysis of the intestinal microbiota of weanling pigs fed genetically modified Bt MON810 maize for 31 days.** S. G. Buzoianu<sup>1,2</sup>, M. C. Walsh<sup>1</sup>, M. C. Rea<sup>3</sup>, O. O'Sullivan<sup>3,4</sup>, P. D. Cotter<sup>3,4</sup>, R. P. Ross<sup>3,4</sup>, G. E. Gardiner<sup>2</sup>, and P. G. Lawlor<sup>\*1</sup>, <sup>1</sup>Teagasc, Pig Development Department, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland, <sup>2</sup>Department of Chemical and Life Sciences, Waterford Institute of Technology, Waterford, Co. Waterford, Ireland, <sup>3</sup>Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork, Ireland, <sup>4</sup>Alimentary Pharmabiotic Centre, University College Cork, Cork, Co. Cork, Ireland.

The aim of this study was to investigate the effect of feeding genetically modified Bt MON810 maize on intestinal microbiota of weanling pigs. Eighteen pigs were weaned at ~28 d, and on d 0, following a 6 d acclimatization period, were blocked by weight and litter and assigned to treatments (39% isogenic or Bt maize in the diet for 31 d; n = 9/treatment). The maize lines were grown in neighboring plots in the same season to avoid differences due to environmental and seasonal variation. Fecal samples were taken on day -1 and 30 and ileal and cecal digesta samples

were taken at harvest on d 31. *Enterobacteriaceae*, *Lactobacillus* and total anaerobes were enumerated in fecal, ileal and colon digesta samples by culturing on selective media. Relative abundance of cecal bacterial populations was investigated using pyrosequencing of 16S rRNA gene amplicons with a total of 177771 and 155117 gene sequences being analyzed for the isogenic and Bt treatments, respectively. Fecal, cecal and ileal counts of total anaerobes, *Enterobacteriaceae* and *Lactobacillus* did not differ between treatments. High-throughput 16S rRNA gene sequencing revealed few differences in the composition of the cecal microbiota. The only differences observed were that pigs fed the Bt maize diet had higher cecal abundance of *Enterococcaceae* [0.06 vs 0%; 0–0.33 5th–95th percentiles;  $P < 0.05$ ], *Erysipelotrichaceae* (1.28 vs 1.17%; 0.16–2.95 5th–95th percentiles;  $P < 0.05$ ) and *Bifidobacterium* (0.04 vs 0%; 0–1.26 5th–95th percentiles;  $P < 0.05$ ) compared with pigs fed the isogenic maize diet. The relative abundance of cecal *Blautia* was also lower in Bt maize-fed pigs compared with isogenic maize-fed pigs (0.23 vs 0.40%; 0–0.73 5th–95th percentiles;  $P < 0.05$ ). These differences are not believed to have major biological significance and were not associated with any adverse health effects. These results indicate that Bt maize is well tolerated by weanling pigs at the level of the intestinal microbiota. Furthermore, these data can potentially be extrapolated to the human host, considering the suitability of pigs as a human model.

**Key Words:** transgenic, gene sequencing, microbiology

**1007 Effects of dietary supplementation with chitooligosaccharide on growth performance, biochemical parameters and intestinal flora in Huanjiang mini-piglets.** G. Q. Lian<sup>1</sup>, X. L. Zhou<sup>2</sup>, X. F. Kong<sup>1</sup>, Z. M. Feng<sup>1</sup>, and Y. L. Yin<sup>\*1</sup>, <sup>1</sup>Huanjiang Observation and Research Station for Karst Ecosystems, Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha, Hunan 410125, China, <sup>2</sup>Key Laboratory of Food Science and Technology, College of Life Science and Food Engineering, Nanchang University, Nanchang 330047, China.

This study was conducted to investigate the feasibility of chitooligosaccharide (COS) as a prebiotic on growth performance, biochemical parameters and intestinal flora in Huanjiang mini-piglets. Twelve Huanjiang mini-piglets weaned at 21 d of age were randomly allocated into 2 groups with 6 replicates. The piglets were fed with a 0.02% antibiotic- or 0.5% COS-supplemented diet for 14 d. Feed intake for each piglet was recorded daily; body weight was recorded and blood samples collected for plasma harvest used for measuring biochemical parameters on d 0 and 14. Ileal and cecal contents were collected on d 14 following euthanasia for enumeration of, *Bifidobacterium*, *Lactobacillus*, *Peptostreptococcus*, *Escherichia* and total bacteria by real-time quantitative PCR, respectively. The results showed that the growth performance in piglets fed COS-supplemented diet was unchanged when compared with the control group; dietary COS increased ( $P < 0.05$ ) the plasma activity of alkaline phosphatase, and decreased ( $P > 0.05$ ) the plasma concentrations of urea nitrogen and ammonia, when compared with the control group.

The PCR analysis showed that the COS supplementation enriched ( $P < 0.05$ ) the amounts of *Lactobacillus* in ileum and *Bifidobacterium* and *Lactobacillus* in cecum, while suppressed ( $P < 0.05$ ) the amounts of *Peptostreptococcus* in ileum and *Peptostreptococcus* and *Escherichia* in cecum. Collectively, these findings suggested that the COS may improve protein metabolism marginally, and enhance intestinal health by regulating the intestinal flora in Huanjiang mini-piglets.

**Key Words:** pigs, digestion and absorption, intestinal flora

**1008 Soybean oligosaccharides alter short-chain fatty acid production and microbial population of colon in vitro.** X. L. Zhou<sup>1,2</sup>, X. F. Kong<sup>1</sup>, and Y. L. Yin<sup>\*1</sup>, <sup>1</sup>*Huanjiang Observation and Research Station for Karst Ecosystems, Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha, Hunan 410125, China*, <sup>2</sup>*Key Laboratory of Food Science and Technology, College of Life Science and Food Engineering, Nanchang University, Nanchang 330047, China*.

This study was conducted to determine the fermentation characteristics of soybean oligosaccharides (SBOS) in an in vitro system. Colon digesta collected from Huanjiang mini-pigs was used as the inoculums, and SBOS (0.2 g per 10 fermentation broth) was used as the substrate during the in vitro fermentation. At the same time, the inoculum or inoculum plus glucose (0.2 g per fermentation broth) were used as negative or positive controls, respectively. Each group was accurately weighed in 3 replicates. The slurry was fermented for 48 h in an anaerobic, gas production recording was taken after 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 28, 32, 36, 42 or 48 h of incubation by referring to the moving scale on the plunger of the glass syringes, and then fermentation kinetic parameters, pH value, NH<sub>3</sub>-N content, short chain fat acids (SCFA) levels and microbial community in the fermentation broth were determined. Our data showed that the maximum volume and gas production rate in the SBOS-supplemented group were higher ( $P < 0.05$ ), and the lag time of gas production in SBOS- or glucose-supplemented groups were lower ( $P < 0.05$ ) than the free-supplemented group; the pH value and NH<sub>3</sub>-N content in fermentation broth supplemented with SBOS were lower ( $P < 0.05$ ) than the free-supplemented group; the SCFA contents in the SBOS- or glucose-supplemented groups were higher ( $P < 0.05$ ) than that of the free-supplemented group, the maximum content of butyrate acid was found in colon supplemented with SBOS. SBOS increased ( $P < 0.05$ ) the microbial diversity and population of *Bifidobacterium* and *Lactobacillus*, while decreased ( $P < 0.05$ ) *Escherichia* and *Streptococcus* when compared with the free-supplemented group based on real-time fluorescent quantitative PCR and terminal restriction fragment length polymorphism analysis. These findings suggested that the SBOS, as a functional dietary ingredient, can be selectively fermented by beneficial commensal bacteria in colon, improve the gut microbiota balance and modulate its metabolism.

**Key Words:** pigs, digestion and absorption, soybean oligosacch

**1009 Effect of a bacterial endo-1,4- $\beta$ -xylanase on ammonia emission in pigs.** R. Mombaerts<sup>1</sup>, A. Goderis<sup>\*1</sup>, and R. Geers<sup>2</sup>, <sup>1</sup>*NUTREX NV, Lille, Belgium*, <sup>2</sup>*Catholic University of Leuven, Leuven, Belgium*.

Ammonia emission from pig husbandry originates mainly from urea which is converted by bacterial urease into NH<sub>3</sub> and CO<sub>2</sub>. It was hypothesized that bacterial endo-1,4- $\beta$ -xylanase (Nutrase Xyla) can reduce NH<sub>3</sub> emission. These xylanases have a superior ability to breakdown both WE- and WU-AX into AXOS thereby stimulating fermentation which increases the content of N fixed in bacterial protein. Some ureum may enter the colon to meet the higher bacterial N-demand. This may partly shift excretion of N via urine to feces which may decrease NH<sub>3</sub> emission. Seventy pigs (21.5  $\pm$  2.1 kg) were allocated to 12 pens and each of 6 pens received a control diet or the control diet + 100 ppm Nutrase Xyla. Body weight and FI were recorded and analyzed with a linear model, based on the R<sup>2</sup> value, root MSE and the distribution of residuals. On d 27, 4 barrows of each group (42  $\pm$  3.02 kg) were housed individually during 2 consecutive periods of 14 d. During the last 4 d of each period, feces and urine were collected and quantified individually. Those 4 barrows that received the control diet during the 1st period, changed to the xylanase-diet during the 2nd period and vice versa. After each period, urine and feces were mixed to measure NH<sub>3</sub>. A fixed volume of slurry was transferred into a flowunit. Air was blown over the slurry surface. A fixed volume of the NH<sub>3</sub>-containing outgoing air was passed through a solution of H<sub>2</sub>SO<sub>4</sub> to measure NH<sub>3</sub> using a photospectrometer. The xylanase group had a higher daily gain (718 g/d vs 706 g/d) and lower FCR (2.78 vs 2.82) compared with the control pigs ( $P > 0.05$ ). In both periods, excretion of fecal-N/kg FI was higher for the xylanase group compared with the control group (5674 vs 5340 and 4602 vs 4317 mg N/kg FI resp.;  $P > 0.05$ ). Nutrase Xyla decreased NH<sub>3</sub> emission by 9% compared with the control group (3.95 vs 3.60 ppmv;  $P > 0.05$ ). The higher fecal N-excretion in the xylanase group is unlikely to be caused by the lower fecal protein digestibility, because Nutrase Xyla improved ADG and FCR compared with the control group. It is concluded that the higher fecal-N excretion, and consequently the lower NH<sub>3</sub> emission, is caused by a shift in urinary-N to fecal-N excretion.

**Key Words:** endo-1,4- $\beta$ -xylanase, ammonia, AXOS

**1010 The influence of grinding intensity and compaction of diets on the microbial community in the gastrointestinal tract of young pigs.** J. Bullermann<sup>1</sup>, S. J. Sander<sup>\*1</sup>, M. Arlinghaus<sup>1</sup>, J. Verspohl<sup>2</sup>, and J. Kamphues<sup>1</sup>, <sup>1</sup>*Institute for Animal Nutrition, University of Veterinary Medicine, Hannover, Germany*, <sup>2</sup>*Institute for Microbiology, University of Veterinary Medicine, Hannover, Germany*.

The aim of this study was to evaluate potential effects of grinding intensity (coarse, fine) and compaction (meal, pellet, extrudate) on the counts of lactobacilli, streptococci/enterococci and coliform bacteria as selected microbial groups in the content of the gastrointestinal tract (GIT) of young pigs. A total of 60 weaned piglets (33 d, 8.0  $\pm$  1.0 kg body weight) were divided into 4 groups with 15 animals



each and fed botanically and chemically identical diets as a coarsely ground meal (CM), a coarsely ground and pelleted (CP), a finely ground and pelleted (FP) or a coarsely ground and extruded (CE) diet for 4 wk. Coarse diets were produced by a roller mill, the fine diet by a hammer mill. At the end of the trial the animals were sacrificed and samples of the digesta were taken from the stomach, the end of the small intestine and the cecum for microbiological analyses (lactobacilli, streptococci/enterococci, coliform bacteria; culture techniques) and determination of pH, lactate and SCFAs. Significant differences regarding the microbial counts were mainly found between the CM and the FP group ( $P < 0.05$ ), while the CP and the CE diet mostly showed intermediate results. Pigs fed the CM diet had significantly highest numbers of lactobacilli in the digesta of the stomach (CM:  $8.0 \pm 0.461^a$ , FP:  $6.9 \pm 0.851^b$ , CP:  $7.4 \pm 0.782^{ab}$ , CE:  $7.5 \pm 0.992^{ab}$  lg cfu/g digesta) and the cecum (CM:  $8.2 \pm 0.657^a$ , FP:  $7.5 \pm 0.600^b$ , CP:  $8.1 \pm 0.564^a$ , CE:  $8.0 \pm 0.749^a$  lg cfu/g). Perhaps due to a more effective stomach barrier, characterized by high lactobacilli counts and a marked pH gradient in the stomach content (cardia:  $5.15 \pm 0.475$ , pylorus:  $2.83 \pm 1.06$ ), the significantly lowest counts of coliform bacteria were found in the distal part of the small intestine also after feeding the CM diet (CM:  $5.0 \pm 1.18^a$ , FP:  $6.1 \pm 0.743^b$ , CP:  $5.7 \pm 0.752^{ab}$ , CE:  $5.3 \pm 0.972^{ab}$  lg cfu/g digesta). These data indicate significant effects of grinding intensity and compaction on the gastrointestinal microflora. Higher lactobacilli and lower coliform numbers implicate advantages of the CM diet on intestinal health of young pigs.

**Key Words:** intestinal microflora, particle size, grinding intensity

**1011 Effect of feeding level on the composition of the intestinal microbiota in weaned piglets.** V. T. S. Rist,\* M. Eklund, E. Bauer, N. Sauer, and R. Mosenthin, *Institute of Animal Nutrition, University of Hohenheim, 70593 Stuttgart, Germany.*

In piglets, the development and composition of intestinal microbiota is influenced by dietary factors. Moreover, a considerable reduction in feed intake during the transition from liquid to solid feed is often accompanied by post-weaning diarrhea. Thus, it is hypothesized that variations in feeding level during weaning may affect intestinal microbial composition. The present study was designed to examine the effects of a high and a low feeding level on the composition of the ileal and fecal microbiota in piglets fed cornstarch-soybean meal or cornstarch-casein based diets. A total of 51 piglets (initial BW of  $6 \pm 0.9$  kg), fitted with simple T-cannulas at the distal ileum, were used in 4 consecutive experiments with 2 periods each. The assay diets contained graded inclusion levels of soybean meal or casein. The pigs received their assay diets at 2 feeding levels corresponding to 30 and 60 g/kg BW ( $n = 24$  for feeding level \* protein source). Each period included 7 d for adaptation to the ration. On d 8, fresh feces of each piglet were sampled once in the morning, whereas ileal digesta were collected at the time of highest digesta flow rate at 1200 h. Bacterial cell numbers of total eubacteria, *Lactobacillus* spp., and the mainly proteolytic *Clostridium leptum*, *Clostridium coccoides*, enterobacteriaceae and *Bacteroides*

*Prevotella*-*Porphyromonas* group (*Bacteroides* group) were determined by use of real-time PCR. There were no differences of bacterial cell numbers in feces ( $P > 0.05$ ). Ileal cell numbers of lactobacilli were increased ( $P < 0.001$ ) at the higher feeding level. In contrast, ileal cell numbers of the *Bacteroides* group ( $P < 0.05$ ) and *Clostridium coccoides* were lower ( $P < 0.001$ ) at the higher feeding level. There were no interactions between feeding level and protein source except for the *Bacteroides* group in ileal digesta. Results indicate that feeding level affects microbial composition in the small intestine, but obviously these changes were compensated in the large intestine. Also, sufficient feed intake during weaning encourages proliferation of beneficial bacteria, thereby contributing to improved gut health.

**Key Words:** feeding level, intestinal microbiota, weaned piglets

**1012 Interactions of *S. cerevisiae* fermentation product and in-feed antibiotic on gastrointestinal and immunological responses in piglets challenged with *E. coli* K88<sup>+</sup>.** E. Kiarie\*<sup>1</sup>, M. Scott<sup>2</sup>, D. O. Krause<sup>1</sup>, H. Khazanehei<sup>1</sup>, E. Khafipour<sup>1</sup>, and C. M. Nyachoti<sup>1</sup>, <sup>1</sup>University of Manitoba, Winnipeg, MB, Canada, <sup>2</sup>Diamond V, Cedar Rapids, IA, USA.

Interactive effects between in-feed antibiotic (PC, 0.04% chlortetracycline + 0.004% Denagard®, Novartis Inc., Canada) and *S. cerevisiae* fermentation product (XPC, Diamond V Original XPC, Cedar Rapids, IA) were investigated to provide insights for production systems seeking to minimize antibiotic usage. Pigs (3/pen) were randomly allotted to one of 6 diets (5 pens/diet) consisting of control (NC, no additives), XPC alone (0.2%), PC alone, or PC plus one of 3 levels of XPC (0.1, 0.2, or 0.4%). On d 7, all pigs were bled for baseline serum pro-inflammatory cytokine analysis, and then orally inoculated with a 6 mL dose of  $2 \times 10^9$  cfu/mL of ciprofloxacin-resistant *E. coli* K88<sup>+</sup> (ETEC). Severity of diarrhea, using fecal score (FS), was assessed on d 8, 9, and 10. On d 10, pigs were bled and 1 pig/pen was killed to obtain gastrointestinal (GIT) samples. Remaining pigs were monitored for another 4 d and then killed to obtain GIT samples. Pigs fed PC alone or in combination with XPC had a lower ( $P = 0.02$ ) FS than NC. PC pigs had lower ( $P = 0.02$ ) serum interleukin-6 and XPC pigs had higher ( $P = 0.003$ ) serum tumor necrosis factor- $\alpha$  than NC pigs. Ileal mucosal ETEC count was lower on d 10 ( $P = 0.04$ ) and d 14 ( $P = 0.003$ ) when additives were fed alone or in combination. Further microbiome (d 3 digesta) analysis using pyrosequencing showed that PC fed with XPC enriched ( $P = 0.01$ ) Streptococcaceae family (6.3 vs. 0.5%) than PC fed alone. On d 10, pigs fed PC alone and in combination with XPC at a lower dose had shallower ( $P = 0.01$ ) crypt depth than those fed higher doses of XPC, XPC alone or NC. Pigs fed XPC had a thicker colon wall on d 10 ( $P < 0.01$ ) compared with those fed non-XPC diets. Ileal and colonic digesta ammonia concentration was lower ( $P < 0.05$ ) for pigs fed additives diets on d 10 and 14. Feeding PC or XPC reduced diarrhea and the number of ETEC attached to the ileal mucosa; however, responses suggest independent and interactive effects that might be associated with the nature of these additives.

**Key Words:** *E. coli* K88<sup>+</sup>, pig gut health, *S. cerevisiae* fermentation product

**1013 Expression of heat shock protein 27 in gut tissue of growing pigs fed diets without and with inclusion of chicory fiber.** H. Y. Liu,<sup>\*</sup> T. Lundh, J. Dicksved, and J. E. Lindberg, *Department of Animal Nutrition and Management, Swedish University of Agricultural Science, Uppsala, Sweden.*

Cytoprotective heat shock protein 27 (Hsp27), one of the major inducible chaperones present in intestinal epithelial cells (IEC), is known to be regulated by various factors including the gut microbiota, their metabolites and probably the diet. The aim of the present work was to localize Hsp27 expression in the gut of healthy pigs and to study if the expression could be linked to the bacterial community structure and related diet effects. Eighteen 7-week-old pigs were fed one of 3 fiber-rich diets for 18 d, comprising a cereal-based control (C) diet and a cereal-based diet with inclusion of either 80 g kg<sup>-1</sup> chicory forage (CF80) or chicory root (CR80). Gut tissue samples were collected from distal ileum and proximal colon for immunohistochemical staining of Hsp27. Digesta samples were collected from the same sites for bacterial community structure analysis using terminal restriction fragment length polymorphism (T-RFLP). Blood was collected to determine the circulating Hsp27 level by ELISA. Statistical analysis was performed with PROC MIXED, PROC FREQ and PROC CORR in SAS (SAS Institute, Cary, NC, USA, version 9.1). Cluster analysis of TRF data was generated using Spearman rank correlation. The Hsp27 was 100% positively stained in both distal ileum and proximal colon samples, while very low level (0.02 ng ml<sup>-1</sup>) of Hsp27 was detected in serum. Hsp27 expression was most intensive in the surface of the IEC in direct contact with luminal contents, lighter in crypt cells and limited in lamina propria. The ileal Peyer's patches, where lymphocytes aggregate, showed a strong expression of Hsp27. This expression was highly correlated (Pearson correlation = 0.853,  $P < 0.0001$ ) with Hsp27 expression in the ileal epithelial cells. The frequency of Hsp27 expression was distributed differently between diets. Interestingly, the ileal microbial composition was distinct from colon, shown as 2 separate clusters. However, no difference was detected in diversity between the 2 segments. This indicates that the unique bacterial community structure, rather than the overall richness, might be associated with Hsp expression.

**Key Words:** heat shock protein 27, gut, chicory

**1014 Effect of pea protein-alginate encapsulation on viability of freeze-dried *Bifidobacterium adolescentis* during storage.** J. Wang<sup>\*1</sup>, M. Nickerson<sup>2</sup>, N. Low<sup>2</sup>, T. Scott<sup>1</sup>, and A. Van Kessel<sup>1</sup>, <sup>1</sup>*Department of Animal and Poultry Science, University of Saskatchewan, Saskatchewan, Canada,* <sup>2</sup>*Department of Food and Bioproduct Sciences, University of Saskatchewan, Saskatchewan, Canada.*

The overall goal of this research was to investigate the effect of pea protein isolate (PPI)-alginate (AL) encapsulation on the viability of *Bifidobacterium adolescentis* during storage. Early stationary phase *B. adolescentis* cultures

were centrifuged, washed and either resuspended in 1 volume of 15% skim milk and 0.5 volume of 30% glucose (BA) or encapsulated in a 4.0% PPI, 0.5% AL and 1.0% fructo-oligosaccharide (FOS) solution followed by extrusion and CaCl<sub>2</sub> crosslinking. Capsules were prepared without additives (PPC), with 0.25% skim milk and 0.075% glucose (PPC-M), 1.5% glycerol (PPC-G) or 0.02% cysteine-HCl (PPC-H). After freeze drying, the moisture content, particle size and loss of probiotic viability in simulated gastric juice (SGJ, pH 2.0) were determined. Aliquots were sealed in plastic bags with or without vacuum and stored at -80°C or room temperature (RT). Probiotic viability was determined (n = 3) on d 0, 14, and 44 of storage. No difference in mean moisture content (6.51%) and particle size (1720 μm) was observed among groups. Following SGJ challenge, a significant ( $P < 0.01$ ) reduction (log cfu/g) in viable *B. adolescentis* of 4.78 ± 0.17<sup>a</sup>, 1.82 ± 0.13<sup>b</sup>, 1.51 ± 0.14<sup>bc</sup>, 1.21 ± 0.14<sup>c</sup> and 1.18 ± 0.16<sup>c</sup> was observed for BA, PPC, PPC-H, PPC-M, and PPC-G, respectively. After storage at -80°C for 44 d, the reduction (log cfu/g) in viable counts was 0.90 ± 0.31 for BA, which was significantly ( $P < 0.01$ ) more than the other groups. After storage at RT for 14 d, the reduction (log cfu/g) in viable counts differed ( $P < 0.01$ ) for BA (2.64 ± 0.16<sup>a</sup>), PPC (2.32 ± 0.17<sup>ab</sup>), PPC-M (2.05 ± 0.29<sup>bc</sup>), PPC-G (1.83 ± 0.24<sup>c</sup>) and PPC-H (1.75 ± 0.28<sup>c</sup>). Vacuum packaging did not improve probiotic viability at -80°C; however at RT vacuum packaging reduced ( $P < 0.05$ ) viability loss (2.21 ± 0.34 vs. 2.02 ± 0.44). The results showed that the encapsulation of *B. adolescentis* in a pea protein-alginate matrix improved its viability in both SGJ and during storage. Additives and vacuum packaging provided additional storage protection. Further testing of the efficacy during feed processing and transit within the pig gastrointestinal tract are warranted.

**Key Words:** probiotic, encapsulation, pea protein

**1015 Effect of wheat DDGS or sugar beet pulp on prevalence of *Salmonella enterica* Typhimurium in weaned pigs.** L. W. Thomson<sup>\*1</sup>, R. Pieper<sup>2,1</sup>, J. K. Marshall<sup>1</sup>, and A. G. Van Kessel<sup>1</sup>, <sup>1</sup>*University of Saskatchewan, Saskatoon, Saskatchewan, Canada,* <sup>2</sup>*Institute of Animal Nutrition, Fachbereich Veterinärmedizin, Berlin, Germany, Europe.*

*Salmonella enterica* Typhimurium (ST) is of concern in the swine industry with relevance for animal health and consumer safety. Nutritional strategies might help to reduce ST infection and transmission. This study examined the potential of wheat distillers dried grains with solubles (DDGS) and sugar beet pulp (SBP) to alter intestinal microbial communities and ST shedding using a Trojan model. Weaned pigs (n = 105; 28.5 ± 3.5 d of age) were separated into 3 treatment groups (7 pigs/pen) and fed a wheat based control diet, or the control diet formulated with 15% wheat DDGS or 6% SBP inclusion. Following 12 d of diet adaptation, 2 pigs per pen were inoculated with 2 × 10<sup>9</sup> cfu ST, resistant to Novobiocin and Naladixic acid. Fecal swabs were taken from infected pigs and pen-mates (contact pigs) for 9 d following challenge, enriched in nutrient broth for 24 h and plated on selective media to determine prevalence of ST. The ranges of prevalence of ST in feces were from 90 to 100% in challenged pigs, and 74–78% in

contact pigs. No influence of treatment on rectal temperature and prevalence of ST in contact pigs were observed. Fifteen contact pigs were euthanized per treatment group on 9 and 10 d post challenge to enumerate in intestinal contents (ileum, cecum, proximal colon) *Lactobacillus* spp., enterobacteriaceae, and clostridium clusters I, VI, and XVI by qPCR and to determine ST prevalence by selective culture. No significant effects of diet were observed with respect to ST prevalence in feces, ileum, cecum, colon, and lymph nodes of contact pigs. Compared with the control diet, DGGs and SBP diets showed a trend toward increased ( $P < 0.1$ ) number of *Lactobacillus* species, and a lower ( $P < 0.1$ ) number of enterobacteriaceae in the cecum and colon. Although both wheat DGGs and SBP tended to increase the *Lactobacillus* spp. to enterobacteriaceae ratio consistent with improved gut health neither of the feed ingredients affected ST prevalence.

**Key Words:** *Salmonella enterica*, distillers dried grains with solubles, sugar beet pulp

**1016 Comparison of fecal methanogenic Archaea between Erhualian and Landrace pigs by using denaturing gradient gel electrophoresis and real-time PCR analysis.** Y. Su<sup>\*1,2</sup>, Y. Luo<sup>1</sup>, L. Zhang<sup>1</sup>, H. Smidt<sup>2</sup>, and W. Zhu<sup>1</sup>, <sup>1</sup>Laboratory of Gastrointestinal Microbiology, College of Animal Science and Technology, Nanjing Agricultural University, Nanjing, Jiangsu province, China, <sup>2</sup>Laboratory of Microbiology, Agrotechnology and Food Sciences Group, Wageningen University, Wageningen, the Netherlands.

Erhualian and Landrace breeds are typical genetically obese and lean pigs, respectively. To compare the fecal methanogenic Archaeal community between these 2 pig breeds, fecal samples from different growth phase pigs were collected, and used for denaturing gradient gel electrophoresis (DGGE) and real-time PCR analysis. Results showed that primer pair 344fGC/519r may be more suitable for community profiling of Archaea in pig feces by PCR-DGGE as compared with primers 519f/915rGC. Sequencing DGGE bands showed that the predominant methanogens in the feces of Erhualian and Landrace pigs belonged to *Methanobrevibacter* spp. and *Methanosphaera stadtmanae*. Real-time PCR analysis revealed that there was no significant difference in the numbers of fecal total methanogens between Erhualian and Landrace pigs, however, pig growth phase affected the numbers of 16S rRNA gene of total methanogens and *Methanobrevibacter smithii*. Dissociation curves of methyl coenzyme-M reductase subunit A (*mcrA*) gene fragments amplified from fecal samples of Erhualian and Landrace pigs with real-time PCR showed all samples possessed a single peak at 82°C which was observed when *M. smithii* DNA was used as a template.

**Key Words:** methanogenic Archaea, Erhualian pig, Landrace pig

**1017 Effects of supplementation with  $\beta$ -glucans on cytokine gene expression in the porcine liver.** M. T. Ryan<sup>1</sup>, C. B. Collins<sup>1</sup>, J. V. O. Doherty<sup>2</sup>, and T. Sweeney<sup>\*1</sup>, <sup>1</sup>School of Veterinary Medicine, University College Dublin,

Belfield, Dublin 4, Ireland, <sup>2</sup>School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4, Ireland.

$\beta$ -glucans are natural biomolecules with immunomodulatory activity and have recently been shown to stimulate the innate immune response in the porcine gastrointestinal system (GIT). The aim of this study was to determine if  $\beta$ -glucan supplementation extend beyond the gut to systemic levels. Hence, we examined the effects of dietary supplementation of  $\beta$ -glucans derived from *Laminaria digitata*, *L. hyperborea* and *Saccharomyces cerevisiae* on cytokine expression in the porcine liver. Weaned pigs were allocated to one of the following 4 dietary groups (n = 8 per group): Basal Diet (BD), BD + *L. hyperborea*, BD + *L. digitata* and BD + *S. cerevisiae*. The  $\beta$ -glucans were included at 250 mg/kg in the diets. Liver tissues of euthanized pigs were incubated with and without LPS (10  $\mu$ g/ml). Total RNA was purified from these tissues and real-time PCR was used to quantify the expression of the following cytokine (*TNF $\alpha$* , *IL10*, *IL8*, *IL6*, *IL4*, *IL1 $\alpha$* , *IL17*, *INF $\gamma$* ) and receptors (*CLECT7*, *TRAF* and *TLR4*). Normalized relative quantities were analyzed using the GLM procedure in SAS. No significant differences in expression were observed for any of the targets in the unchallenged liver tissue. However, in the LPS challenged tissue several differences were observed: *IL6* and *TRAF* expression were downregulated in the *S. cerevisiae* exposed liver samples in comparison to BD ( $P = 0.05$  and  $0.04$  respectively); *IL6* and *TLR4* expression were downregulated in the *L. digitata* exposed liver samples in comparison to BD ( $P = 0.04$  and  $0.017$  respectively); *IL10* and *IL1 $\alpha$*  expression were upregulated in the *L. hyperborea* exposed liver samples in comparison to BD ( $P = 0.06$  and  $0.02$  respectively). In fact there was a ~3 fold increase in both *IL10* and *IL1 $\alpha$*  in *L. hyperborea* exposed liver samples relative to *L. digitata* ( $P = 0.0008$  and  $0.0025$  respectively). These results indicate that supplementation with  $\beta$ -Glucans from both yeast and seaweed sources have systemic effects on cytokine expression in the liver. The most statistically significant differences were observed between the soluble (*L. digitata*) and insoluble (*L. hyperborea*)  $\beta$ -glucans in relation to their effects of LPS challenged liver tissue.

**Key Words:**  $\beta$ -glucans, liver

**1018 Effect of a bacillary probiotic on health and performance of sows and piglets.** T. Marubashi<sup>\*1</sup>, S. K. Krittas<sup>2</sup>, G. Filioussis<sup>2</sup>, G. Christodoulouopoulos<sup>3</sup>, E. Petridou<sup>2</sup>, AR Burriel<sup>3</sup>, E. Papadopoulos<sup>2</sup>, A. Tzivara<sup>3</sup>, and E. McCartney<sup>4</sup>, <sup>1</sup>Calpis Co., Ltd., Tokyo, Japan, <sup>2</sup>School of Veterinary Medicine, Aristotle University of Thessaloniki, Thessaloniki, Greece, <sup>3</sup>Veterinary Faculty, University of Thessaly- Karditsa, Karditsa, Greece, <sup>4</sup>EU Pen & Tec Consulting SCP, Barcelona, Spain.

Sow body condition during pregnancy and lactation is critical to her health and performance as well as that of her litter. Previous research indicates that administering beneficial bacteria (probiotics) in feed improves both health and performance in pigs, poultry and other species. We investigated the effects of Calsporin<sup>®</sup> (Calpis Co. Ltd., Japan), a probiotic based on viable spores of *Bacillus*



*subtilis* C-3102 (C-3102), on health and productivity of sows and their litters. The study was performed in a farrow-to-finish farm with a capacity of 350 sows and its own feed mill, using an all-in-all-out batch management system. Following weaning of the previous litter, sows were housed in individual crates for 30 d, until served and pregnancy confirmed. Subsequently, weekly batches of 14-15 sows at the same gestation stage were loose-housed in a pen with individual feeders until 103-110 d of gestation, then moved to a farrowing room until weaning of piglets at approximately 26 d of age. Four batches of sows were studied throughout pregnancy and lactation. Of these, two batches of sows (T2) were fed a top-dressing supplying  $3 \times 10^5$  cfu C-3102 per gram complete feed, and two control batches (T1) were fed the basal top-dressing free of probiotic. The offspring of the T1 control group were offered T1 basal creep feed, while piglets of the T2 group were offered basal feed supplemented with C-3102 supplying  $3 \times 10^5$  cfu C-3102 per gram complete feed. Each dam with her litter represented an experimental unit (replicate). Treatment groups (T1 and T2) were similar with respect to sow age/parity distribution. During lactation, weight loss of T2 sows was significantly lower, while mean weaning weight and growth, birth to weaning, of T2 piglets were significantly improved. The positive effect of C-3102 on sow condition during lactation, as evidenced by reduced weight loss, may improve sow milk production and conception rate. By weaning, T2 piglets were on average 0.5 kg heavier than T1 control piglets, possibly due to indirect (through the dam), or direct (through the creep feed) effects of the probiotic.

**Key Words:** sows, *Bacillus subtilis* C-3102, creep feed

**1019 G protein-coupled receptor120 (GPR120) transcription in intestinal epithelial cells are significantly affected by bacteria belonging to the Bacteroides, Proteobacteria, and Firmicutes phyla.** M. Fredborg, P. K. Theil, B. B. Jensen, and S. Purup,\* *Aarhus University, Denmark.*

Free fatty acids (FFAs) are produced in the intestine by microbial fermentation. Recently, a family of G protein-coupled receptors (GPR) acting as FFA transporters has been reported; including GPR120 which is expressed by intestinal epithelial cells and has been reported to function as a control point for anti-inflammatory effects. The aim of the present study was to evaluate whether 12 selected intestinal bacteria, representing the 3 major phyla present in the intestine, affects intestinal epithelial cell GPR120-transcription. Caco-2 intestinal epithelial cells were cultured on filter inserts for 21 d until fully differentiated. Supernatants of the 12 bacteria were added to cell culture medium at the apical side in a cell:bacteria ratio of 1:200. After 4 h incubation, changes in cellular transcription of GPR120 by bacterial supernatant were examined using real time reverse transcriptase polymerase chain reaction (RT-PCR). Supernatants from 6 of the 12 bacteria analyzed influenced the mRNA level of GPR120 significantly ( $P < 0.05$ ) compared with cells without added bacteria. A significant increase in cellular GPR120 mRNA was observed by *E. faecium*, *L. reuteri*, *L. salivarius*, *E. coli* K-12, *B. fragilis* and *F. prausnitzii*. The greatest increase was observed by the latter 2, which

was observed to increase cellular GPR120 mRNA level by  $>2.1$  fold. Intriguingly, these bacteria are categorized as either probiotics or bacteria capable of introducing an anti-inflammatory effect. The beneficial effect of these bacteria may very well be mediated by regulation of GPR120. The regulation of GPR120 by intestinal microbiota represents a direct signaling pathway for gut bacteria to affect host health and metabolism.

**Key Words:** bacteria, GPR120, intestinal epithelial cells

**1020 Intestinal delivery of probiotics bacteria protected with succinylated  $\beta$ -lactoglobulin tablets and their effects on pig intestinal microbiota.** I. Paquette<sup>1,2</sup>, J.-P. Brousseau<sup>2</sup>, G. Talbot<sup>2</sup>, M. Lessard<sup>2</sup>, R. Caillard<sup>1</sup>, and M. Subirade<sup>1</sup>, <sup>1</sup>*Université Laval, Département des sciences et technologie des aliments, Québec, Québec, Canada,* <sup>2</sup>*Dairy and Swine R & D Centre, Agriculture and Agri-Food Canada, Sherbrooke, Québec, Canada.*

This study was performed to evaluate the potential of succinylated  $\beta$ -lactoglobulin ( $\beta$ -lg) tablets to protect 2 probiotics, *Lactobacillus helveticus* (Lh) and *Bifidobacterium longum* (Bl) from in vitro gastric condition and to determine, in vivo, the influence of delivering protected probiotics in succinylated  $\beta$ -lg tablets on intestinal microbiota. To realize in vivo study, 48 weaned piglets of 28 d-old, were divided into 3 groups and received one of the following tablets daily: Group 1) succinylated  $\beta$ -lg tablets without probiotics, Group 2) non-succinylated  $\beta$ -lg tablets with  $10^9$  cfu of Lh and Bl, Group 3) succinylated  $\beta$ -lg tablets with  $10^9$  cfu of Lh and Bl. After 14 and 28 d of treatment, 8 piglets per group were euthanized and colon contents were sampled to characterize bacterial population (selective medium and T-RFLP) and confirm the presence of Bl by qPCR. In vitro study showed that after 1 h incubation in simulated gastric condition, more than  $10^9$  cfu of each strain were still viable when incorporated in succinylated  $\beta$ -lg tablets. In vivo, piglets receiving protected probiotics had higher ( $P \leq 0.05$ ) bifidobacteria counts in colon content than groups 1 and 2 after 28 d. These results suggest that the use of succinylated  $\beta$ -lg tablets helped maintain the viability of the probiotics as they were delivered into the intestine. Analysis of colonic microbiota T-RFLP profiles showed that the relative abundance of bacterial population belonging to Ruminococcaceae was significantly different between treatments ( $P \leq 0.05$ ), with a higher abundance for group 3. However, diversity indices (Evenness and Shannon) calculated from T-RFLP profiles revealed no major influence of our treatments on the colonic microbiota. Using specific primers for Bl, qPCR assays showed its presence in the colon of animals receiving tablets containing probiotics (groups 2 and 3). In conclusion, these results suggest that the protected probiotics were delivered alive in the intestine and their daily administration can modulate specific bacterial populations without affecting the overall microbiota.

**Key Words:** probiotics, microbiota, encapsulation

**1021 Dietary supplementation with alkaline phosphatase affects intestinal microbial populations of nursery pigs.** M. H. Rostagno<sup>1</sup>, J. Ferrel<sup>2</sup>, J. S. Radcliffe<sup>3</sup>, and B. T.

Richert<sup>3</sup>, <sup>1</sup>USDA-ARS, Livestock Behavior Research Unit, West Lafayette, IN, USA, <sup>2</sup>ChemGen Corporation, Gaithersburg, MD, USA, <sup>3</sup>Purdue University, Department of Animal Sciences, West Lafayette, IN, USA.

Supplementation of swine diets with exogenous enzymes has generated increased interest with the objective of improving growth performance and reducing nutrients excreted to the environment. However, the potential effect of dietary exogenous enzymes on the intestinal microbial ecosystem of young pigs is mostly unknown. Therefore, a study was conducted to determine the effect of dietary supplementation with alkaline phosphatase (AP, 0.066 MU/kg) on the intestinal microbial populations of nursery pigs. Seven days post-weaning (weaning at 19 d of age), 36 pigs were individually housed and randomly assigned to one of the following treatments (9 pigs/treatment) fed in 2 phases (d 0–5 and d 5–19): 1) positive control (3429 and 3406 kcal ME, and 0.55 and 0.45% available phosphorus, phase 1 and 2, respectively); 2) negative control (100 kcal/kg ME reduction, and 80% of the available phosphorus); 3) negative control + AP; and 4) negative control + AP + phosphorus (0.55 and 0.45% available phosphorus). Individual ileal, cecal, and fecal samples were collected on d 19 for microbial analysis. Conventional bacteriological enumeration was performed to determine levels of coliforms (MacConkey agar), *Escherichia coli* (Eosin Methylene Blue agar), lactobacilli (Rogosa agar), bifidobacteria (BSM agar), aerobes and anaerobes (Brain Heart Infusion agar), and enterococci (m-Enterococcus agar). No differences among treatments were detected in microbial populations analyzed in cecal and fecal samples ( $P > 0.10$ ). However, ileal samples revealed significant differences between treatments. *Escherichia coli* and enterococci were reduced in treatment 3 ( $P < 0.05$ ), whereas coliforms, aerobes, and anaerobes were reduced in treatment 4 ( $P < 0.05$ ), compared with the other treatments (1 and 2), which did not include AP supplementation. No effects were observed in lactobacilli and bifidobacteria ( $P > 0.10$ ). In conclusion, this study shows that supplementation of diets with exogenous enzymes has potential as an intestinal microbial modulator tool in swine production.

**Key Words:** swine, microbiota, alkaline phosphatase

**1022 Medium chain fatty acids and organic acid based feed additives improve animal performance and reduce bacterial overgrowth in the small intestine of weaning piglets.** A. Awati<sup>\*1</sup>, C. H. Smits<sup>1</sup>, and H. M. Timmerman<sup>2</sup>, <sup>1</sup>Nutreco Research and Development, Boxmeer, The Netherlands, <sup>2</sup>NIZO Food Research, Ede, The Netherlands.

Medium chain fatty acids (MCFA) and organic acids (OA) are often used as feed additives in piglet diets for pathogen control. An in vivo study was conducted to evaluate the effect of 0.3% addition of MCFA+OA mixture (C8, C10, C12 and sorbic acid, benzoic acid and butyric acid) to diet on microbial population in the piglet intestine. Each of 96 weaning piglets (~3 weeks old and average BW 5.7 kg) were housed in groups of 4 piglets per pen (24 pens in total). Each pen was subjected to either control or MCFA+OA added diet. Control diet was a corn, wheat and soybean

meal based high quality commercial diet. No anti-microbial growth promoter (AMGP) was added in the diets. Piglets had ad-libitum access to fresh feed and drinking water. Piglets were challenged by creating a microbiological contaminated environment by spreading manure and not cleaning the stables. On d 14 post-weaning, jejunal and ileal digesta samples were collected from one pig per pen and individual samples from every pig were analyzed by qPCR for total bacterial count (TBC) and by barcoded pyrosequencing (~8000 reads/sample) for profiling the microbial community and assessing microbial diversity. TBC was significantly lower in jejunum of MCFA+OA group compared with control (8.1 vs 8.7 log copies/g digesta;  $P < 0.05$ ). Microbial diversity in the jejunum of MCFA+OA group was numerically higher for all metrics calculated (Phylogenetic Diversity (UNIFRAC) (+14%), Shannon's diversity (29%), Chao1 index (28%) and the number of species (+26%). These changes in TBC and microbial diversity were also observed in the ileum, however, did not reach statistical significance. Over the entire 5 weeks study period MCFA+OA group piglets showed significantly higher feed efficiency (0.79 vs 0.75  $P < 0.01$ ) and reduction in diarrhea incidence (35% lower  $P < 0.1$ ) compared with control diet group. It was concluded that MCFA+OA may exert their positive effects on performance and reduction in diarrhea incidence by reducing microbial overgrowth in the proximal intestine of weaning piglets.

**Key Words:** microbial diversity, medium chain fatty acids, total bacterial counts

**1023 Barcoded pyrosequencing reveals a decrease in microbial diversity in small intestine after weaning of piglets irrespective of rearing conditions.** A. Awati<sup>\*1</sup>, C. H. Smits<sup>1</sup>, and H. M. Timmerman<sup>2</sup>, <sup>1</sup>Nutreco Research and Development, Boxmeer, The Netherlands, <sup>2</sup>NIZO Food Research, Ede, The Netherlands.

Two in vivo studies were done to study the effects of weaning on microbial diversity in the small intestine. In both studies, piglets (~3 weeks old) were subjected to corn, wheat and soybean meal based high quality commercial diet. No anti-microbial growth promoter (AMGP) was added in the diets. Piglets had ad-libitum access to fresh feed and drinking water. In the first study 12 piglets were individually housed in a high hygiene facility and in the second study 18 piglets were housed in groups in low-hygiene facility. In both studies 6 piglets were sacrificed at d 0 (pre-weaning) and 6 piglets on d 7 post-weaning for study 1 and 12 piglets on d 14 post-weaning for study 2. In both studies, jejunal and ileal samples were collected and each sample from individual piglet was analyzed by barcoded pyro-sequencing (~6000 reads/sample) for profiling the microbial community as well as assessing microbial diversity. In both studies, microbial diversity in the jejunum of post-weaning piglets was significantly lower for all metrics calculated (In first study, Phylogenetic Diversity (UNIFRAC) (-25%), Shannon's diversity (-14%), Chao1 index (-11%) and the number of species (-14%) and in second study, Phylogenetic Diversity (UNIFRAC) (-55%), Shannon's diversity (-64%), Chao1 index (-54%) and the number of species (-62%). The aforementioned

changes in microbial diversity were also observed in the ileum, however, only the differences observed in first study were statistically significant. It is concluded from these observations that irrespective of group against individual housing and clean against dirty environment, change from sow's milk to weaning diet decreased the microbial diversity in small intestine.

**Key Words:** microbial diversity, small intestine, weaning

**1024 Increasing amylose content of starch shifts bacterial populations in the cecum and colon of weaned pigs.** J. M. Fohse<sup>\*1</sup>, M. G. Gänzle<sup>1</sup>, P. R. Regmi<sup>1</sup>, T. A. T. G. van Kempen<sup>2</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>North Carolina State University, Raleigh, NC, U.S.A.

After weaning, pigs have an unstable microbiome and compromised gut integrity, which can lead to gut disorders. We hypothesized that increasing dietary amylose shifts microbial profile in the cecum and colon and changes gut morphology. Weaned pigs (n = 32) were randomly allocated to 1 of 4 diets in 2 replicates. Diets contained 70% purified starch with amylose contents of 0, 20, 28 or 63%. Experimental diets were introduced 6 d post-weaning and gradually increased up to 3 × maintenance. Cecum and colon digesta and gut tissues were collected following slaughter, 27–30 d post-weaning, to evaluate microbial profile and gut morphology. Genomic DNA was extracted from digesta to quantify gene copies of *Lactobacillus* spp. (*LAB*), *Bacteroides-Prevotella-Porphyrmonas*, (*BAC*) and *Enterobacteriaceae* spp. (*ENT*) using quantitative PCR. Transverse sections of the duodenum, jejunum, ileum and colon were stained and analyzed under an image analyzer to determine crypt depth and villus height. In the cecum, diets with moderate amylose content (28%) decreased ( $P < 0.05$ ) *LAB* compared with diets with 0, 20, and 63% amylose content (7.5 vs. 8.2, 8.5 and 8.2 ± 0.2 log/g wet wt) and colon (6.7 vs. 7.8, 7.9 and 7.9 ± 0.3 log/g wet wt). In the colon, diets with high amylose content (63%) increased ( $P < 0.05$ ) *BAC* compared with diets with 20 and 28% amylose contents (10.9 vs. 10.5 and 10.5 ± 0.1 log/g wet wt). Dietary differences were not observed for *BAC* and *ENT* in the cecum and *ENT* in the colon. Increasing amylose from 0 to 63% did not affect crypt depth or villus height in the duodenum, jejunum, ileum or colon. This lack of change was perhaps not unexpected due to morphology being measured 4 weeks post-weaning, when pigs had recovered from weaning stress. In conclusion, manipulating dietary amylose content altered the microbial profile of *LAC* in the cecum and colon and *BAC* in the colon; however, amylose content did not affect crypt depth and villus height.

**Key Words:** starch, amylose, bacteria

**1025 Comparison between the effects of spray dried and wet dietary supplementation of laminarin and fucoidan on microbiology and inflammatory cytokine gene expression in the pig gut.** A. Mukhopadhyay<sup>\*1</sup>, J. V. O'Doherty<sup>2</sup>, A. Smith<sup>1</sup>, B. Bahar<sup>1,2</sup>, and T. Sweeney<sup>1</sup>, <sup>1</sup>School of Veterinary Medicine, Veterinary Science

Centre, University College Dublin, Belfield, Dublin-4, Ireland., <sup>2</sup>School of Agriculture and Food Science, University College Dublin, Belfield, Dublin-4, Ireland.

Weaning piglets are exposed to several stresses leading to health issues and subsequent lower performance. Bioactive food ingredients are proposed to ameliorate pathogenic and inflammatory health problems. Seaweeds and seaweed extracts (SWE) are a rich source of laminarin and fucoidan, which have antimicrobial, anti-inflammatory and prebiotic properties. Spray-dried bioactive food ingredients are preferred over wet forms by food industry due to their stability, low storage costs and easy encapsulation. The aim of this experiment was to compare the effect of spray-dried or wet laminarin and fucoidan from *Laminaria digitata* on microbiology and inflammatory cytokine profile of ileum and colon in newly weaned pigs. Weaning piglets were assigned to either: 1) basal diet, 2) basal diet + wet SWE (185 g DM/kg) or 3) basal diet + dry SWE (940 g DM/kg) for 21 d. The inclusion rate of laminarin and fucoidan was 500 and 400-ppm, respectively. Digesta samples were collected for bacterial population count using plate culture methodology. Bacteria counts were indicated in colony forming units (cfu) /g fresh feces. Ileal and colonic tissues were collected for total RNA extraction and qPCR. Gene expression levels of mucin (*MUC2* and *MUC4*), trefoil factor (*TFF3*), pro-inflammatory (*IL-1 $\alpha$* , *IL-4*, *IL-6*, *IL-8*, *IL-17A*, *IFN $\gamma$* , *TNF $\alpha$* ) and anti-inflammatory cytokine (*IL-10*) were evaluated by qPCR from total RNA. Bifidobacteria counts were higher in wet SWE formulation in comparison to both spray dried SWE and basal diet in ileum, while the bifidobacteria counts in spray dried SWE formulation were similar to basal diet. No differences were observed between wet and spray dried SWE formulation on cytokine profile of the selected panel of genes in ileum and colon. Thus, in conclusion, while no major effect of wet and spray dried SWE formulation was observed on the inflammatory cytokine gene expression levels in ileum and colon, wet SWE formulation of laminarin and fucoidan had a prebiotic effect in ileum of piglets which was lost in spray dried SWE formulation due to drying.

**Key Words:** seaweed, cytokine, prebiotic

**1026 Effect of feeding different extruded and non-extruded cereals on the gut mucosa and gut microbiota of piglets during the first week post-weaning.** D. Torralardona<sup>\*1</sup>, N. Andrés-Elias<sup>1</sup>, S. López<sup>2</sup>, I. Badiola<sup>2</sup>, and M. Cerdà-Cuéllar<sup>2</sup>, <sup>1</sup>IRTA-Mas de Bover, E-43120 Constantí, Spain, <sup>2</sup>CRESA, UAB-IRTA, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain.

Two trials were conducted to evaluate the effect of different cereals in piglet diets on the jejunal mucosa and the ileal and cecal microbiota during the first days post-weaning. In trial-1, 48 newly-weaned pigs (7.56 kg BW; 26 d of age) were individually housed and distributed among 3 experimental diets containing white rice, naked oats or barley as the cereal source. At the start of the trial (weaning; d 0), 12 piglets were slaughtered and sampled to obtain initial reference values for histology and microbiology determinations. An additional 4 pigs per treatment per day were slaughtered and sampled on d 1, 2 and 6 post-weaning. Villus height (VH), crypt depth



(CD) and intraepithelial lymphocytes (IEL) in jejunal mucosa were measured, and microbiota in ileal and cecal digesta was evaluated by restriction fragment length polymorphism (RFLP). The Manhattan distances between RFLP profiles were calculated, and for each treatment and sampling day intra-group similarities (IGS) were calculated. In trial-2, an additional 48 pigs were used (7.95 kg BW; 26 d of age), and the same experimental procedures were performed except that the 3 experimental diets contained extruded white rice, extruded naked oats or extruded barley as the cereal source. A reduction in VH was observed in both trials between d 0 to 6 ( $P < 0.05$ ). In trial-1 (raw cereals), more IEL and deeper crypts were observed for the barley than for the naked oats based diets ( $P < 0.05$ ). In trial-2, no differences among extruded cereals were observed for the histological parameters. In trial-1, naked oats resulted in smaller IGS (increased heterogeneity) of the microbiota in the ileum and in the cecum compared with rice and barley ( $P < 0.05$ ). In trial-2, extruded barley presented a smaller IGS in the ileum than extruded naked oats and extruded rice, whereas in the cecum, both extruded barley and extruded rice had a smaller IGS in the ileum than extruded naked oats ( $P < 0.05$ ). It is concluded that cereal nature and technological treatment affect the composition of the microbiota and the morphology of the gut mucosa in newly weaned pigs.

**Key Words:** cereal, extrusion, microbiota

**1027 Effect of feeding different cereal-based diets on the performance and gut health of weaned piglets with or without previous access to creep feed during lactation.** D. Torrallardona<sup>\*1</sup>, N. Andrés-Elias<sup>1</sup>, S. López<sup>2</sup>, I. Badiola<sup>2</sup>, and M. Cerdà-Cuellar<sup>2</sup>, <sup>1</sup>IRTA-Mas de Bover, E-43120 Constantí, Spain, <sup>2</sup>CRESA, UAB-IRTA, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain.

A trial was conducted to evaluate the effect of different cereals on the performance, gut mucosa and microbiota of weanling pigs with or without previous access to creep feed during lactation. A total of 108 newly-weaned pigs (7.4 kg BW; 26 d of age; 1/2 with and 1/2 without creep feed) were used. Piglets were distributed by BW into 36 pens according to a 2 × 6 factorial distribution of treatments with previous access to creep feed (with or without) and cereal source in the experimental diet (barley, rice-wheat bran, corn, naked oats, oats or rice) as main factors. Pigs were offered the experimental diets for 21 d and performance was monitored at weekly intervals. At the end of the trial, 4 piglets from each treatment (total of 48) were slaughtered and sampled for the histological evaluation of jejunal mucosa and the study of ileal and cecal microbiota by restriction fragment length polymorphism (RFLP). The Manhattan distances between RFLP profiles were calculated, and for each treatment and sampling day intra-group similarities (IGS) were calculated. An interaction between creep feeding and cereal nature was observed for ADG during the second wk of trial ( $P < 0.05$ ). Access to creep feed resulted in improved ADG in the piglets fed the rice-wheat bran diet, but no differences were observed for the other cereals. No differences in mucosal morphology were observed, except for deeper crypts in pigs that did not have previous access to creep feed ( $P < 0.05$ ). Interactions between creep feeding and cereal were also

observed for the IGS of the ileal and the cecal microbiota at d 21 ( $P < 0.05$ ). At the ileal level, access to creep feed resulted in reduced IGS (increased heterogeneity of the microflora) in the piglets fed oats, but no differences were observed for the other cereal sources. Similarly, at the cecal level access to creep feed reduced IGS only in the piglets fed oats or barley. It is concluded that the effect of creep feeding during lactation on the performance and the microbiota of piglets after weaning is dependent of the nature of the cereal in the post-weaning diet.

**Key Words:** cereal, creep feeding, microbiota

**1028 Improved growth performance of weaned piglets by dietary supplementation of plant material from Caucasian wingnut (*Pterokarya fraxinifolia*).** O. Hojberg<sup>\*1</sup>, R. M. Engberg<sup>1</sup>, B. B. Jensen<sup>1</sup>, and R. J. Wallace<sup>2</sup>, <sup>1</sup>Aarhus University, Tjele, Denmark, <sup>2</sup>Rowett Institute of Nutrition and Health, Aberdeen, UK.

To identify potential alternatives to in-feed antibiotics, the EU FP6 project REPLACE screened 500 European plants for antimicrobial properties; we here present data obtained with a plant not previously known for these properties. Freeze-dried leaves and immature fruits of the deciduous tree Caucasian wingnut (*Pterokarya fraxinifolia*, Juglandaceae) were observed to suppress *E. coli* F4 (K88); a causative agent of piglet post-weaning diarrhea. Added in concentrations of 0.1 to 5%, the wingnut powder inhibited in vitro growth of *E. coli* F4 in ileum content at pH 6.0–6.5 and reduced its survival in stomach content at pH 4.0–4.2 in a dose-dependent manner. Feed intake was investigated pre- and post-weaning for piglets weaned at either 32 (12 piglets) or 42 (12 piglets) days of age and fed a standard weaner diet supplemented with 1% wingnut powder; no signs of intoxication were observed and feed intake did not differ significantly ( $P > 0.05$ ) from the non-supplemented control group. The influence on piglet growth performance was then investigated in further detail by dietary inclusion of wingnut powder in concentrations of 0, 0.5, 1 or 2%. The trial included 8 replicate blocks of 4 piglets per treatment, in total 128 piglets from 32 litters, weaned at 28 d of age. For piglets offered the wingnut supplemented diets, daily feed intake and live body weight were numerically higher, feed conversion ratio (kg feed per kilo weight increase) was numerically lower and daily weight gain was significantly ( $P = 0.001$ ) higher over the entire post-weaning period. However, no dose-dependent response was observed; actually daily weight gain was numerically higher for piglets receiving the diet supplemented with 0.5% wingnut powder compared with those supplemented with either 1 or 2% powder; the former group also showed the best fecal score (indicator of diarrhea). No significant differences ( $P > 0.05$ ) were observed regarding fecal pH and coliform counts, indicating that the influence of the active compounds (presently under scrutiny) may be allocated to the upper gastrointestinal parts (stomach and ileum).

**Key Words:** antimicrobials, wingnut, postweaning diarrhea

**1029 Supplementation of a sow's diet with oat pro-motes improved indices of health in their offspring.**

R. Minor,\* T. Dortch, L. Kloc, L. Williams, and A. Woldegebriel, *North Carolina A&T State University, Greensboro, North Carolina, USA.*

The stress of early weaning, coupled with an immature immune system, contributes to the development of post-weaning diarrhea a condition that is associated with an imbalance of gut microbiota and intestinal inflammation. Intestinal microbiota is a key contributor to the maturation of the immune system. Studies have shown that inclusion of probiotics and prebiotics in the maternal diet during gestation and lactation can promote health of their offspring. A study was conducted to specifically evaluate the impact of oat supplementation during gestation and lactation on the intestinal health of piglets. Sows were fed gestation and lactation diet (containing corn and soybean meal) with or without oat at an inclusion rate of 15%. Data relating to piglet weight at birth and weaning, intestinal IgA content and fecal levels of beneficial bacteria, bifidobacteria and lactobacilli, and the pathogenic bacteria commonly associated with post-weaning diarrhea, *Escherichia coli* and *Salmonella*, were collected. While we report that piglets of dams on control diet weighed significantly more at birth ( $P < 0.0001$ ), piglets born of dams who consumed oat weighed significantly ( $P < 0.05$ ) more on the day of weaning and 28 d post weaning. Microbiological culture analysis of fecal material collected at the time of weaning revealed no significant differences in the level of pathogenic and beneficial bacteria however, by d 28 post-weaning, there was significantly ( $P < 0.05$ ) more beneficial bacteria (bifidobacteria and lactobacilli) than pathogenic bacteria (*Escherichia coli* and *Salmonella*) in the feces of piglets born of dams that consumed oat. Moreover, we report that dietary inclusion of oat at 15% during lactation and gestation resulted in increased levels of IgA in the small intestine of piglets whose dams consumed a diet supplemented with oat. Together these data suggest that inclusion of oat in the gestation and lactation feed of sows and positively affect the intestinal health of their offsprings.

**Key Words:** prebiotic, post-weaning diarrhea, immunoglobulins

**1030 Assessment of RNA integrity in the post-mortem pig colonic tissue ex-vivo.** B. Bahar\*<sup>1,2</sup>, J. O'Doherty<sup>1</sup>, and T. Sweeney<sup>2</sup>, <sup>1</sup>*School of Agriculture and Food Science, University College Dublin, Belfield, Dublin, Ireland*, <sup>2</sup>*School of Veterinary Medicine, University College Dublin, Belfield, Dublin, Ireland.*

Surgical removal of porcine intestine post-mortem followed by an ex vivo challenge is an alternative technique of testing the anti-inflammatory effect of bioactive compounds in the intestine of live pigs. This technique is based on the assumption that tissue remains physiologically viable and that the cellular RNA remains intact during the ex-vivo period. The present experiment investigated the effect of ex-vivo incubation of porcine colonic tissue on the quantity and quality of total RNA over a 12-h time period. A portion of colonic tissues of pigs (n = 6) was surgically removed immediately post- slaughter and the overlying muscle layer removed. A section of approximately 1.5 × 1.5 cm of the

colon was transferred into 1 mL DMEM and incubated for 0, 3, 6 and 12 h in a humidified cell culture incubator. Tissue samples were collected in RNAlater and processed for RNA extraction. The quantity and quality of total RNA were assessed on a NanoDrop Spectrophotometer and an Agilent 2100 Bioanalyzer, respectively. Ex-vivo incubation time had a significant effect on the quantity ( $P < 0.001$ ) and quality ( $P < 0.001$ ) of total RNA in colonic tissue. Compared with RNA yield at the 0 h time point ( $505.0 \pm 84.25 \mu\text{g}/\text{mg}$  of tissue), the yield was numerically reduced after 3 h ( $367.2 \pm 23.13 \mu\text{g}/\text{mg}$ ) while RNA yield was significantly reduced after 6h ( $227.6 \pm 51.04 \mu\text{g}/\text{mg}$ ,  $P < 0.001$ ) and 12 h ( $159.3 \pm 41.91 \mu\text{g}/\text{mg}$ ,  $P < 0.001$ ) of incubation. In the Bioanalyzer profile of total RNA, the 28S and 18S ribosomal RNA (rRNA) bands were visibly intact at 0, 3 and 6 h of incubation. However, after 12 h of incubation, these 2 rRNA populations disintegrated and a degraded RNA profile was evident. The RNA integrity (RIN) values for the 0, 3, 6 and 12 h of incubation were  $9.4 \pm 0.17$ ,  $9.0 \pm 0.17$ ,  $6.7 \pm 0.33$  ( $P < 0.001$ ) and  $3.3 \pm 0.42$  ( $P < 0.001$ ), respectively which further indicates that there is only a small reduction in RIN values after 3 h of incubation. It is concluded that the incubation of porcine colonic tissue ex-vivo for up to 3 h may generate good quality total RNA suitable for gene expression studies.

**Key Words:** RNA stability, colon, RNA integrity

**1031 Extracts of brown seaweeds can attenuate the bacterial lipopolysaccharide (LPS) induced pro-inflammatory response in the porcine colon ex vivo.** B. Bahar\*<sup>1,3</sup>, J. O'Doherty<sup>1</sup>, M. Hayes<sup>2</sup>, and T. Sweeney<sup>3</sup>, <sup>1</sup>*School of Agriculture and Food Science, University College Dublin, Belfield, Dublin, Ireland*, <sup>2</sup>*Ashtown Food Research Centre, Teagasc, Ashtown, Dublin 15, Ireland*, <sup>3</sup>*School of Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland.*

Brown seaweeds, a rich source of bioactive compounds, are demonstrated to have numerous health benefits including anti-microbial and immunomodulatory bioactivities in the pig intestine. This experiment was conducted to evaluate the effects of extracts of brown seaweed (*Ascophyllum* and *Fucus*) in suppressing the pro-inflammatory response induced by bacterial lipopolysaccharide (LPS) treatment in the pig colonic tissue ex-vivo. A section of colonic tissues of pig (n = 6) was surgically removed immediately post-slaughter and the overlying muscle layer removed. Approximately 1.5 × 1.5 cm of the colon was transferred into 1 mL Dulbecco's Modified Eagle Medium containing bacterial LPS (10  $\mu\text{g}$ ) and seaweed extracts (1 mg). Extracts of *Ascophyllum nodosum* and *Fucus serratus* seaweeds were tested in this experiment. Tissue samples were incubated for 3 h in a humidified cell culture incubator with 5% CO<sub>2</sub> at 37°C. Tissue samples were collected in RNAlater and processed for RNA extraction. Gene expression analysis of interleukin-8 (IL8), interleukin-6 (IL6) and tumor necrosis factor- $\alpha$  (TNF $\alpha$ ) genes were performed by quantitative real time PCR. Compared with the basal level of gene expression, LPS treatment induced the expression of IL8, IL6 and TNF $\alpha$  genes to  $2.38 \pm 0.86$  ( $P < 0.01$ ),  $1.90 \pm 0.66$  ( $P < 0.05$ ) and  $1.90 \pm 0.57$  ( $P < 0.001$ ) fold, respectively.

The pro-inflammatory response induced by the LPS was suppressed by one extract of *Ascophyllum nodosum* which inhibited the expression of IL8, IL6 and TNF $\alpha$  genes to  $0.99 \pm 0.53$  ( $P < 0.05$ ),  $0.75 \pm 0.33$  ( $P < 0.05$ ) and  $1.01 \pm 0.17$  ( $P < 0.05$ ) fold, respectively. One extract of *Fucus serratus* also inhibited the expression of these cytokine genes as induced by LPS to  $0.70 \pm 0.32$  ( $P < 0.01$ ),  $0.69 \pm 0.38$  ( $P < 0.05$ ) and  $1.15 \pm 0.25$  fold, respectively. It is concluded that the extracts of *Ascophyllum nodosum* and *Fucus serratus* seaweeds have potential to suppress the pro-inflammatory response induced by the bacterial LPS in the pig colon.

**Key Words:** anti-inflammatory, cytokine, bioactive

**1032 The addition of a *Bacillus licheniformis* CECT 4536 probiotic to piglet diets improves animal intestinal microbiota and performance parameters.** J. J. Mallo\*<sup>1</sup>, M. Oficialdegui<sup>2</sup>, M. I. Gracia<sup>3</sup>, M. Gutierrez<sup>1</sup>, and P. Honrubia<sup>1</sup>, <sup>1</sup>Norel S.A., Madrid, Spain, <sup>2</sup>Granja Los Alecos S.A., Navarra, Spain, <sup>3</sup>Imasde Agroalimentaria S.L., Madrid, Spain.

The trial investigated the effects of adding a new probiotic, composed of spores of *B. licheniformis* strain CECT 4536 ( $10^9$  cfu/g of product) to a standard piglet post-weaning feeding program (C) on intestinal microbiota and growth performance. The probiotic was added at a dosage of 1 kg/T of feed, giving a bacterial concentration of  $10^6$  cfu/g of feed (T). In this trial 480 piglets were randomly housed in 16 pens and monitored from d 21 to 74 of age for differences in performance parameters. Results were analyzed with a PROC GLM test. The inclusion of the probiotic produced heavier piglets; at the end of the trial, T piglets tended to weigh more than C piglets (22.9 vs 21.7 kg;  $P < 0.12$ ). Additionally, the inclusion of *B. licheniformis* tended to improve piglet growth during the trial (337 vs 313 g/d;  $P < 0.12$ ) and Feed Conversion Ratio (FCR) (1.54 vs 1.67 g feed/g gain;  $P < 0.12$ ). These differences were mainly produced in the last 2 wk of the trial, where the T animals tended to grow more (+10.8%; 706 vs 637 g/d;  $P < 0.12$ ), and had better FCR (-20%; 1.36 vs 1.70 g feed/g gain;  $P < 0.05$ ) than C animals. At the same time, samples of feces were taken at d 0, 21 and 53 of trial to evaluate how the probiotic affected fecal microflora. The use of the probiotic showed higher counts of lactobacilli in feces ( $6.52 \log_{10}$  vs  $5.76 \log_{10}$ ;  $P < 0.05$ ) at d 53; with no statistical differences in total mesophilic bacteria, coliforms, clostridia or salmonella at d 53, and no differences at d 0 or 21. It was, therefore, concluded that the addition of *B. licheniformis* CECT 4536 at a dosage of 106 cfu/g to the diet improves intestinal microbiota balance in the piglets and promotes an easier transition to solid feed, producing higher body weights, better growth and improved feed conversion after weaning.

**Key Words:** probiotic, bacillus, microflora

**1033 Influence of antibiotic treatment of sows on intestinal microbiota in their offsprings.** J. Zhang\*<sup>1</sup>, O. Pérez<sup>1</sup>, J. P. Lallès<sup>2</sup>, and H. Smidt<sup>1</sup>, <sup>1</sup>Laboratory of Microbiology, Wageningen University, Dreijenplein 10, 6703 HB Wageningen, the Netherlands, <sup>2</sup>Institut National de la

*Recherche Agronomique, UR1341 ADNC, F-35590 Saint-Gilles, France.*

Early disturbance by antibiotic treatment on the microbial colonization process can have drastic consequences for gastrointestinal tract development. This study aimed at evaluating the effects of amoxicillin treatment (AT) of sows before and after farrowing on the intestinal microbiota in their offspring during the suckling and the post-weaning period. Two groups of 4 sows each were defined as control and treatment. In the treatment, sows were treated orally with amoxicillin (40 mg/kg BW/d) during 10 d before and 21 d after parturition. Feces of sows were collected at the beginning and the end of the AT. Offsprings (1/sow/time) were sacrificed at d 14, 21, 28 and 42 after birth, to collect ileal digesta. The microbial composition of feces and ileal digesta was analyzed by the Pig Gastrointestinal Tract Chip. Cluster analysis of microbiota profiles of sows showed separate grouping of samples from treated sows at the end of AT. This was further confirmed by principal response curves (PRC) analysis which showed a large deviation of the treatment from the control at the end of AT and indicated a significant effect ( $P = 0.045$ ) of AT. PRC analysis revealed a reduction of abundance of *Mycoplasma*-like, *L. gasseri*-like, *Porphyromonas asaccharolytica*-like and *L. delbrueckii*-like organisms of treated sows. Cluster analysis of ileal microbiota of piglets showed samples from d 42 grouped in a distinct assembly, while all other samples formed, with few exceptions, 2 clusters according to treatment, indicating AT of sows influenced the microbiota of piglets. Microbial diversity of piglets derived from treated sows was lower than that of controls at all time points, and was significantly different at d 42 ( $P = 0.018$ ). The PRC analysis showed deviations of the treatment from the control at each sampling point and confirmed the sustained AT effect on the ileal microbiota. Reduction of *L. gasseri*-like and *Mycoplasma*-like organisms of sows caused by AT also appeared in digesta of piglets. In conclusion, pre- and postpartum AT had a significant effect on intestinal microbiota of sows, which in turn influenced the microbial colonization of their offspring.

**Key Words:** microbiota, amoxicillin, piglet

**1034 Effects of yeast-dried milk (YDM) product in creep and Phase-1 nursery diets on circulating IgA and fecal microbiota of nursing and nursery pigs.** H. Tran,\* J. W. Bundy, E. E. Hinkle, J. Walter, P. S. Miller, and T. E. Burkey, University of Nebraska, Lincoln, NE, USA.

Four experiments were conducted to evaluate effects of YDM in creep and phase-1 nursery diets. In Exp. 1, 24 parity-4 litters (8 litters/trt) were used. Dietary treatments included: No creep (NC), Control creep (CTL), and Experimental creep (EC; 10% YDM). Creep diets were fed ad libitum from d 7 after birth until weaning. In Exp. 2, 108 weaned pigs (BW, 7.2 kg) were selected based on mean BW of pigs from each of 3 treatments in Exp. 1 and assigned to 1 of 18 pens (6 pens/trt). Pigs fed creep diets during Exp. 1 received the same diet during phase 1 of Exp. 2, followed by a common diet containing antibiotics in phase 2 (d 7 to 21). Blood and fecal samples were collected at weaning,



d 7, 14, and 21 postweaning (pw) to evaluate serum IgA and fecal microbiota. In Exp. 2, pigs fed CTL and EC had greater ( $P = 0.10$  and  $0.03$ ; respectively) IgA compared with NC pigs. On d 7 post-weaning, pigs fed EC had greater ( $P = 0.005$ ) microbial diversity compared with CTL; however, there was no difference in diversity indices between EC and NC pigs. In addition, microbial similarity within group decreased ( $P < 0.05$ ) in pigs fed EC compared with other treatments on d 7 and 21 pw. Overall (d 0 to 14), lactobacilli 16S rRNA gene copy numbers were greater ( $P = 0.03$ ) in EC ( $7.3 \log_{10}$ ) compared with NC pigs ( $6.9 \log_{10}$ ). Exp. 3 (23 parity-1 litters; 7 litters/trt) had the same treatment design as Exp. 1. There was lower ( $P = 0.02$ ) *L. reuteri* in the CTL ( $5.1 \log_{10}$ ) compared with NC pigs ( $5.6 \log_{10}$ ). In Exp. 4, 108 weaned pigs (BW, 6.6 kg) were selected based on the mean BW of all pigs from Exp. 3 and assigned to 18 pens (6 pens/trt). Exp. 4 had the same experimental design as Exp. 2 except no antibiotic was included in phase-2 diet. Pigs fed CTL ( $4.8 \log_{10}$ ) and EC ( $4.8 \log_{10}$ ) had lower ( $P < 0.01$ ) fecal *L. johnsonii* compared with NC pigs ( $5.2 \log_{10}$ ). Lactobacilli, *L. johnsonii*, and *L. reuteri* gene copy numbers decreased ( $P < 0.001$ ) from d 7 to d 21 postfarrowing (Exp. 3) and increased at d 7 post-weaning (Exp. 4). Microbial ecology and immune parameters in nursing and nursery pigs may be affected by YDM product.

**Key Words:** immunoglobulin A, microbiota, yeast

**1035 Evaluation of the growth performance and fecal microbiota profile in developing gilts fed high-fiber diets.** W. Burger,\* H. Tran, J. W. Bundy, E. E. Hinkle, R. K. Johnson, P. S. Miller, and T. E. Burkey, *University of Nebraska, Lincoln, NE, USA.*

Restricting feed and energy intake during gilt development improves lifetime productivity and lowers breakeven selling prices for market pigs. Inclusion of dietary insoluble fiber

at high concentrations is a strategy to limit energy intake in gilts fed ad libitum. Thus, an experiment was conducted to evaluate the effects of low energy feedstuffs on growth performance and fecal microbial profiles in developing gilts fed high-fiber diets in a 4-wk feeding period. Fifty-six gilts (initial BW,  $83.4 \pm 2.3$  kg) were housed in individual pens and 8 pens were assigned to each of 7 treatments: 1) control (corn-soybean meal; CTL); 2) alfalfa (ALFA); 3) beet pulp (BEET); 4) corn bran (CBRA); 5) corn cobs (COBS); 6) rice hulls (RIHU); and 7) soy hulls (SOHU). The experimental diets were formulated to contain approximately 80% ME values of the CTL diet. Pig BW were recorded (d 0, 8, 15, 21, and 28) for ADG, ADFI, and GF calculation. Fecal samples were collected (3 pigs/treatment) coinciding with BW measurements for microbial diversity and similarity analyses using denaturing gradient gel electrophoresis. Overall, decreases ( $P < 0.05$ ) in BW (in gilts fed BEET and COBS), ADG (in gilts fed ALFA, BEET, and COBS), and ADFI (in gilts fed BEET) were observed compared with CTL gilts. In addition, gilts fed RIHU had increased ( $P < 0.05$ ) ADFI compared with the CTL. With respect to microbial profiles, there were no differences in microbial similarity coefficient within group or diversity indices among gilts fed various sources of dietary fiber on d 0, 8, and 15; however, gilts fed ALFA (d 21), BEET (d 28), and SOHU (d 28) had greater ( $P < 0.05$ ) microbial diversity (Shannon's and Simpson's) compared with the CTL. Gilts fed RIHU, COBS, and CBRA had greater ( $P = 0.03$ ) similarity within group on d 28 compared with the CTL. There was lower ( $P < 0.01$ ) bacterial similarity between CTL and SOHU pigs on d 28 (65%) compared with d 0 (91%). Briefly, high fiber feedstuffs affect growth performance and microbial profiles; however, further research is needed to evaluate how changes in gut microbes affect lifetime productivity and health of developing gilts and their progeny.

**Key Words:** fiber, gilt, microbial diversity



## **Session II: Nutrient Digestion and Absorption**

**1036 Invited review: Starch and fiber properties affect their kinetics of digestion and thereby digestive physiology in pigs.** R. T. Zijlstra<sup>1</sup>, R. Jha<sup>1</sup>, A. D. Woodward<sup>1</sup>, J. Fohse<sup>1</sup>, and T. A. T. G. van Kempen<sup>2,3</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>Nutreco, Boxmeer, The Netherlands, <sup>3</sup>North Carolina State Univ., Raleigh, NC, USA.

Traditionally in swine nutrition, analyses of starch and fiber have focused on assessing quantity; however, both have a wide range of functional properties making them underappreciated nutrients. Starches ranging from low to high amylose change from rapidly digestible in the upper gut to poorly digestible but fermentable in the lower gut becoming a source of glucose or VFA. Likewise, fibers ranging from low to high viscous affect digesta flow and from slowly to rapidly fermentable alter production of VFA serving as energy for the gut or whole body. Our hypothesis is that total extent, kinetics, and site of digestion or fermentation of starch and fiber are important for whole body energy utilization and intestine health. To elucidate their effects, we developed in vitro, lab-based methodologies to describe kinetics of digestion and fermentation and linked these with in vivo models including: 1) ileum cannulation to collect digesta, 2) portal-vein catheterization to sequentially sample blood, 3) slaughter method to collect site-specific intestine tissue and digesta, and 4) indirect calorimetry. Using these models, kinetics of nutrient absorption was associated with pancreatic and intestinal hormones released into the portal vein, intestinal microbiota, and gene expression in intestinal tissue and microbiota. To confirm, slowly digestible starch is partially degraded in the large intestine and fermented into VFA including butyrate (10-fold increase in net portal appearance), reducing insulin responses by 60% and whole body energy utilization. Starch entering the distal intestine altered mRNA abundance of nutrient transporters and was bifidogenic. Viscous fiber dampened glycemic responses and reduced digesta passage rate by 50%, thereby increasing ileal digestion of dietary nutrients. Fermentable fiber increased butyrate and insulin production. These methods will thus support elucidation of mechanisms that link starch and fiber properties to whole body nutrient use and intestine health.

**Key Words:** digestion, fiber, starch

**1037 Modelling the digestibility of dietary phosphorus: Model logic and concepts.** V. Symeou,\* I. Leinonen, S. Edwards, and I. Kyriazakis, *School of Agriculture, Food and Rural Development, Newcastle University, United Kingdom.*

Phosphorus (P) in plant feedstuff includes some non-phytate P (NPP) that is readily digested, but is mostly of phytate P (oP) that is indigestible, unless it is dephosphorylated. The ability of pigs to dephosphorylate oP using endogenous phytase enzymes is limited and is a function of calcium (Ca). Exogenous microbial and plant phytase can also dephosphorylate oP. The objective was to estimate the digestibility of P under different dietary conditions. The effect of exogenous phytase activity (FTU) on oP dephosphorylation in the

stomach and duodenum was quantified using exponential equations. Experiments with graded doses of microbial phytase which reached > 6000 FTU were used for this. For plant phytase activity, INRA (2004) feed tables were used. The effect of 2 exogenous phytase were not additive. In the small intestine, only endogenous phytase was assumed to be active. A linear equation of oP dephosphorylation against graded levels of dietary Ca, at a constant FTU was fitted. In the large intestine, oP was dephosphorylated by microfloral phytase and it was also linearly expressed as a function of Ca, using data from ileum cannulated pigs. The dephosphorylation of oP (kg/kg) by microbial and plant phytase was estimated to be  $0.56*(1-\exp(-0.001*FTU))$  and  $0.38*(1-\exp(-0.002*FTU))$ , respectively; thus microbial phytase was more effective in dephosphorylating oP compared with plant phytase. The effect of Ca (g/kg diet) on the dephosphorylation of oP (kg/kg) in the large and small intestine was  $0.26-(0.015*dietary\ Ca)$  and  $0.69-(0.059*dietary\ Ca)$ , respectively. The dephosphorylated oP in the large intestine was not digested. The digestibility (kg/kg) of NPP and dephosphorylated oP was constant at a 0.8. Exogenous and endogenous phytase can dephosphorylate oP to give a maximum digestibility of 0.8, so as to be available for digestion. Dietary Ca has a greater effect in decreasing the oP dephosphorylation by microfloral compared with endogenous phytase. The model can be used to minimize the supplementation of inorganic P by maximizing the dephosphorylation of oP. This will lead to both environmental and economic benefits.

**Key Words:** phytate phosphorus, phytase enzymes, calcium

**1038 Segment-specific glucose transport characteristics in the porcine small intestine.** J. Herrmann,\* B. Schroeder, and G. Breves, *University of Veterinary Medicine Hannover, Foundation, Department of Physiology, Hannover, Germany.*

Although higher SGLT1 abundance in the porcine jejunum was reported it has also been described that glucose absorption seems to be more efficient in the distal small intestines. The aim of this study was to evaluate basal efficiency of glucose absorption and its respective dynamics in the porcine jejunum and ileum by electrophysiological methods. Stripped intestinal epithelia from jejunum and ileum were taken from growing pigs and mounted into Ussing chambers. Increases in short-circuit currents (Isc) after luminal administration of 5 mM glucose were measured. SGLT1 was inhibited by phlorizin and decreases in glucose induced Isc were monitored. Brush-border membrane vesicles (BBMV) were prepared from both tissues to perform glucose uptake studies with or without phlorizin. Expression levels of SGLT1, SGLT3 and Na<sup>+</sup>/K<sup>+</sup>-ATPase were determined along the intestinal axis. Different basal Isc were found in jejunal and ileal tissue ( $P < 0.001$ ;  $n = 12$ ). Glucose induced increase in Isc was higher in the ileum ( $P < 0.001$ ;  $n = 12$ ). The response to glucose in the ileum was more rapid and reached 50% and 75% of the maximal electrogenic response ~6 times faster than in jejunal tissues ( $P < 0.001$ ;  $n = 12$ ). The data were confirmed by elevated glucose uptake rates into ileal BBMV resulting

in ~2-fold higher ileal  $V_{max}$  values without affecting the SGLT1 glucose binding affinities in both segments ( $n = 5$ ). Administration of phlorizin decreased glucose induced  $I_{sc}$  ( $P < 0.01$ ;  $n = 9$ ), glucose flux rates ( $P < 0.001$ ;  $n = 4$ ) as well as BBMV glucose uptake ( $P < 0.05$ ;  $n = 3$ ) at higher level in the ileum as compared with the jejunum. Western blot and mRNA analyses revealed that SGLT1 expression was slightly higher in the jejunum. The expression analyses of candidate modulators of segmental diverse SGLT1 activity revealed that SGLT3 was slightly more abundant in the jejunum while the basolateral localized  $Na^+/K^+$ -ATPase showed similar abundance and activity in both segments. Electrogenic glucose absorption occurs more efficient in the ileum than in the jejunum independent from SGLT1 abundance. Posttranslational modifications of SGLT1 might be responsible for these segmental transport characteristics.

**Key Words:** glucose, SGLT1, segment-specificity

**1039 The impact of lower gut nitrogen supply on nitrogen balance and urea kinetics in growing pigs.** D. Columbus<sup>\*1</sup>, H. Lapierre<sup>3</sup>, M. F. Fuller<sup>2</sup>, and C. F. M. de Lange<sup>1</sup>, <sup>1</sup>Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada, <sup>2</sup>Department of Surgery, State University of New York, Stony Brook, New York, USA, <sup>3</sup>Dairy and Swine Research and Development Centre, Agriculture and Agri-Food Canada, Sherbrooke, Quebec, Canada.

Nitrogen (N) absorption from the lower gut is generally thought to be of little nutritional significance. However, studies have shown the presence of amino acid (AA) transporters in colonocytes. In addition, ammonia can be absorbed from the lower gut, converted to urea, recycled into the upper gut, and incorporated into microbial AA that may be absorbed and utilized by the host. An N-balance and isotope dilution study was performed to determine the effect of lower gut N supply on N retention and urea kinetics in growing pigs. Nine cecally cannulated and jugular catheterized barrows (initial BW of  $22.4 \pm 1.2$  kg) were randomly assigned to 1 of 3 cecal N infusion treatments: saline, casein, or urea, the latter 2 treatments infused at a rate of 40% of daily N intake. The infusion period was 9 d in duration and consisted of a 5 d infusion adaptation period followed by a 4 d N-balance period.  $^{15}N^{15}N$ -urea was infused intravenously at a rate of 0.40 mmol/kg BW/d during the N-balance period. Among essential AA, the potential contribution of microbial protein to the host's AA supply is largest for valine, therefore, all pigs were fed a valine-limiting cornstarch-soybean meal based diet at 2.8 times maintenance DE requirements in 3 equal meals. There was no impact of cecal N infusions on apparent fecal digestibility of N ( $P > 0.05$ ). The efficiency (% of apparent ileal digestible intake) of using N ( $72.9 \pm 1.9$ ,  $84.9 \pm 1.9$ , and  $85.6 \pm 2.3\%$ ;  $P = 0.01$ ; for saline, casein, and urea, respectively) and valine ( $76.9 \pm 1.9$ ,  $86.5 \pm 1.9$ , and  $86.5 \pm 2.4$ ;  $P = 0.02$ ) for whole body protein and valine retention increased for casein and urea. Urea flux and urinary N excretion increased by the same increment for both N infusions ( $P < 0.05$ ) but this increase did not fully account for lower gut N disappearance. Lower gut N disappearance is

in the form of non-protein N which can be used for microbial AA production in the upper gut and – based on valine and N utilization – improves body protein gain by more than 10%. Lower gut N metabolism should be considered when determining N and AA requirements.

**Key Words:** lower gut, microbial amino acids, urea recycling

**1040 Molecular weight distribution of soluble fiber fractions and short-chain fatty acids in ileal digesta of growing pigs.** E. Ivarsson<sup>\*1</sup>, R. Andersson<sup>2</sup>, and J. E. Lindberg<sup>1</sup>, <sup>1</sup>Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden, <sup>2</sup>Department of Food Science, Swedish University of Agricultural Sciences, Uppsala, Sweden.

The effect of fiber source on molecular weight (Mw) distribution of soluble fiber fractions and short chain fatty acids (SCFA) in ileal digesta of 7 post valve t-cecum (PVTC) cannulated growing pigs was studied. The pigs were fed semi-synthetic diets with sugar beet pulp (SBP) or chicory forage (CFO) as fiber sources. The diets were formulated to be similar in (~100 g/kg DM) total non-starch polysaccharides (NSP) and in soluble NSP (~20 g/kg DM). The soluble NSP fraction in both diets originated mainly from pectin. The Mw distribution of the soluble NSP fraction in diets and ileal digesta were analyzed with a high-performance size exclusion chromatography system. Three Mw intervals (g/mol) were selected;  $MwL = 10\ 000\ 000 - 1\ 000\ 000$ ;  $MwM = 1\ 000\ 000 - 200\ 000$  and  $MwS = 200\ 000 - 10\ 000$ . The relative distribution (% of total) of molecules in each interval was calculated. The SCFA in ileal digesta was analyzed by high-performance liquid chromatography. The MwL fraction was higher in diet SBP than in diet CFO (19.8 vs. 9.8), whereas the MwS fraction was higher in diet CFO than in diet SBP (34.5 vs. 45.5). There was no ( $P > 0.05$ ) difference between diets in the distribution of the MwL fraction in ileal digesta. However, the MwM fraction was higher in ileal digesta of pigs fed diet SBP ( $P < 0.05$ ) and the MwS fraction was higher in ileal digesta of pigs fed diet CFO ( $P < 0.05$ ). The mol-% of propionic acid (HPr) was higher ( $P < 0.010$ ) and the mol-% of butyric acid (HBu) tended to be higher ( $P = 0.055$ ) in pigs fed diet SBP, whereas pigs fed diet CFO had higher ( $P < 0.010$ ) mol-% acetic acid (HAc). The proportion of the MwL and MwM fractions in ileal digesta were negatively correlated to HAc ( $r = -0.52$ ,  $P = 0.05$ ; and  $r = -0.62$ ,  $P = 0.02$ ; respectively). The proportion of MwM in ileal digesta was positively correlated to HPr ( $r = 0.83$ ;  $P = 0.001$ ), whereas there was a negative correlation ( $r = -0.76$ ;  $P = 0.002$ ) between MwS and HPr. The results indicate that the bacterial degradation of the soluble NSP fraction is selective and that the Mw distribution may explain differences in SCFA production.

**Key Words:** molecular weight distribution, short chain fatty acids, fiber

**1041 Porcine periweaning failure to thrive syndrome is driven by poor appetite and nutrient digestibility, but not ileal morphology or absorptive capacity.** C. K.



Jones,\* N. K. Gabler, and J. F. Patience, *Iowa State University, Ames, IA, USA.*

Although an increasingly important pathology, the etiology of periweaning failure to thrive syndrome (PFTS) is still unknown. Our objective was to determine if pigs with PFTS differ from normal pigs in nutrient digestibility, blood metabolites, thyroid hormone concentrations, organ weight, intestinal structure and function. Ninety-six barrows were selected from 960 weanling pigs to represent pigs from each of the 10% lightest, median, and heaviest categories. Pigs were placed in metabolism cages and allowed ad libitum water and feed. Growth rate was evaluated for 27 d and a 3-d urine and fecal grab sample collection for nutrient digestibility determination by the marker method. Pigs with ADG 2 standard deviations below the mean were considered PFTS ( $n = 4$ ). These pigs also met the clinical case definition of PFTS. All other pigs ( $n = 92$ ) were considered normal contemporaries. At the end of the experiment, pigs were fasted overnight, and whole blood and serum were collected. Pigs were euthanized and organ weights collected. Ileal segments were sampled for morphology and absorptive capacity by Ussing chambers. Data were analyzed using the GLIMMIX procedure of SAS. Pigs with PFTS had slower ADG (167 vs. 568 g/d,  $P < 0.0001$ ), which may be attributed to less feed intake (222 vs. 680 g/d,  $P < 0.0001$ ) and lower gross energy digestibility (83.9 vs. 86.6%,  $P < 0.001$ ). Compared with normal pigs, PFTS pigs had decreased blood hemoglobin ( $P < 0.04$ ), albumin, sodium, and anion gap concentrations, suggesting anemia. Pigs with PFTS also had lower serum T3 concentrations (2.7 vs. 3.3 ng/mL,  $P < 0.01$ ), but similar T4 and IGF-1 levels. These pigs also had increased digestive organ weights relative to body size ( $P < 0.02$ ), suggesting a higher maintenance cost. Finally, PFTS was associated with increased ileum crypt depth (210 vs. 257  $\mu\text{m}$ ,  $P < 0.0001$ ), but not villous height or differences in absorptive capacity. These are the first data to explain PFTS in a nutritional context, and suggest it is driven by poor appetite and nutrient digestibility, but not ileal morphology or absorptive capacity.

**Key Words:** nutrition, periweaning failure to thrive syndrome, pig

**1042 The contribution of portal-drained viscera to circadian homocysteinemia in pigs.** J. J. Matte\*<sup>1</sup>, F. Guay<sup>2</sup>, and C. L. Girard<sup>1</sup>, <sup>1</sup>*Agriculture and Agri-Food Canada, Sherbrooke, Qc, Canada*, <sup>2</sup>*Université Laval, Québec city, Qc Canada.*

Homocysteine (Hcy) is an intermediary sulfur-containing amino acid produced by the methylation process within all cells. It is known as a powerful prooxidant with multiple deleterious effects on immune and physiological functions. Blood plasma total Hcy (tHcy), the most common indicator of Hcy status, can be reduced by dietary folates or vitamin B<sub>12</sub> but, in pigs, values remain 2 to 5 times higher than in other mammals. Homocysteinemia is routinely assessed after an overnight fast ( $\geq 12$  h) although no information is available on circadian tHcy changes. Using a sub-group of pigs from a study on portal appearance of vitamin B<sub>12</sub> after a single meal containing 0, 25 or 250  $\mu\text{g}$  of cyanocobalamin,

the present study aimed to report the circadian kinetic of post-meal blood plasma tHcy and estimate the contribution of portal drained viscera (PDV) to the systemic tHcy. Four pigs ( $39.7 \pm 1.07$  kg BW) were surgically equipped at  $101.0 \pm 8.2$  d of age with catheters in the portal vein and carotid artery; an ultrasonic flow probe was also fitted around the portal vein for blood flow recordings. Blood samples were collected simultaneously from the 2 catheters once before meal and every h during 24 h after ingestion of 1.2 kg of a vitamin-free semi-purified diet. Arterial tHcy changed considerably during the post-meal 24-h period ( $P < 0.001$ ; SE  $< 0.8$ ). In fact, from 12.3  $\mu\text{M}$ , 10 min before meal, tHcy gradually reached a maximum of 23.4  $\mu\text{M}$ , 12 h post-meal and returned to 15.5  $\mu\text{M}$ , 23 h after the meal. Net fluxes of tHcy across PDV were not influenced neither by levels of dietary vitamin B<sub>12</sub>, post-prandial time or their interaction ( $P > 0.25$ ); in fact, none of the net flux values differed from zero ( $P > 0.07$ ). These results suggest that systemic tHcy is mostly produced during the first 12-h following a meal by metabolic pools other than PDV. It appears that an overnight fast of 12 h will reflect the peak rather than the basal value for tHcy. The duration of the fasting period is therefore a critical factor for a reliable interpretation of tHcy homeostasis in pigs; such information may be also relevant for human health and nutrition.

**Key Words:** homocysteine, circadian, pig

**1043 Dietary energy density affects the preference for protein or carbohydrate solutions and piglet performance after weaning.** S. A. Guzmán-Pino<sup>1</sup>, D. Solà-Oriol\*<sup>1</sup>, J. Figueroa<sup>1</sup>, E. Borda<sup>2</sup>, and J. F. Pérez<sup>1</sup>, <sup>1</sup>*Universitat Autònoma de Barcelona, Bellaterra, Spain*, <sup>2</sup>*Bioibérica, Palafolls, Spain.*

Physiological state or the dietary nutrient content are key determinants of sensory perception and reflect feed preferences. The aim of the present study was to assess whether the preference for protein or carbohydrate is affected by dietary energy source for piglets. A total of 240 weanling piglets (2 8d-old, initial BW  $7.18 \pm 0.01$  kg) were allocated in 24 pens (10 pigs/pen) according to body weight. Piglets were split up in 2 groups and had ad libitum access to a high energy (HE, 3.90 Mcal DE/kg, crude fat 129 g/kg) or a low energy diet (LE, 3.35 Mcal DE/kg, crude fat 60 g/kg) with similar CP content (190 g/kg) and water from weaning to 21 d. Piglet performance and the preference for protein (porcine digestible peptides (PDP, Palbio 62SP®) 20 g/l) or carbohydrate (sucrose 20 g/l) solutions were measured on 14 and 21d after weaning by using a double-choice test (DCHT) protocol. Up to 14 d, LE diet promoted a higher ADFI, ADG and BW than HE diet (ADG 198 vs. 155 g/d;  $P < 0.01$ ). The same situation was observed on 21 d after weaning, with higher piglet BW for the animals fed the LE diet than those fed the HE diet (12.8 vs. 11.5 kg;  $P < 0.001$ ). Higher growth was achieved for the animals fed a higher protein-to-energy ratio (56.7 vs. 48.7 g CP/Mcal DE;  $P < 0.01$ ). No preference ( $P > 0.05$ ) was observed for protein or carbohydrate solutions on 14 or 21d in piglets fed the LE diet. On the other hand, the animals fed the HE diet showed high preference (75% on 14 d and 65% on 21 d,  $P < 0.01$ ) for sucrose solution. In conclusion, dietary energy level and



consequent nutrient imbalances, such as the protein-to-energy ratio, may act as a gut-brain signal and may affect the feed preference for protein or carbohydrate of piglets.

**Key Words:** energy, piglet, preference

**1044 Supplementation of barley-based diets with  $\beta$ -glucanase for pigs: Energy and amino acid digestibility responses.** C. Kong\* and O. Adeola, *Purdue University, West Lafayette, IN USA.*

An experiment was conducted to determine the effect of graded levels of  $\beta$ -glucanase supplementation to barley-based diets on the digestibility of DM, GE, N and amino acids (AA) for growing-finishing pigs. Eight pigs (initial BW: 53.3  $\pm$  3.2 kg) were fitted with a T-cannula in the distal ileum and allotted to a replicated 4  $\times$  4 Latin square design with 4 diets and 4 periods in each square. Dietary treatments were based on barley-soybean meal (SBM) basal diet (BD) containing 199 g of CP, 3,286 kcal of DE, 8.4 g of Ca, and 5.5 g of nonphytate P per kg of diet. Treatments consisted of the BD and the BD + 10K, 20K, or 30K units of  $\beta$ -glucanase per kg at the expense of corn. Chromic oxide (0.5%) was included as an indigestible marker. Each experimental period consisted of 3 d of adaptation and collection. Fecal samples were collected for 48 h on d 4 and 5, and ileal digesta for a total of 24 h on d 5 and 6. Apparent total tract digestibility of DM ranged from 80.1 to 82.8% and was not affected by  $\beta$ -glucanase supplementation. In the BD, apparent total tract digestibility of GE and N were 82.8 and 82.9%, respectively; and were not different in the basal diet supplemented with 30K units of  $\beta$ -glucanase per kg at 83.3 and 83%, respectively. Increasing levels of  $\beta$ -glucanase supplementation to the barley-SBM based diet had no effect on the apparent total tract digestibility of any criteria measured. Apparent ileal digestibility for DM, GE and N ranged from 60.6, 65.4 and 70.8% (10K) to 66.4, 70.3 and 74.9% (20K), respectively. For indispensable amino acids, apparent ileal digestibility for Lys and Met was lowest (78.7 and 78.1%, respectively) in the BD supplemented with 10K units of  $\beta$ -glucanase per kg; and were not different ( $P > 0.10$ ) from numerically highest digestibility of Lys and Met in the BD with added 30K units of  $\beta$ -glucanase per kg at 80.8 and 79.9%, respectively. There were neither significant linear nor quadratic effects of  $\beta$ -glucanase supplementation on the apparent ileal digestibility of DM, GE, N and AA.

**Key Words:**  $\beta$ -glucanase, ileal cannulated pigs, digestibility

**1045 Effect of L-valine supplementation to a wheat diet with Leu excess on performance, gene expression and serum concentration of amino acids.** H. García<sup>1</sup>, A. Morales<sup>1</sup>, A. B. Araiza<sup>1</sup>, J. K. Htoo<sup>2</sup>, M. Cota<sup>1</sup>, and M. Cervantes<sup>\*1</sup>, <sup>1</sup>ICA, *Universidad Autónoma de Baja California, Mexicali, Mexicali, BC, México*, <sup>2</sup>Evonik Industries AG, *Hanau, Germany*.

Previous studies show that excess level of Leu in a wheat-based diet supplemented with L-Lys, L-Thr, DL-Met, and L-Ile (W-LTMI) affects the expression of cationic amino acids (AA) transporter (CAT) bo,+ , the absorption of Lys and

Arg and reduces feed intake and average daily gain (ADG) of pigs. Also, since Leu competes with Val for absorption, it was speculated that Leu excess may reduce Val absorption and availability. An experiment was conducted to analyze the effect of adding L-Val to the W-LTMI containing 100% excess of Leu, on performance, expression of genes for coding CAT bo,+ and Cat-1, and serum concentration (SC) of indispensable AA. Sixteen crossbred pigs (BW of 30.3  $\pm$  2.10 kg) were used. Treatments (T) were: T1, W-LTMI diet (wheat supplemented with 0.69% L-Lys, 0.27% L-Thr, 0.10% DL-Met, and 0.43% L-Ile) plus 0.80% L-Leu (excess Leu); T2, as in T1 plus 0.44% L-Val. The study lasted 3 weeks, one week for adaptation and 2 weeks for performance data collection. At the end of the study, all pigs were euthanized and blood samples were collected to analyze the SC of AA, and jejunal mucosa to measure the expression of bo,+ and Cat-1. The ADG and feed conversion (FG) ratio were: ADG, 470 and 540 g/d; FG, 2.82 and 2.45, for T1 and T2, respectively. Relative expression (arbitrary units, bo,+ or Cat-1 mRNA Mol/18S rRNA Mol) were: bo,+ , 0.100 and 0.110; Cat-1, 0.0046 and 0.0011, for T1 and T2, respectively. Serum AA concentrations (mg/100 mL) were: Arg, 2.45, 3.16; Ile, 3.05, 4.19; Leu, 5.59, 6.06; Lys, 6.17, 8.28; Met, 1.03, 0.841; Phe, 1.18, 1.33; Thr, 5.24, 5.04; Val, 1.03, 7.01, for T1 and T2, respectively. Supplemental L-Val increased ADG and improved FG ( $P < 0.05$ ); did not affect the expression of bo,+ and Cat-1 ( $P > 0.10$ ); increased SC of Val, Lys, and Arg ( $P < 0.05$ ). Although the analyzed Val content in the W-LTMI diet was lower than the calculated value (requirement), these data may suggest that Leu excess limits the availability of Val, and that supplemental L-Val could correct the negative effects of Leu excess on the performance of growing pigs

**Key Words:** gene expression, valine, leucine

**1046 Growth performance and nutrient digestibilities in nursery pigs receiving varying doses of xylanase and  $\beta$ -glucanase blend in pelleted wheat and barley-based diets.** A. Owusu-Asiedu<sup>\*1</sup>, E. Kiarie<sup>1</sup>, A. Péron<sup>1</sup>, T. A. Woyengo<sup>2</sup>, and C. M. Nyachoti<sup>2</sup>, <sup>1</sup>Danisco Animal Nutrition, *Marlborough, England*, <sup>2</sup>University of Manitoba, *Winnipeg, Manitoba, Canada*.

Two experiments were carried out to investigate the dose response efficacy of a xylanase and  $\beta$ -glucanase blend (XB) on growth performance and ileal nutrient digestibilities in nursery pigs fed pelleted wheat and barley-based diets. A basal diet (meeting the 1998 NRC specifications for 6 to 30 kg BW except for DE; ~5% less) was supplemented with XB to give 4 diets (0, 50, 100 and 200 g/MT). The enzyme blend; XB was formulated to contain minimum activity of 12,200 and 1,520 U/g, for xylanase and  $\beta$ -glucanase, respectively. Exp.1 evaluated growth performance of 192 nursery pigs (mean initial BW of 6.5 kg) randomly assigned to the 4 experimental diets to give 12 replicates pens (4 pigs/pen) per dietary treatment, for a 42 d feeding period. Exp. 2 evaluated AID of energy and AA in 4 individually housed ileal cannulated barrows (~21 kg BW) according to a 4  $\times$  4 Latin square design. In Exp. 1, XB linearly and quadratically ( $P < 0.05$ ) improved feed efficiency compared with control. Adding the highest dose of XB (200 g/MT) improved overall

feed efficiency by 16% compared with control. In Exp. 2, adding XB (200 g/MT) XB increased ( $P < 0.05$ ) AID of DM, CP, energy and mean indispensable AA by 2.4, 4.1, 3.3 and 4.6 percentage units, respectively, compared with control. In conclusion, supplemental xylanase and  $\beta$ -glucanase in pelleted nursery wheat and barley-based diets deficient in DE resulted in improved energy and nutrient utilization, resulting in better feed efficiency from weaning to 42 d of age. Results of the 2 studies suggest that an enzyme product containing a combination of xylanase and  $\beta$ -glucanase activities allowed young pigs to derive more nutrients and energy in a wheat and barley-based diet formulated to be deficient in energy.

**Key Words:** enzyme, pigs, digestibility

**1047 Total-tract phosphorus digestibility of monocalcium phosphate in 15-kg pigs.** H. Zhai\* and O. Adeola, *Purdue University, West Lafayette, IN, USA.*

The objective of this study was to determine the standardized total-tract phosphorus digestibility (SPD) in monocalcium phosphate for 15-kg pigs using the regression technique. Forty-eight pigs (initial BW  $15.7 \pm 1.53$  kg) were used in a randomized complete block design. There were 8 dietary treatments with 6 replicates per treatment. The dietary treatments included a negative control (3.30 g/kg total P) and 7 additional dietary treatments with incremental addition of 0.74 g/kg P through monocalcium phosphate resulting in a range of 3.30 to 8.45 g/kg total P in the dietary treatments. The ingredient composition of the negative control was 600 g/kg corn, 300 g/kg soybean meal, 64.85 g/kg cornstarch, 20 g/kg soybean oil, 3.3 g/kg salt, 6.05 g/kg limestone, 3.0 g/kg vitamin + mineral premix, and 2.8 g/kg synthetic amino acids. Limestone was used to keep the Ca:P ratio constant at 1.25 across all dietary treatments and cornstarch was used to fill the slack. Five days were allowed for the pigs to adapt, followed by a 5-d period of total collection of feces. Fecal collection was initiated and ended with the appearance of ferric oxide-marked feces. Daily feed allowance was set at between 3.5 and 4.0% of the BW of pigs to guarantee that the feed waste was minimized. Water was supplied separately at an allowance of 2 times the amount of feed. The results showed that dietary P intake, fecal P output, and digested P increased linearly ( $P < 0.001$ ) with the increasing P level whereas the apparent P digestibility in diets increased both linearly ( $P < 0.001$ ) and quadratically ( $P = 0.007$ ). The regression of daily digested P against daily P intake gave an estimated SPD 67.5% for monocalcium phosphate and the endogenous P losses at 494 mg/d, which translates to 1,023 mg/kg dry matter intake. The  $r^2$  with this linear regression was 0.93. In conclusion, a strong linear relationship was obtained between digested P and P intake; the SPD in monocalcium phosphate was determined to be 67.5% for 15-kg pigs.

**Key Words:** monocalcium phosphate, total-tract phosphorus digestibility, pigs

**1048 Ileal digestibility of amino acids in co-products of corn processing into ethanol for pigs.** O. Adeola,\* *Purdue University, West Lafayette, IN, USA.*

Barrows with an average initial BW of 45 kg and fitted with T-cannula at distal ileum were fed 5 diets to determine the apparent (AID) and standardized ileal digestibility (SID) of amino acids (AA) in corn distillers dried grains (DDG), DDG with solubles (DDGS), high-protein DDG (HPDDG) and high-protein DDGS (HPDDGS). On a DM basis, the test ingredients contained 33.7% CP, 19.2% ADF, and 53.1% NDF for DDG; 30.3% CP, 11.8% ADF, and 40.6% NDF for DDGS; 62.5% CP, 28.4% ADF, and 45.1% NDF for HPDDG; and 52.4% CP, 17.4% ADF, and 30.4% NDF for HPDDGS. The 5 diets consisted of a nitrogen-free diet (NFD) and 4 semi-purified diets in which the test ingredient was the sole protein source with chromic oxide added at 5 g/kg as an indigestible marker. The NFD was used to determine basal endogenous AA losses. Each diet was fed to 6 barrows and each period consisted of a 5 d of adjustment period and 2 d of ileal digesta collection for 10 h on each of d 6 and d 7. The results showed basal endogenous loss ranged from 82 mg/kg DMI for Met to 3,390 mg/kg DMI for Pro. Proline and Gly (1,122 mg/kg DMI) were the 2 most abundant endogenous AA in endogenous flow and together accounted for approximately 42% of the total endogenous AA flow. The least abundant AA in endogenous AA flow were Met and Trp (89 mg/kg DMI), which together accounted for less than 2% of the total endogenous AA flow. Amino acids in the test ingredients were well digested by pigs with AID ranging from 70% for Lys in DDGS to 95% for Met in HPDDG. Statistical difference ( $P < 0.05$ ) in AID among test ingredients were observed between HPDDG and DDGS for most of the AA. Standardized ileal digestibility of the Lys for DDG, DDGS, HPDDG, and HPDDGS were 88.6, 79.9, 94.6, and 85.8%, respectively. Corresponding values for Met 93.9, 92.8, 97.1, and 94.6%. The SID of Lys was greater ( $P < 0.05$ ) in HPDDG than DDGS. In general, digestibility of AA in the high-protein co-product of the dry-grind processing of corn into ethanol was more than in the regular co-product and less in the co-product with added solubles.

**Key Words:** amino acids, pigs, standardized ileal digestibility

**1049 Total tract digestibility of nitrogen in pigs exposed to high environmental temperatures.** M. Brestenský,\* S. Nitrayová, P. Patráš, and J. Heger, *Animal Production Research Centre Nitra, Hlohovecká 2, Lužianky 951 41, Slovakia.*

The effect of environmental heat stress on total tract digestibility and retention of nitrogen (N) was studied using 7 gilts (initial BW  $50.5 \pm 1.7$  kg). The pigs were housed in metabolism cages in a climate-controlled room. After a 4-d adaptation period, two 14-d experimental periods followed during which the pigs were exposed to thermoneutral (NT;  $20.6 \pm 0.1^\circ\text{C}$ ) or high environmental (HT;  $30.4 \pm 0.4^\circ\text{C}$ ) temperatures. Pigs were fed with a standard diet twice a day in 2 equal doses at a daily rate of 90 g/kg<sup>0.75</sup>. Water was offered ad libitum. In each experimental period, two 24-h balance periods were carried out on d 6–7 and 13–14 during which urine (via bladder catheters) and feces were collected and subsequently pooled for N analysis. Based on N intake and N excretion, N balance was calculated. The experimental data were subjected to ANOVA and

when significant value for treatment effect ( $P < 0.05$ ) was observed, the differences between means were assessed using Fisher's LSD procedure. At HT conditions, feed intake was lower ( $P = 0.016$ ) than at NT conditions. Exposure of pigs to high environmental temperature tended to lower ( $P = 0.07$ ) digestibility of nitrogen (85.2%) as compared with NT conditions (87.6%). Urinary N excretion increased by 19.6% ( $P = 0.0175$ ) and N retention decreased by 20.6% ( $P = 0.001$ ) at HT in comparison with NT. The N retention at NT and HT conditions was 32.6 and 25.8 g/d, respectively. Daily nitrogen retention decreased by 4.6 g per each  $1^{\circ}\text{C}$  above upper critical temperature of animals ( $y = -4.5819x + 164.03$ ;  $R^2 = 0.4083$ ;  $P < 0.001$ ). In conclusion, when pigs are exposed for long-term periods to continuous high environmental temperatures, N retention and digestibility decrease, presumably due to decreased utilization of metabolisable energy during respiration.

**Key Words:** heat stress, pigs, nitrogen retention

**1050 The supplementation of low-P diets with microbial 6 phytase from *Aspergillus oryzae* improves P and Ca digestibility in growing pigs.** D. Torrallardona\*<sup>1</sup>, R. Salvadó<sup>1</sup>, and J. Broz<sup>2</sup>, <sup>1</sup>IRTA-Mas de Bover, E-43120 Constantí, Spain, <sup>2</sup>DSM Nutritional Products Ltd., CH-4002 Basel, Switzerland.

A trial was conducted to evaluate a novel microbial 6 phytase obtained from *Aspergillus oryzae* (Ronozyme<sup>®</sup> HiPhos, DSM) at different doses in pigs. Forty 8 individually housed pigs (*Landrace* x *Pietrain*; 52 kg BW; 1/2 males, 1/2 females) were distributed among 6 experimental treatments consisting of a basal control diet low in P (3.5 g P/kg; 1.1 g digestible P/kg), which was supplemented with 500, 1,000, 2,000, or 4,000 FYT/kg of phytase, and a positive control diet supplemented with dicalcium phosphate (4.5 g P/kg; 1.8 g digestible P/kg). After 21d, fresh feces were sampled from all the animals and the apparent fecal digestibility of nutrients was measured using  $\text{TiO}_2$  as indigestible marker. Blood samples were also obtained from each pig and analyzed for P and Ca concentrations. The basal control low-P diet increased Ca and reduced P blood concentrations ( $P < 0.05$ ) relative to the positive control diet (10.8 vs. 10.2 and 6.7 vs. 7.7 mg/dL, respectively). Phytase supplementation reduced Ca (from 10.8 to 9.9 mg/dL; linear response;  $P < 0.001$ ) and increased P concentrations (from 6.7 to 8.0 mg/dL; linear and quadratic responses;  $P < 0.001$ ) in blood, and reduced P concentration in feces (from 13.8 to 7.7 g/kg DM; linear and quadratic responses;  $P < 0.001$ ). Phytase also improved the fecal digestibility of P (from 29.6 to 62.4%; linear and quadratic responses;  $P < 0.001$  and  $P < 0.05$ ), Ca (from 55.3 to 75.9%; quadratic response;  $P < 0.01$ ) and ash (from 46.4 to 57.7%; quadratic response;  $P < 0.01$ ). It is concluded that the microbial 6-phytase tested improves the apparent fecal digestibility of P in growing pigs and reduces P excretion in feces in a dose-dependent manner.

**Key Words:** phytase, digestibility, pigs

**1051 The supplementation of low-P diets with microbial 6 phytase from *Aspergillus oryzae* improves P digestibility in sows.** D. Torrallardona\*<sup>1</sup>, L. Llauradó<sup>1</sup>,

and J. Broz<sup>2</sup>, <sup>1</sup>IRTA-Mas de Bover, E-43120 Constantí, Spain, <sup>2</sup>DSM Nutritional Products Ltd., CH-4002 Basel, Switzerland.

Two trials were conducted to evaluate a novel microbial 6 phytase obtained from *Aspergillus oryzae* (Ronozyme HiPhos, DSM) in gestating and lactating sows. In the first trial, 24 sows (Duroc x Landrace; 223 kg BW) were offered, at 16 d of gestation, a low-P control diet (4.0 g total P/kg; 1.5 g digestible P/kg) supplemented with 0, 500 or 1,000 FYT/kg of phytase. Two weeks later, fresh feces were sampled from all the animals and the apparent fecal digestibility of P was measured using  $\text{TiO}_2$  as indigestible marker. Phytase supplementation did not significantly ( $P > 0.1$ ) affect the fecal digestibility of P despite of numerical improvements from 8.7% in the non-supplemented diet to 17.6 and 19.1% in the diets with 500 and 1,000 FYT/kg of phytase, respectively, but reduced P concentration in feces (from 14.5 to 12.0 and 12.0 g/kg DM;  $P < 0.05$ ). In the second trial, 32 lactating sows (Duroc x Landrace; 282 kg BW) were used. They were offered, at 7 d of lactation, a low-P control diet (6.1 g total P/kg; 3 g digestible P/kg) or the same diet supplemented with 500 FYT/kg of phytase. After 2 weeks, fresh feces were sampled from all the animals and the apparent fecal digestibility of P was measured using  $\text{TiO}_2$  as indigestible marker. Phytase supplementation improved the apparent fecal digestibility of P from 27.5 to 38.7% ( $P < 0.001$ ) and reduced P concentration in feces (from 27.5 to 21.4 g/kg DM;  $P < 0.001$ ). It is concluded that the microbial 6-phytase tested improves the apparent fecal digestibility of P in sows and reduces P excretion in feces.

**Key Words:** phytase, digestibility, sows

**1052 Differences in portal appearance of lysine, threonine and methionine in Iberian and Landrace pigs fed diets differing in protein content.** L. Gonzalez-Valero, J. M. Rodriguez-Lopez, M. Lachica, and I. Fernandez-Figares,\* *Estacion Experimental del Zaidin, CSIC, Granada, Spain.*

The Iberian pig is an obese breed that is used for production of unique and value added pork products. Compared with modern breeds, Iberian pigs have lower rates of muscle protein deposition and body weight gain. Factors that limit growth performance of Iberian pigs are not known. The objective of this work was to determine the portal appearance of Lys, Thr and Met, the AAs most frequently limiting in practical diets, in Iberian and Landrace gilts fed diets with different protein content. Net portal absorption of AAs during the 6 h postprandial period was measured in 6 Iberian and 6 Landrace gilts (28 kg BW) fitted with chronic catheters placed in the portal vein, carotid artery and mesenteric vein, trained to consume 25 and 75% of their daily ration (85% ad libitum) at 9.00 and 15.00, respectively. Blood samples were taken every 30 min for 4 h and then hourly until 6 h after feeding 2 isoenergetic barley-soybean meal diets (14–14.5 MJ ME/kg DM) with different CP (14 vs. 16%) in a crossover design, with an adaptation period of one week for both diets. Net portal AA absorption was calculated by multiplying porto-arterial plasma AA concentration difference by portal vein plasma



flow rate estimated using p-aminohippuric acid infused into the mesenteric vein. Repeated measures analyses were carried out using the mixed procedure of SAS. The interaction of diet and breed with time was not significant ( $P > 0.10$ ). Portal plasma Lys and Met concentrations in pigs were maximal by 0.5 h postprandial although Thr peak occurred 1.5 h postprandial. Net portal absorption of Lys was greatest ( $P < 0.05$ ) when pigs consumed the 16% CP (34 vs. 24  $\mu\text{mol}/\text{min}$ ) diet and no differences ( $P > 0.10$ ) were found between breeds. Net portal absorption of Thr was greatest in Landrace (154 vs. 46  $\mu\text{mol}/\text{min}$ ;  $P < 0.001$ ) and in pigs fed 16% CP diet (135 vs. 66  $\mu\text{mol}/\text{min}$ ;  $P < 0.01$ ). Net portal absorption of Met (3.7  $\mu\text{mol}/\text{min}$ ) was neither affected by breed or diet ( $P > 0.10$ ). Differences in portal appearance of limiting AAs may partially explain the disparate growth capacity of Iberian pigs compared with modern genotypes.

**Key Words:** portal absorption, amino acid, pig

**1053 Lower gut nitrogen supply has no effect on apparent ileal digestibility of nitrogen or amino acids in growing pigs.** D. Columbus<sup>1</sup>, M. F. Fuller<sup>2</sup>, and C. F. M. de Lange<sup>1</sup>, <sup>1</sup>Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada, <sup>2</sup>Department of Surgery, State University of New York, Stony Brook, New York, USA.

An implicit assumption in measures of ileal digestibility (ID) to estimate bioavailability of amino acids (AA) and nitrogen is that ID is not influenced by lower gut nitrogen metabolism. The absorption of nitrogenous compounds from the lower gut, derived from fermentative AA catabolism, may have an impact on nitrogen metabolism and microbial AA synthesis in the upper gut as a result of urea recycling. The objective of this trial was to determine the apparent ID of nitrogen and AA in growing pigs fed a cornstarch and soybean meal-based diet and receiving an infusion of nitrogen into the cecum at 40% of nitrogen intake. Eight pigs (initial BW of 23.3  $\pm$  0.55 kg) were fitted with simple T-cannulas in the ileum and cecum, and randomly assigned to 1 of 3 continuous cecal infusion treatments (saline, sodium caseinate, or urea) according to a crossover design with 3 periods. Each experimental period lasted 9 d and consisted of a 5 d adaptation period followed by 2 consecutive 2 d collection periods. Digesta samples were collected and pooled per pig for each 2 d period, freeze-dried, ground, and analyzed for dry matter, organic matter, total nitrogen, and AA. Titanium dioxide was included in the diet as an indigestible marker. There was no effect of lower gut nitrogen supply on apparent ID of dry matter, organic matter, total nitrogen (85.4, 83.4, and 82.7  $\pm$  1.74%;  $P = 0.31$ ), or any AA (90.1, 89.0, and 89.9  $\pm$  1.08% for lysine;  $P = 0.70$ ) for saline, casein, and urea treatments, respectively. Apparent ileal digestibility may be an insufficiently sensitive measure to determine effects of lower gut nitrogen metabolism on nitrogen absorption from the lower gut and subsequent recycling into the upper gut.

**Key Words:** lower gut, fermentation, ileal digestibility

**1054 The effect of supplementing a xylanase to nursery diets on growth performance of 9 to 36 kg BW pigs.** E. Fruge<sup>2</sup>, E. Hansen<sup>2</sup>, R. Cabrera<sup>\*1</sup>, and J. Foss<sup>1</sup>, <sup>1</sup>Huvepharma USA, Inc., Peachtree City, GA, <sup>2</sup>Hubbard Feeds, Inc., Mankato, MN.

Enzymes are promising tools to counteract the price volatility in raw materials due to their ability to affect nutrient digestibility. The challenge is to match the types and amounts of non-starch polysaccharides (NSP) in ingredients with the appropriate enzymes. The objective of this trial is to determine the impact of a xylanase on growth and economic performance in nursery pigs. A total of 991 pigs were randomly allocated to 3 dietary energy treatments: positive control (PC) with 3,344 kcal/kg of ME, negative control (NC) with 3,267 kcal/kg of ME and negative control + Xylanase (NC+X) with 3,267 kcal/kg of ME. Xylanase was added to phase 2 and 3 diets at 1,500 EPU/kg of feed respectively. Phase 2 diet had corn, SBM, ground steam rolled oats and 10% DDGS. Phase 3 diet was a straight corn-SBM with 20% DDGS. Pens of pigs were weighed every 7 d until the end of the experiment on d 42. Each treatment had 12 pens and pigs were stocked 27 pigs/pen. PROC GLM of SAS was used and  $P < 0.05$  was chosen to determine the statistical differences among the treatments. From d 0 to d 14 (9 to 15 kg of BW), dietary treatments did not differ for ADG, ADFI, FG, and total gain. From d 14 to d 42 (15 to 36 kg of BW), PC and NC+X treatments had greater ( $P = 0.03$ ) ADG (0.74 and 0.73 vs. 0.71 kg/d respectively) and total gain (20.6 and 20.4 vs. 19.8 kg respectively) than NC. PC also had increased ( $P = 0.05$ ) feed conversion (1.47 vs 1.54) when compared with NC. From d 0 to d 42 (9 to 36 kg of BW), NC+X had intermediate response in both ADG and total gain when compared with PC and NC treatments. PC had greater ( $P = 0.05$ ) ADG (0.64 vs. 0.62 kg/d respectively) and total gain (26.9 vs. 26.2 kg respectively) than NC and increased ( $P = 0.05$ ) feed conversion (1.41 vs. 1.47 and 1.45 respectively) when compared with either NC or NC+X. In conclusion, the improvement in FCR of pigs fed NC + X confirms an improvement of dietary energy utilization equal to approximately 33 Kcal/kg of ME.

**Key Words:** xylanase, metabolizable energy, FCR

**1055 The effects of supplementation of a novel bacterial 6-phytase on mineral digestibility and plasma minerals in lactating sows.** Z. Nasir<sup>\*1</sup>, J. Broz<sup>2</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>DSM Nutritional Products, Basel, Switzerland.

Phosphorus present in plant feedstuffs is poorly digested by pigs because endogenous phytase enzyme to hydrolyze P from its complex phytate (inositol hexaphosphate) is lacking, resulting in P excretion in feces. Phytate can also bind other minerals. In most studies with piglets and grower-finisher pigs, supplemental phytase increased digestibility of minerals including P and Ca; however, data on efficacy of phytase in lactating sows are scarce. As such, effects of adding a novel bacterial 6-phytase expressed in a strain of *Aspergillus oryzae* (Ronozyme HiPhos, DSM Nutritional Products) on apparent total tract digestibility (ATTD) of P, Ca and other minerals was assessed in 45 lactating sows with free access to feed for the majority of the lactation.

Three experimental diets were prepared: 1) positive control (PC; 0.52% available P), regular sow diet containing inorganic P; 2) negative control (NC; 0.20% available P) without inorganic P; and 3) NC plus 500 U of phytase/kg diet. Each diet was offered to 15 randomly selected sows for 21 d (from 5 d before farrowing to 15 d post farrowing). At d 15 post farrowing, ATTD of P did not differ between PC and NC. Supplementation of phytase to the NC increased ( $P < 0.001$ ) the ATTD of P from 32 to 48%, but did not affect ( $P > 0.05$ ) the ATTD of crude protein and Ca. Plasma P concentration was reduced ( $P < 0.05$ ) by 0.5 mmol/L in sows fed NC instead of PC, while phytase supplementation increased ( $P < 0.05$ ) plasma P by 0.2 mmol/L. Diet did not affect plasma Na, K, Mn, Fe, Co, Cu, Zn, Se, Mb, urea, creatinine, glucose, total protein, albumin and globulin or sow BW changes and piglet ADG during lactation. Plasma variables were in normal physiological range. In conclusion, phytase supplementation increased P digestibility with the potential to reduce P excretion in lactating sows.

**Key Words:** phosphorus, phytase, sow

**1056 Effects of particle size and heat treatment of soybean meal on standardized ileal digestibility of amino acids in growing pigs.** U. Messerschmidt<sup>\*1</sup>, M. Eklund<sup>1</sup>, V. T. S. Rist<sup>1</sup>, P. Rosenfelder<sup>1</sup>, H. K. Spindler<sup>1</sup>, J. K. Htoo<sup>2</sup>, and R. Mosenthin<sup>1</sup>, <sup>1</sup>*Institute of Animal Nutrition, University of Hohenheim, 70593 Stuttgart, Germany*, <sup>2</sup>*Evonik Industries, 63457 Hanau, Germany*.

A study with growing barrows was conducted to evaluate the effects of variations in particle size and degree of heat treatment during processing on standardized ileal digestibility (SID) of AA in soybean meal (SBM). A commercial SBM batch was visually identified to be overheated due to its brownish color, and was separated into a fine and coarse fraction by using a 1-mm mesh sieve. In addition, 3 SBM were produced from 1 batch of soybean and exposed to different processing conditions (temperature and direct steam contact), referred to as mild (105°C; 34 min), medium (112°C; 45 min) and strong (139°C; 7 min). Trypsin inhibitor activity (TIA, g pure trypsin inhibited/kg of sample, DM) amounted to 2.2, 2.4, 10.8, 2.7 and 8.3 for the fine, coarse, mild, medium and strong SBM, respectively. In total, 5 SBM-cornstarch based diets were formulated to contain SBM as the sole source of dietary protein. An N-free diet was fed to determine basal ileal endogenous AA losses. This experiment was conducted according to a 6 × 6 Latin Square design using 6 barrows (German Landrace × Piétrain) with an initial BW of 23 kg. Animals were surgically fitted with a T-cannula at the distal ileum. Diets were fed in mash form at 35 g (as-fed)/kg average BW. Each period included 5 d adaptation to the diet and 2 d for digesta collection. With increasing particle size, SID of His, Asp, Glu and Pro increased ( $P < 0.05$ ), whereas SID of the other AA did not differ between the fine and coarse fraction ( $P > 0.05$ ). Lower SID values in the fine compared with the coarse SBM fraction indicate more pronounced heat damage possibly due to their enlarged surface area. The SID of AA was considerably lower ( $P < 0.001$ ) for mild and strong compared with medium toasted SBM, with SID values for most AA ranging between 18 to 35 percentage

units below those obtained for medium toasted SBM. These differences in SID are reflected in varying contents of TIA and reactive Lys, with lowest level of TIA and high level of reactive Lys in medium toasted SBM due to a more optimal processing condition in terms of temperature and duration of heat treatment.

**Key Words:** amino acid digestibility, pig, soybean meal

**1057 Prececal digestibility of various sources of starch (wheat, rice, potato, maize, pea) in minipigs with or without experimentally induced lack of exocrine pancreatic function.** A. Moessler<sup>\*1</sup>, N. Kramer<sup>1</sup>, C. Becker<sup>1</sup>, P. C. Gregory<sup>2</sup>, and J. Kamphues<sup>1</sup>, <sup>1</sup>*Institute of Animal Nutrition, University of Veterinary Medicine Hannover, Foundation, Germany, Hannover, Germany*, <sup>2</sup>*Abbott Products GmbH (Germany), Hannover Germany*.

Low prececal digestibility (prc dig) of starch increases starch flux into the hindgut, causing prebiotic effects (lower Salmonella prevalence but also energy losses and meteorism). In case of exocrine pancreatic insufficiency (EPI), the lack of pancreatic amylase can be compensated to a high extent by hindgut fermentation. Even in pigs with complete loss of exocrine pancreatic function, starch digestion over the entire tract is reaching levels of controls. Eight minipigs, with an ileo-cecal re-entrant fistula, were used. In 5 pigs the pancreatic duct was ligated (PL) to induce EPI, 3 served as controls (C). Different starch sources were tested in a screening-test, and the term disappearance rate (DR) was used. Test meal consisted of 175 g complete diet (CD; consisting of wheat semolina, polished rice, potato starch, maize starch, poultry meal, fish meal, casein and cellulose) plus 75 g of test starch (raw purified starch, without thermal treatment) and Cr<sub>2</sub>O<sub>3</sub>. Test meal (including added starch) contained (% DM): 67 starch, 1.7 crude fat, 15 crude protein; 2.0 crude fiber; 0.25 Cr<sub>2</sub>O<sub>3</sub>. For PL, prc dig of starch was lower ( $P \leq 0.05$ ) for all starch sources than for C. In C, prc DR of starch was almost complete (~90%) but was lower ( $P \leq 0.05$ ) for potato starch (75.4 ± 4.61%). Prc DR of starch was highest in PL for wheat starch (61.2%), while DR of maize starch was lower ( $P \leq 0.05$ ). Most values ranged between 40 and 50% and was lowest for rice starch (33.4 ± 14.7%). Raw potato starch may have prebiotic effects in healthy pigs. In patients with EPI, it is of special interest to maximize energy supply and minimize side effects of bacterial fermentation. Interestingly, ranking of starch DR differed between C and PL; thus, this study clearly underlines the need for investigations on patients when trying to optimize diet formulation. Wheat starch seems to be most favorable under the aspect of high prc DR for patients with EPI.

**Key Words:** starch digestion, prececal, EPI

**1058 Endogenous nitrogen losses (prececal and total) in pigs with exocrine pancreatic insufficiency (experimentally induced by pancreatic duct ligation).** A. Moessler<sup>\*1</sup>, H. Looock<sup>1</sup>, J. Classen<sup>1</sup>, P. C. Gregory<sup>2</sup>, and J. Kamphues<sup>1</sup>, <sup>1</sup>*Institute of Animal Nutrition, University of Veterinary Medicine Hannover, Foundation, Germany*,

Hannover, Germany, <sup>2</sup>Abbott Products GmbH (Germany), Hannover, Germany.

The pancreatic duct ligated minipig (PL) is an established model of exocrine pancreatic insufficiency (EPI), but can also be used as a model for studying effects of reduced prececal nutrient digestibility. The EPI distinctly reduces prececal digestion and absorption of nutrients with diverse consequences. This study was conducted to quantify endogenous N losses (ileocecal flux and fecal losses) in PL pigs and healthy controls (C) fed a N-free diet. Eight Göttinger minipigs (mean bw: ~30 kg) were fitted with an ileo-cecal re-entrant fistula. In 4 pigs the pancreatic duct was ligated (PL) to induce EPI. The diet fed was almost N-free [maize starch (88.8%), soy oil (4%), methylcellulose (4%) and minerals] with a crude protein content (cp) of 0.3%. 250 g of the diet was fed twice a day (= 447 g dry matter (DM)/day) beginning in the morning when chyme or feces collection started. Ileal chyme was collected over 12 h for 7 d (except d 6). In a second study feces were collected for 10 d. In PL pigs the amount of collected chyme was much higher than in C ( $P \leq 0.05$ ). Also DM content of chyme was higher ( $P \leq 0.05$ ) in PL. Cp content of chyme did not differ. Basal ileocecal cp flux (g/kg DM intake) was higher ( $P \leq 0.05$ ) in PL ( $41.3 \pm 11.1$ ) than in C ( $15.0 \pm 5.52$ ). The amount of feces did not differ but cp-losses via feces were higher in PL ( $P \leq 0.05$ ). Lowest fecal endogenous cp losses (g/kg DM intake) were ~2.5 times higher in PL ( $20.6 \pm 10.6$ ) than in C ( $7.10 \pm 3.94$ ). In C endogenous N losses were comparable with those of other studies (prc. 15; total tract: 7.10 g cp / kg DM intake), while those in PL-pigs were 2 to 3 times higher. In conclusion, the pancreatic duct ligation reduces DM digestibility and increases endogenous N-losses. These unexpected findings (loss of pancreatic secretion was expected to lower endogenous losses) indicate, that the effect of increase of chyme mass is the predominate factor.

**Key Words:** endogenous losses, crude protein, EPI

**1059 Effect of highly insoluble, low fermentable fiber on energy, fiber, and amino acid digestibility and on hindgut fermentation of fiber in growing pigs.** N. A. Gutierrez<sup>\*1</sup>, B. J. Kerr<sup>2</sup>, and J. F. Patience<sup>1</sup>, <sup>1</sup>Iowa State University, Ames, IA, USA, <sup>2</sup>USDA-ARS, Ames, IA, USA.

An experiment was conducted to determine the effect of increasing amounts of highly insoluble, low fermentable fiber from corn bran on digestibility of energy, fiber, and AA, and on hindgut fermentation of fiber. A total of 15 growing pigs (initial BW:  $28.7 \pm 2.1$  kg BW) were fitted with a T-cannula in the distal ileum and allotted to 5 dietary treatment groups in a 3-period incomplete block design with 9 observations per treatment. Treatments included a corn-casein basal diet and 4 diets containing increasing levels of corn bran with solubles (26.5% total dietary fiber, TDF): 10, 20, 30 and 40%. The TDF content of treatments was 7.3, 8.7, 9.1, 11.4, and 14.7% (as-fed basis). Corn or corn bran were the only sources of dietary fiber, and SID Lys:ME was maintained at 2.6 g/Mcal of ME across treatments. Feed was provided at 90% of predicted ad libitum intake of the basal diet. Hindgut fermentation of energy and fiber

were determined by difference between apparent total tract digestibility (ATTD) and apparent ileal digestibility (AID) of GE, TDF and NDF. The AID of AA was also calculated. Ileal and total tract flow of DM, GE, TDF and NDF increased (linear,  $P < 0.001$ ) with dietary fiber level. The AID of GE (78.8 vs. 72.2%) decreased (linear,  $P < 0.001$ ), but the AID of TDF (14.9 vs. 19.9%) and NDF (23.0 vs. 25.2%) were not affected ( $P = 0.15$  and  $P = 0.76$ , respectively) by dietary fiber level. The ATTD of GE (85.4 vs. 76.9%), TDF (36.6 vs. 29.1%), and NDF (42.6 vs. 30.5%) decreased (linear,  $P < 0.001$ ) with dietary fiber level. The hindgut fermentation of NDF (19.6% vs. 5.9%) and TDF (21.9 vs. 9.7%) decreased linearly ( $P < 0.001$ ), and GE (6.5 vs 4.8%) tended to decrease (linear,  $P = 0.07$ ) with dietary fiber level. The AID of indispensable AA (84.3 vs. 78.9%, mean value) and of Asp, Glu and Tyr decreased (linear,  $P < 0.001$ ) with dietary fiber level. In conclusion, increasing levels of highly insoluble and low fermentable fiber of cornorigin reaching the hindgut may reduce the growing pig's ability to ferment the fiber component of the diet, and may also decrease the digestibility of dietary AA.

**Key Words:** insoluble fiber, dietary fiber, pigs

**1060 Lactose in diet influences the degradation of mixed linked  $\beta$ -D-glucan in the small intestine of pigs.** K. E. B. Knudsen,<sup>\*</sup> Aarhus University, Blichers Alle 20, 8830 Tjele, Denmark.

The present study was undertaken to study the cause for the variation in the digestibility of mixed linked  $\beta(1-3;1-4)$ -D-glucan ( $\beta$ -glucan) in the small intestine of growing pigs.  $\beta$ -glucan is an important cell wall (dietary fiber, DF) component of the endosperm of barley and oats. The digestibility of  $\beta$ -glucan in the small intestine from both cereals is among the highest of all DF components, but in one particular study with oat-based diets it was lower ( $P < 0.001$ ) than what was found in other studies. In this study, whey protein containing lactose was used as protein supplement. Lactose is slowly digestible in the small intestine. To investigate if lactose could be causative for the lower digestibility of  $\beta$ -glucan in the study with whey protein, it was decided to quantify the content of lactose in the diets and to analyze for lactose in digesta samples from the small intestine (the small intestine was divided in 3 by length equal segments: SI1, SI2, SI3) and ileal digesta along with parameters for organic acids (lactic acids and short-chain fatty acids). Diets containing lactose were based on oat goats, oat flour, and oat bran (lactose 1.2–3.8% of DM), whereas the reference diets were based on rolled oats, rolled oats and oat bran, wheat flour with added oat bran and wheat flour with added  $\beta$ -glucan (lactose 0–0.1% of DM). Lactose was identified in digesta up to SI2, but disappeared in digesta from SI3 and the ileum. There was no difference in the digestibility of  $\beta$ -glucan among diets up to SI3 (mean 18%), whereas the digestibility in ileum was 66% in diets without lactose and 27% in diets containing lactose ( $P < 0.001$ ). With all diets,  $\beta$ -glucan was virtually completely digested in the cecum (mean 96%). No difference was found in the concentration of organic acids between diets either in SI3, ileum or cecum. In conclusion, slowly digestible lactose was the most likely cause of the



reduced digestibility of  $\beta$ -glucan in oat diets containing lactose.

**Key Words:**  $\beta$ -glucan, digestibility, lactose

**1061 Assessment of the presence of chemosensing receptors based on bitter and fat taste in the gastrointestinal tract of young pig.** M. Colombo, P. Trevisi,\* G. Gandolfi, and P. Bosi, *DIPROVAL, University of Bologna, Bologna, Italy.*

Recent research indicates that the presence of chemosensing receptors for bitter and fat taste is not restricted to the mouth, but is extended to several body compartments. Particularly the localization along the entire digestive tract contributes to the control of secreting activity, to the regulation of several hormones and to afferent neuronal modulation. However, knowledge on porcine bitter and fat taste receptors and on their expression in gastrointestinal tract of pigs is very scarce. We searched for the presence of porcine homologous sequences for 13 human transcripts of bitter and fat taste receptors, in ENSEMBL and NCBI databases. For TAS2R8 no alignment was seen; for TAS2R1, TAS2R3 and TAS2R9 a predicted sequence was found in NCBI database, but only for the last gene full homology was found by ENSEMBL. For TAS2R13 and TAS2R46 the porcine predicted sequence aligned also with several other human bitter genes. For 4 genes for bitter taste (TAS2R7, TAS2R10, TAS2R16, TAS2R38) and for 3 genes for fat taste (GPR40, GPR43, GPR120), a full homology for exons sequences was found and primers were designed by PRIMER3. These 7 genes were amplified with RT Real-Time PCR and verified on agarose gel, in 5 gastro-intestinal segments of weaned pigs: oxyntic (ST1), pyloric (ST2) and cardial to oxyntic transition mucosa (ST3); jejunum (JEJ) and colon (COL). Suitability of mRNA was verified by amplifying RPL4 and HMBS2 genes. Each taste gene was detectable on agarose gel in the following segments: TAS2R7 and TAS2R10 in ST1, ST2, ST3; TAS2R38 in ST1, ST2, ST3, JEJ; TAS2R16, GPR43 and GPR120 in all the segments. The inspection of bitter taste genes amplification curve indicated that the expression was in general very low. No expression was found for GPR40. The presence of gene expression for several chemosensing receptors for bitter and fat taste in different compartments of the stomach confirms that this organ should be considered a player for the detection of bolus composition, and, presumably, for digestive and metabolic adjustments, including the eating behavior.

**Key Words:** taste receptors, stomach, bitter

**1062 Ileal and total tract digestibility of wet and dried wheat distillers grain products in growing pigs.** K. Lyberg,\* J. Borling, and J. E. Lindberg, *Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, SE-750 07 Uppsala, Sweden.*

The apparent ileal (AID) and total tract (ATTD) digestibility of nutrients were evaluated in 2 commercially available wheat distillers grain products; one wet wheat distillers

grain with solubles (WDGS) from an ethanol company (Absolut AB, Åhus, Sweden) and one dried wheat distillers grain with solubles (DDGS) from a biofuel ethanol company (Lantmännen Agroetanol AB, Norrköping, Sweden). Acetic and lactic acid level of the WDGS was 115 and 17 mmol/L, respectively, and pH was 3.9. The experimental diets were composed, on DM basis, of 50% WDGS + 50% basal diet (W), and 50% DDGS + 50% basal diet (D). The basal diet was composed of corn starch, sugar, vitamins and minerals. Seven castrated male pigs with post valve t-cecum (PVTC) cannulas with an average initial body weight of 79 kg were fed the experimental diets according to a change-over design during two 14-d periods. In a pre- and post- period, casein was given as only protein source with the basal diet to estimate endogenous losses of nitrogen and amino acids. The endogenous losses were calculated separately for each pig and were used to estimate the standardized ileal digestibility (SID). The AID of OM did not differ between diets, but ATTD of OM was higher ( $P < 0.05$ ) for diet W. The AID (76 vs. 69%) and ATTD of CP was higher ( $P < 0.05$ ) in diet W than diet D. The SID for CP was higher ( $P < 0.05$ ) in diet W than diet D. The SID for lysine (76 vs. 52%) and methionine (76 vs. 70%) was higher ( $P < 0.01$ ) in WDGS than DDGS. The results indicate that drying of wheat distillers grain products can markedly lower the ileal digestibility of lysine and methionine, while the negative impact on the energy value will be small.

**Key Words:** digestibility, distillers grain, wheat

**1063 Meta-analysis of the effect of microbial phytase on the digestibility and bioavailability of copper and zinc in growing pigs.** P. Bikker\*<sup>1</sup>, A. W. Jongbloed<sup>1</sup>, and J. T. N. M. Thissen<sup>2</sup>, <sup>1</sup>Wageningen UR Livestock Research, Lelystad, The Netherlands, <sup>2</sup>Wageningen UR Biometris, Wageningen, The Netherlands.

Complexation of cations by dietary phytate is a major cause of reduced bioavailability of zinc (Zn) and possibly copper (Cu) in pig diets. Consequently, the majority of the dietary content of these trace elements is excreted in pig manure and contributes to accumulation in the soil. Several studies have shown an increased availability of zinc by the inclusion of microbial phytase in the diet. The aim of this study was to quantify the effect of microbial phytase on the digestibility and bioavailability of these trace elements in pig diets, based on experiments predominantly published in peer reviewed journals. Effects on digestibility of calcium (Ca) and phosphorus (P) were also determined to verify the validity of the methodology. Based on results of 32 experiments, blocks of 2 to 5 observations were created in which only the concentration of added phytase (in FTU/kg diet) varied and all other (dietary) factors were kept constant. A REML analysis was performed with  $\ln(\text{FTU})$  as fixed term and block, block  $\times \ln(\text{FTU})$  and the deviation of the fitted line in each block as random terms, to allow for different slopes within blocks. Inclusion of microbial phytase significantly increased the digestibility of zinc ( $P=0.002$ ), the dietary digestible zinc content ( $P=0.005$ ), the plasma zinc level ( $P<0.001$ ), and the dietary digestible copper content ( $P=0.02$ ) and numerically increased the copper digestibility ( $P=0.14$ ) according to the logarithmic model. Surprisingly,

phytase inclusion numerically decreased the plasma copper level ( $P=0.12$ ). The meta-analysis indicated that 500 FTU phytase/kg generated 0.80 g digestible P, 0.75 g digestible Ca, 2.1 mg digestible Cu and 3.6 mg digestible zinc. Based on published response studies with different levels of zinc sulfate in the diet, we estimated that inclusion of 500 FTU microbial phytase/kg allows a reduction of 20-40 mg zinc from zinc sulfate/kg. The contribution of phytase to the dietary copper supply remains inconclusive.

**Key Words:** phytase, zinc, copper

**1064 Modelling the retention and excretion of digestible phosphorus for different genotypes.** V. Symeou,\* I. Leinonen, S. Edwards, and I. Kyriazakis, *School of Agriculture, Food and Rural Development, Newcastle University, United Kingdom.*

A model has been developed to enable better match between digestible phosphorus (dP) supply and retention in pigs of different genotypes and thus reduce P excretion. Maintenance dP was modeled as functions of the body protein mass (Pr) and mature Pr mass ( $Pr_m$ ) to accommodate differences in genotypes:  $0.1293 \cdot Pr \cdot Pr_m^{-0.27}$  (g/day). This was an advance over the expression of maintenance dP as a function of live weight. From literature, the efficiency of dP utilization for retention was estimated at 0.9 and assumed to be independent of live weight and genotype. dP retention was found to be isometrically related to Pr retention:  $0.0337 \cdot dPr/dt$ . This allowed the dP retention to be expressed as simple functions of Pr. However within an insufficient lysine diet, when the ratio tLysine: Ash was below 0.45 g/g in the diet, the P: Pr ratio of empty body weight was estimated:  $0.06 - (0.046 \times \text{tLysine:Ash diet})$ . Above the 0.45 threshold, the P: Pr ratio in the body was constant at 0.0337. The model allows for robust predictions of dP utilization under different feeding scenarios for pigs of different genotypes. As BSAS (2003) standard are the only ones that account for genotype effects on P utilization, comparisons to our predictions suggest that BSAS (2003) moderately underestimate the requirements for dP for intermediate pig genotype, while for the commercial BSAS (2003) pig genotype the same standards overestimate dP requirements.

**Key Words:** maintenance phosphorus, phosphorus retention, efficiency of utilization

**1065 Prediction of apparent, standardized and true ileal digestible total and reactive lysine contents in heat-treated soybean meal samples.** J. C. Kim\*<sup>1</sup>, B. P. Mullan<sup>1</sup>, and J. R. Pluske<sup>2</sup>, *<sup>1</sup>Livestock Innovation, Department of Agriculture and Food, 3 Baron-Hay Court, South Perth, WA 6151, Australia, <sup>2</sup>School of Veterinary and Biomedical Sciences, Murdoch University, South Street, Murdoch, WA 6150, Australia.*

An experiment was conducted to establish linear regression equations to predict apparent, standardized and true ileal digestible total and reactive lysine content in heat-treated soybean meal (SBM) samples. Forty-two individually-

housed entire male crossbred pigs weighing  $37.5 \pm 0.15$  kg (mean  $\pm$  SEM) were used in a randomized block study with 7 dietary treatments ( $n = 6$ ). The dietary treatments were 5 SBM-based semi-synthetic diets containing 350 g/kg of SBM with variable heat treatments (0, 7, 14, 21, and 28 min autoclaved at 135°C), a protein free (N-free) diet, and an enzymically-hydrolyzed casein (EHC) diet. Pigs were randomly allocated to the experimental diets based on live weight and fed the respective diet for 5 d at 2.5 times maintenance [ $2.5 \times (0.458 \text{ MJ} \times \text{BW}^{0.75})/\text{diet DE}$ ]. On d 6, pigs were euthanized  $9 \text{ h} \pm 20 \text{ min}$ . from the start of feeding. Digesta samples were collected within 5 min. of euthanasia from the ileum 40 cm proximal to the ileo-cecal junction, and later analyzed for amino acids and the digestibility marker, titanium dioxide. Ileal samples collected from pigs fed the EHC diet were ultrafiltered at 10k Daltons. Reactive lysine content was determined using the homoarginine method. Standardised and true ileal digestibility were calculated by adjusting apparent ileal digestibility with the endogenous amino acid flows determined under N-free and EHC-ultrafiltration methods, respectively. One-way ANOVA and polynomial comparison were conducted using Genstat 12. Heat treatment linearly decreased total lysine content from 30.4 g/kg to 21.5 g/kg ( $P < 0.001$ ) and reactive lysine content from 25.9 g/kg to 13.2 g/kg ( $P < 0.001$ ). Apparent, standardized and true ileal digestible total and reactive lysine contents linearly decreased with increasing severity of heat treatment ( $P < 0.001$ ) and were accurately predictable from total and reactive lysine content in heat-damaged soybean meals ( $P < 0.001$ ). The result indicates that excessive heat processing of SBM reduced both the content ( $P < 0.001$ ) and digestibility ( $P < 0.001$ ) of total and reactive lysine in SBM.

**Key Words:** soybean meal, reactive lysine, ileal digestibility

**1066 Digestible and metabolizable energy concentrations in copra meal, palm kernel meal, and cassava root fed to growing pigs.** A. R. Son\*<sup>1</sup>, S. Y. Ji<sup>2</sup>, and B. G. Kim<sup>1</sup>, *<sup>1</sup>Department of Animal Science and Environment, Konkuk University, Seoul, Republic of Korea, <sup>2</sup>Animal Nutrition and Physiology Team, National Institute of Animal Science, RDA, Suwon, Republic of Korea.*

An experiment was conducted to measure DE and ME in copra meal (CM), palm kernel meal (PKM), and cassava root (CR). Copra meal contained 88.7% DM, 4,232 kcal GE/kg, 21.0% CP, 7.5% ether extract, 54.5% NDF, and 6.7% ash; PKM contained 92.6% DM, 4,466 kcal GE/kg, 16.9% CP, 6.7% ether extract, 68.3% NDF, and 4.0% ash; and CR contained 88.1% DM, 3,556 kcal GE/kg, 4.0% CP, 0.5% ether extract, 19.4% NDF, and 6.8% ash on an as-fed basis. Eight boars with an initial mean BW of 67.3 kg (SD = 5.8) were individually housed in metabolism crates that were equipped with a feeder and a nipple drinker. A replicated  $4 \times 4$  Latin square design was employed with 4 dietary treatments, 4 periods, and 8 animals. A basal diet mainly contained corn and soybean meal. Three additional diets were formulated to contain 30% of CM, PKM, and CR. All diets contained the same proportion of corn:soybean meal ratio at 4.14:1. The marker-to-marker method was used for fecal collection with 4-d adaptation and 4-d collection

periods. This method enabled feces collection originating from measured feed intake by coloring 2 meals identifying the initiation and termination. The difference procedure was used to calculate DE and ME in CM, PKM, and CR. The apparent total tract digestibility of energy was 89.5, 84.1, 82.4, and 87.9% (SEM = 0.5;  $P < 0.001$ ) in the basal, CM, PKM, and CR diets, respectively. The DE in CM and PKM were greater than in CR (3,440 and 3,238 vs. 2,966 kcal/kg on an as-fed basis;  $P < 0.05$ ). The DE:GE in CM and CR were greater than in PKM (81.3 and 83.4 vs. 72.5%;  $P < 0.05$ ). The ME in CM was greater than in CR (3,340 vs. 2,935 kcal/kg on an as-fed basis;  $P < 0.05$ ), but not different from the ME in PKM (3,168 kcal/kg). In conclusion, CM and PKM have a higher DE value than CR, and CM has a higher ME value than CR.

**Key Words:** copra meal, palm kernel meal, cassava root

**1067 Comparison of standardized ileal amino acid digestibilities in protein supplements and cereal grains for weaned pigs.** N. Sauer\*<sup>1</sup>, M. Eklund<sup>1</sup>, S. Hoerner<sup>1</sup>, M. Rademacher<sup>2</sup>, and R. Mosenthin<sup>1</sup>, <sup>1</sup>Institute of Animal Nutrition, University of Hohenheim, Stuttgart, Germany, <sup>2</sup>Evonik Industries, Health and Nutrition feed additives, Hanau-Wolfgang, Germany.

Standardized ileal digestibilities (SID) of AA in protein ingredients and grains were determined in weaned piglets (5 kg initial BW), using the difference method. Animals were fitted with a simple ileal T-cannula on d 24 or 25 of age. A synthetic diet based on cornstarch and casein was either supplemented with an extruded soybean meal (ESM, 467 g CP/kg DM), rice protein concentrate (RPC, 717 g CP/kg DM), full fat heat treated soybeans (SB, 412 g CP/kg DM), corn (87 g CP/kg DM), barley (125 g CP/kg DM) or wheat (143 g CP/kg DM). The contribution of CP and AA from casein and from the assay feed ingredients to the assay diet averaged 50% for each. Each diet was fed to 6 animals according to a row-column design with 3 periods. Apparent ileal digestibility were corrected for basal ileal endogenous losses of AA (literature values) and transformed into SID values. The SID of indispensable AA in the protein ingredients ranged from 50 to 73% for Thr to 57–85% for Lys (Table). Between RPC and soy products, differences ( $P < 0.05$ ) in SID of Lys, Met and Thr were greater than within soy products (ESM, SB). The SID of Lys, Thr, and Trp did not differ ( $P > 0.05$ ) between barley and wheat, whereas SID of Met was lowest ( $P < 0.05$ ) in barley. In conclusion, the use of RPC, despite its high CP content, in diets for weaned piglets is limited, due to its low SID of Lys and Met compared with the soy products (ESM, SB).

**Table 1.** Standardized ileal digestibility of amino acids in the assay feedstuffs (LSMeans ± SEM; %)

Item	Feedstuffs						P-value
	ESM	SB	RPC	Corn	Barley	Wheat	
n <sup>1</sup>	5	6	6	6	5	5	
Lys	85 <sup>a</sup> ± 6.6	77 <sup>ab</sup> ± 6.0	57 <sup>c</sup> ± 6.0	49 <sup>c</sup> ± 6.0	64 <sup>bc</sup> ± 6.6	63 <sup>bc</sup> ± 6.6	0.004
Met	85 <sup>a</sup> ± 2.9	72 <sup>b</sup> ± 2.6	51 <sup>d</sup> ± 2.6	71 <sup>b</sup> ± 2.6	60 <sup>c</sup> ± 2.9	76 <sup>ab</sup> ± 2.9	<0.001
Thr	73 <sup>a</sup> ± 5.1	63 <sup>ab</sup> ± 4.7	50 <sup>b</sup> ± 4.7	48 <sup>b</sup> ± 4.7	57 <sup>b</sup> ± 5.1	55 <sup>b</sup> ± 5.1	0.014
Trp	73 <sup>a</sup> ± 6.0	67 <sup>ab</sup> ± 5.4	53 <sup>bc</sup> ± 5.4	27 <sup>c</sup> ± 5.4	58 <sup>abc</sup> ± 6.0	67 <sup>ab</sup> ± 6.0	<0.001

<sup>a,b,c</sup>LSMeans within a column with different superscripts differ ( $P < 0.05$ ).

<sup>1</sup>Observations having a Cook's D > 0.5 were considered as influential and hence deleted from further analysis

**Key Words:** difference method, standardized ileal digestibility, pig

**1068 Performance and fecal phosphorus and calcium digestibility in grower-finisher pigs fed diets with and without phytase.** I. Kühn\*<sup>1</sup> and K. Männer<sup>2</sup>, <sup>1</sup>AB Vista, Darmstadt, Germany, <sup>2</sup>Institut of Animal Nutrition, Berlin, Germany.

The efficacy of a thermotolerant 6-phytase (Quantum Blue) was evaluated in 96 crossbred barrows (8 replicates, 3 pigs each, allotted at random) fed 4 different diets. Diets based on corn, a heat-treated grain mix and soybean meal with recommended (PC) or reduced (NC) phosphorus (P) and calcium (Ca) levels were fed from 25 to 110 kg live weight. Diets (PC) contained 0.54% P and 0.72% Ca from 25 to 45 kg, 0.52% P and 0.66% Ca from 45 to 70 kg and 0.48% P and 0.51% Ca from 70 to 110 kg live weight. NC diets were reduced in P by 1.9 to 2.2 g/kg and in Ca by 1.4 to 1.8 g/kg with phytase added at 0, 250 and 500 FTU/kg (confirmed by a validated method). Performance was measured at the end of each feeding period. Fecal P and Ca digestibility was evaluated at an average body weight of 45 and 70 kg (7 d adaptation. Three d sampling, twice a day by rectal stimulation in 2 pigs per pen, inert marker Cr2O3, 5 g/kg). Homogeneity of the data was evaluated by ANOVA and means compared by Tukey test. The final weight of the NC pigs (111.9 kg) was increased by P (120.3 kg, PC) and by both phytase inclusion rates (116.5 and 117.6 kg, respectively,  $P < 0.05$ ). Daily gain of NC pigs (781 g/d) was increased by phytase (5.5 and 6.6%), with pigs fed 500 FTU/kg achieving similar daily gain as PC pigs (833 and 858g/d, respectively  $P > 0.05$ ). Feed efficiency was lower in NC pigs (0.308 kg/kg,  $P < 0.05$ ) than in pigs fed the PC (0.328 kg/kg) or the phytase diets with 250 or 500 FTU/kg (0.324 and 0.330 kg/kg, respectively). Fecal P digestibility in both sampling periods was lowest in pigs fed NC diets (35.5% in starter and 32.2% in grower period). Phytase improved P digestibility in both periods at both application rates with 500 FTU/kg diet being superior to 250 FTU/kg ( $P < 0.05$ ) and on the same level or above the PC pigs (40.1% in starter and 43.7% in grower period). Similar but less pronounced effects were evaluated for Ca digestibility. Addition of the phytase tested allows relevant P and Ca reduction in diets by nearly restoring performance to the level of pigs fed diets with adequate P and Ca level and by improving P and Ca digestibility of low P diets.

**Key Words:** phytase, pig, digestibility

**1069 Effects of β-hydroxy β-methyl butyrate supplementation to sows in late gestation on absorption and hepatic metabolism of glucose and amino acids during transition.** C. Flummer\*<sup>1</sup>, H. Lyby<sup>2</sup>, K. S. Storli<sup>2</sup>, V. Bjerre-Harpøth<sup>1</sup>, B. M. Nielsen<sup>3</sup>, M. Krämer<sup>1</sup>, B. A. Røjen<sup>1</sup>, N. B. Kristensen<sup>1,4</sup>, and P. K. Theil<sup>1</sup>, <sup>1</sup>Department of Animal Science, Aarhus University, Tjele, Denmark, <sup>2</sup>Department of



*Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway, <sup>3</sup>Department of Food Science, Aarhus University, Tjele, Denmark, <sup>4</sup>Syddansk Kvæg, Vojens, Denmark.*

$\beta$ -hydroxy  $\beta$ -methyl butyrate (HMB), a metabolite of leucine, has proved to positively affect sow performance. However, effects on nutrient absorption and hepatic metabolism are unknown. A multi-catheter sow model was established to study the effects of dietary HMB on net portal (NPF) and net hepatic (NHF) fluxes of HMB, glucose, and the AAs: Ala, Gly, Ile, Leu, Phe, Pro, Tyr and Val. Eight second parity LY sows were fitted with permanent indwelling catheters in an artery and in portal, hepatic and mesenteric veins. Eight hourly sets of blood samples were taken, starting 30 min before the morning meal, on d-3 and d3 relative to parturition. Control sows (CON) were fed a standard lactation diet from d-15 and throughout the experiment. HMB sows were fed the control diet with 15 mg Ca(HMB)<sub>2</sub>/kg BW mixed in one third of the morning meal from d-10 until the day of parturition. Fixed effects of HMB on plasma metabolites were tested while accounting for repeated blood sampling within sow and day. Net portal flux of HMB was affected by treatment (trt) ( $P < 0.01$ ) and peaked at 6.85 mmol/h 30 min after the morning meal, and then decreased toward preprandial level (-0.009 mmol/h) 3.5 h after the meal, indicating that dietary HMB was rapidly absorbed from the intestine in the HMB sows. The NHF of HMB tended to be affected by trt ( $P = 0.06$ ) showing a small hepatic uptake of HMB (1.05 mmol/h). The trt x time interaction affected the NPF of glucose and studied AAs ( $P < 0.01$ ), except for Gly and Tyr. The NPF were always positive, indicating absorption from gut to blood. The rates of absorption appeared to be more stable for HMB sows than for CON. Net hepatic flux of glucose was not affected by HMB. It was negative, indicating hepatic uptake, 1.5 to 2.5 h after the meal, but otherwise positive, indicating net hepatic release of glucose. Net hepatic fluxes of AAs remained negative and were not affected by treatment. In conclusion, HMB reduced the diurnal variation in glucose and AA absorption and suggest that a more uniform nutrient absorption to portal blood is advantageous for sow performance.

**Key Words:** portal flux, HMB, pig

**1070 The degradation of arabinoxylan rich cell walls in digesta obtained from piglets fed on wheat-based diets by exogenous xylanases and auxiliary enzymes.** N. R. Pedersen<sup>\*1</sup>, D. M. Le<sup>2</sup>, P. Fojan<sup>2</sup>, E. Azem<sup>3</sup>, J. Broz<sup>3</sup>, P. Guggenbuhl<sup>4</sup>, and D. Pettersson<sup>1</sup>, <sup>1</sup>Novozymes, Bagsværd, Denmark, <sup>2</sup>Aalborg University, Aalborg, Denmark, <sup>3</sup>DSM Nutritional Products, Animal Nutrition & Health, 4002 Basel, Switzerland, <sup>4</sup>DSM Nutritional Products, Animal Nutrition & Health, 68305 Saint Louis cedex, France.

The objective of the present study was to compare the ability of experimental and commercial xylanases to degrade, in vitro, the arabinoxylan fraction in digesta from pigs fed a wheat based diet. Piglets were sacrificed at 1, 2, 3, or 4 h after feeding and stomach and ileum contents were isolated and frozen and later used for the in vitro

studies. Xylan solubilisation (measured as xylose) provided information regarding the ability of the enzymes to degrade the arabinoxylans during the harsh in vivo conditions prevailing in the gastro intestinal tract. The hydrolytic capacity of a commercial xylanase was compared with that of an experimental xylanase using stomach digesta (pH 2.8) obtained at 4 h after feeding. Relative to the control without supplemental xylanase, both xylanases enzymes increased ( $P < 0.05$ ) xylose solubilisation 3 times compared with the control. In the ileal digesta (1 h) the solubilisation was also increased ( $P < 0.05$ ) in a similar way for both xylanases by 36%. Notably, inclusion of arabinofuranosidases in the ileal digesta further increased ( $P < 0.05$ ) the capacity of the experimental enzyme to degrade the arabinoxylans when compared with the commercial xylanase, with or without supplemental arabinofuranosidases. However, arabinofuranosidases added to either of the xylanases in stomach samples did not increase to xylanase. Our results illustrate clearly the importance of using different conditions and substrates when enzyme performance is studied in vitro as a pre-screening tool for setting up in vivo trials.

**Key Words:** xylanase, digesta, xylose

**1071 Effects of dietary supplementation with a protease on the apparent ileal digestibility of the weaned piglet.** P. Guggenbuhl<sup>\*1</sup>, Y. Wache<sup>1</sup>, and J. Wilson<sup>2</sup>, <sup>1</sup>DSM Nutritional Products France, 68305 Saint-Louis cedex, France, <sup>2</sup>DSM Nutritional Products LCC, Parsippany, NJ, United States.

The effects on the nutrient valorisation of an acid-stable protease (Ronozyme<sup>®</sup> ProAct) supplemented to a corn soybean meal based diet were evaluated for the apparent ileal nutrient digestibility in 120 28-d old weaned piglets (8.17  $\pm$  0.90 kg). Pigs were divided into 2 equal groups and had free access to mash diet containing 0.4% chromium oxide as indigestible marker (Std) or this diet supplemented with the protease at a concentration of 200 mg/kg (Prot). The analyzed added protease activities in the Std and Prot diets were 0 and 107%, respectively. The ileal content was collected for the digestibility determination after euthanasia of 35 piglets of each group after 14 d of study and 25 piglets of each group after 29 d. The piglets grew similarly in both experimental groups. Compared with group Std, the apparent ileal digestibility of total nitrogen (68.7%) was ( $P \leq 0.05$ ) increased by 6.7% after 29 d of treatment in group Prot. The digestibility of the essential amino acids (80.4%), the sulfur amino acids (78.6%) and the branched chain amino acids (78.3%) was ( $P \leq 0.05$ ) increased at the end by 5.3, 6.9 and 5.8%, respectively. The individual amino acids presented a tendency for a better digestibility in the protease-supplemented animals after 14 d of treatment. At the end of the study, the apparent ileal digestibility of arginine (83.0%), aspartate-asparagine (75.0%), glutamate-glutamine (80.6%), histidine (78.5%), isoleucine (76.9%), lysine (89.5%), phenylalanine (78.4%), threonine (69.5%), tyrosine (75.1%) and valine (76.2%) in the Prot group was ( $P \leq 0.05$ ) increased by 3.7, 6.4, 6.3, 6.8, 7.8, 4.0, 4.5, 7.4, 5.4 and 8.8%, respectively. In conclusion, protease increased apparent ileal digestibility of amino acids by piglets.



**Key Words:** protease, amino acid digestibility, piglets

**1072 Nutritional characteristics of byproducts originating from a Central European ethanol fuel industry for pigs.** S. Nitrayová,\* M. Brestenský, P. Patráš, and J. Heger, *Animal Production Research Centre Nitra, Hlohovecká 2, Lužianky, 951 41, Slovakia.*

Chemical composition and nutrient and energy digestibilities were determined in 4 samples of dried distillers grains with solubles (DDGS) and one sample of wet distillers grains (WDG) from 4 ethanol fuel manufacturers. The cereal sources used for ethanol production were wheat (1 sample), wheat + barley (2 samples) and maize (2 samples). The nutrient contents (expressed in % of dry matter) were variable, ranging from 30.5 to 39.5 CP, 4.4 to 12.3 fat, 7.5 to 12.9 crude fiber, 2.7 to 7.8 ash and 3.0 to 9.4 total phosphorus. The concentration of lysine, which was the first-limiting amino acid in all samples, ranged from 2.05 to 5.20 g/kg DM. The diets were fed to 6 gilts (average body weight  $39.9 \pm 1.9$  kg) fitted with ileal T-cannula using a  $5 \times 6$  factorial arrangement. Each experimental period comprised of a 5-d preliminary period followed by a 2-d collection period during which urine and feces were collected. Samples of ileal digesta were collected the last 24 h of each experimental period. The experimental data were subjected to ANOVA and when significant value for treatment effect ( $P < 0.05$ ) was observed, the differences between means were assessed using Fisher's LSD procedure. Using acid insoluble ash as a marker, apparent total tract (ATD) and ileal (AID) digestibilities of nutrients and energy and AID of amino acids were calculated. The ATD of N ranged from 55.7 to 83.7%. Nitrogen retention expressed as % of N intake varied from 10.2 to 32.0. Except for the wheat-based DDGS, the mean AID of N was 66.8%. The mean values ATD and AID of NDF were 52.8% and 24.4% respectively. The concentration of total P in WDG was about one half of the values found in DDGS ( $P < 0.001$ ) which corresponds to its very low ATD (1.4%). The ATD and the AID of energy ranged from 58.8 to 73.9% and from 40.6 to 54.1%, respectively. The AID of AA was highest ( $P < 0.001$ ) in WDG (71.8%) and lowest ( $P < 0.001$ ) in DDGS from wheat (42.3%). Tested distillers grains are good sources of energy and, except for one sample, of P, but their nutritional value vary among sources.

**Key Words:** distillers grains, digestibility, pigs

**1073 Effect of dietary fiber concentration on retention and redistribution of nitrogen in pigs.** P. Patráš,\* S. Nitrayová, M. Brestenský, and J. Heger, *Animal Production Research Centre Nitra, Hlohovecká 2, Lužianky, 951 41, Slovakia.*

Eight gilts (initial BW  $29.9 \pm 1.7$  kg) were used to evaluate the effect of dietary fibre (measured as crude fiber) on the redistribution of N between feces and urine at different levels of dietary N. Pigs were randomly assigned to 4 dietary treatments according to a replicated  $4 \times 4$  Latin square design. The treatments were (1) low N (14% CP), low fiber (3.25%); (2) low N, high fiber (4.46%); (3) high N (18.8% CP), low fiber and (4) high N, high fiber. Diets were based on soybean meal, wheat, and maize and were

supplemented with crystalline amino acids. High fiber diets contained 15% beet pulp. Pigs were housed in metabolism cages and fed in 2 equal doses at 07:00 and 17:00 at a daily rate of 90 g/kg<sup>0.75</sup>. Water was offered ad libitum. Each experimental period consisted of a 6-d adaptation followed by a 4-d collection during which feces and urine (using bladder catheters) were collected. The experimental data were subjected to ANOVA and when significant value for treatment effect ( $P < 0.05$ ) was observed, the differences between means were assessed using Fisher's LSD procedure. The N intake, fecal N excretion and absorption and retention of N increased ( $P < 0.03$ ) in pigs fed high-protein diets with added fiber. However, urinary N excretion (g/d) was reduced ( $P < 0.02$ ) only in the low - protein diets. Urinary N as a percentage of N intake was reduced ( $P < 0.01$ ) in all experimental groups fed high fiber diets irrespective of N content in the diet. The coefficients of determination between fecal N and dietary fiber calculated for diets with low and high protein content were  $R^2 = 0.074$  and  $R^2 = 0.194$ , respectively. Dietary fiber level did not affect dry matter intake. DM output (g/d) was higher ( $P < 0.02$ ) in diet with high N and fiber content in comparison with high N and low fiber content. In conclusion, fiber added to diets with higher CP content increased fecal N, reduced urinary N and increased overall N retention.

**Key Words:** fiber, nitrogen, pigs

**1074 Evaluation of optimal supplementation level of emulsifier (lysophospholipids) in low energy diets for growing pigs.** J. H. Cho\*<sup>1</sup>, J. W. Hong<sup>2</sup>, and I. H. Kim<sup>1</sup>, <sup>1</sup>*Department of Animal Resource & Science, Dankook University, Cheonan, Choongnam, South Korea,* <sup>2</sup>*Dongwon Farmsco, Nonsan, Choongnam, South Korea.*

Supplementation of emulsifier may improve energy utilization and save feed cost of energy source in growing pig diets. This study was conducted to evaluate the optimal supplementation level of emulsifier in low energy diets for growing pigs. Six growing pigs [(Yorkshire  $\times$  Landrace)  $\times$  Duroc, BW =  $22.41 \pm 2.21$  kg] were fed 6 diets for 6 periods (every period lasted for 7 d) in a  $6 \times 6$  Latin square design. Dietary treatments were: 1) PC (positive control: 3,410 kcal ME/kg—calculated value), 2) NC (negative control: 3,310 kcal ME/kg), 3) E0.05 (NC with 0.05% lysophospholipids), 4) E0.07 (NC with 0.07% lysophospholipids), 5) E0.09 (NC with 0.09% lysophospholipids, and 6) E0.11 (NC with 0.11% lysophospholipids). Pigs were individually housed in metabolism crates. Pigs were fed twice daily (08:00 and 20:00, identical amount of feed each time) and consumed all the feed within 30 min. Each period consisted of a 7-d adjustment period and a 2-d of fecal and urine total collection (for 48 h) during d 8 and 9 (24 h). No difference ( $P > 0.05$ ) was observed in digestibility of DM (dry matter: 94.4, 93.1, 93.2, 93.9, 94.1, and 93.6%) and energy (93.9, 93.0, 93.3, 93.5, 93.3, and 92.9%), and urinary loss (DM-ME: 3.9, 4.3, 4.2, 4.0, 3.7, and 4.2%) among treatments. In conclusion, positive effects were not observed when emulsifier was supplemented as feed additive for improving energy utilization in low energy diet of growing pigs.

**Key Words:** lysophospholipids, digestibility, growing pigs

**1075 Effects of molasses supplementation on growth performance, nutrient digestibility, blood characteristics, fecal moisture, fecal noxious gas emission, and meat quality in finishing pigs.** S. M. Hong,\* J. Li, J. H. Cho, and I. H. Kim, *Department of Animal Resource & Science, Dankook University, Cheonan, Choongnam, South Korea.*

Molasses, the by-products of the sugar cane, is widely used as a cereal substitute in livestock feeds. Final cane molasses ("C" molasses) can be an effective energy substitute for cereals, despite its laxative effect. A total of 120 finishing pigs [(Landrace × Yorkshire) × Duroc, BW = 54.21 ± 2.62 kg] were used in a 10-week feeding trial to evaluate the effect of dietary molasses. Pigs were randomly assigned to 1 of 3 dietary treatments on the basis of BW (10 replicate pens per treatment with 4 pigs per pen). Dietary treatments were: CON, basal diet; T1, CON + 2.5% molasses; T2, CON + 5.0% molasses. All diets were formulated to meet or exceed the NRC requirements for finishing pigs. Each pen was equipped with a 1-sided self-feeder and a nipple drinker, pigs were allowed ad libitum access to feed and water throughout the experimental period. Chromic oxide (0.20%) was added to calculate the ATTD of DM and N. Blood samples were taken by anterior vena cava puncture at wk 0, 5, and 10. The concentrations of RBC, WBC, and lymphocyte counts were evaluated utilizing an automatic blood analyzer. Longissimus muscle sample was obtained at the 10th rib for the determination of L\*, a\*, b\*, WHC, pH, LMA, drip loss, and cooking loss. Fresh feces and urine samples were collected at the end of wk 5 and 10, and stored in 2.6-L plastic boxes to determine the concentration of NH<sub>3</sub> and acetic acid emissions. Growth performance and nutrient digestibility did not differ ( $P > 0.05$ ) among dietary treatments. The lymphocyte percentage in T1 was 10.50% higher ( $P < 0.05$ ) than that in CON (69.78% vs 63.15%) at wk 10, but the concentrations of RBC and WBC did not differ ( $P > 0.05$ ). Application of molasses did not change ( $P > 0.05$ ) meat quality, fecal noxious gas emission, and fecal moisture. In conclusion, supplementation of 2.5% molasses increased blood lymphocyte percentage, but did not affect growth performance, fecal gas emissions, and meat quality in finishing pigs.

**Key Words:** growth performance, molasses, finishing pigs

**1076 Effects of phytase with different calcium and phosphorous density diet on growth performance, nutrient digestibility, blood profiles, fecal noxious gas emission, and meat quality in finishing pigs.** L. Yan,\* Z. F. Zhang, J. P. Wang, J. H. Cho, and I. H. Kim, *Department of Animal Resource & Science, Dankook University, Cheonan, Choongnam, South Korea.*

A total of 112 finishing pigs [(Landrace × Yorkshire) × Duroc, BW = 57.1 ± 2.34 kg] were used in a 10-week growth trial to evaluate the effects of phytase in diets with different Ca and P density. Dietary treatments were: 1) T1, CON (0.65% Ca, 0.60% P); 2) T2, CON + 0.01% phytase (0.60% Ca, 0.55% P); 3) T3, CON + 0.015% phytase (0.55% Ca, 0.50% P), and 4) T4, CON + 0.02% phytase (0.50% Ca, 0.45% P). The activity of phytase was 5,000 FTU. There

were 7 replicate pens per treatment with 4 pigs per pen. Chromic oxide (0.20%) was added to calculate the ATTD of DM, N, energy, Ca, and P. Blood samples were taken at wk 5 and 10 to evaluate the concentrations of RBC, WBC, lymphocyte counts, Ca, and P. Longissimus muscle sample was obtained for the determination of L\*, a\*, b\*, color, marbling, firmness, WHC, pH, LMA, drip loss, and cooking loss. Fresh feces and urine were collected at the end of wk 5 and 10 to determine the concentration of NH<sub>3</sub>, H<sub>2</sub>S, total mercaptans, and acetic acid emissions. Final BW was 2.7% and 2.3% increased ( $P < 0.05$ ) in T2 and T3 compared with T1. During 0–5 wk and the overall period, pigs fed the T2 and T3 diets had a 7.7% (T2, 0–5 wk), 7.0% (T3, 0–5 wk), 5.6% (T2, 0–10 wk), and 4.9% (T3, 0–10 wk) higher ( $P < 0.05$ ) ADG than those fed T1 diet. The concentrations of serum inorganic phosphorus in T2 and T3 were 21% and 18% higher ( $P < 0.05$ ) than that in T1 at 5 week. At the end of 10 week, the NH<sub>3</sub> emission was 15% (T3, d 3), 18% (T4, d 3), 11% (T3, d 5), and 14% (T4, d 5) higher ( $P < 0.05$ ) in T1 than that in T3 and T4 on d 3 and d 5. Total mercaptans emission was 9.0% higher ( $P < 0.05$ ) in T4 than T1 on d 5, and the H<sub>2</sub>S emission in T4 was 18% and 17% lower ( $P < 0.05$ ) than those in T1 and T2. The H<sub>2</sub>S emission was 7.8% and 9.9% decreased ( $P < 0.05$ ) in T3 and T4 compared with T1 on d 7. In conclusion, dietary supplementation with phytase improved growth performance and decreased fecal noxious gas emission in finishing pigs.

**Key Words:** phytase, growth performance, finishing pigs

**1077 Effects of sericite supplementation on apparent total tract digestibility, blood profiles, and odor gas emission from manure in growing pigs.** P. Y. Zhao,\* J. H. Jung, J. H. Cho, and I. H. Kim, *Department of Animal Resource & Science, Dankook University, Cheonan, Choongnam, South Korea.*

Sericite is typically defined as a fine-grained type of either of the minerals muscovite or paragonite. It has a very wide range of uses for rubber, plastics, coatings, paints, ceramics, insulation, cosmetics, paint, paper making, metallurgy and other industries. A total of 3 barrows [(Landrace × Yorkshire) × Duroc, BW = 25.48 ± 0.57 kg] were used in this trial to determine the effects of sericite supplementation on apparent total tract digestibility (ATTD), blood profiles, and odor gas emission from manure. Pigs were fed 3 diets (0, 0.5, and 1.0% sericite) for 3 periods in a 3 × 3 Latin square design. The barrows were housed individually in stainless steel metabolic cage (1.2 × 0.6 m) in a temperature controlled room (28°C). Pigs were fed twice daily (08:00 and 20:00, equal portion at each meal). The daily feed allowance was 0.05 × BW<sup>0.9</sup>, and BW was checked before each period started. Water was provided for ad libitum. Each period lasted 7 d, and the initial 5 d was an adaptation period to the diet. Chromic oxide was added (0.20%) in the diets as an indigestible marker to apparent digestibility determinations throughout the experiment. Blood samples were collected at the beginning and end of each period 24 h after a meal for the determination of serum Fe and total iron-binding capacity. The inclusion of sericite increased ( $P < 0.05$ ) the ATTD of DM and N compared with CON group. No difference was observed ( $P$

> 0.05) on the ATTD of energy among treatments. Pigs fed the S1.0 diet had higher ( $P < 0.05$ ) serum Fe concentration compared with those fed the CON and S0.5 diets at the end of the experiment. There was no difference in total iron-binding capacity among dietary treatments. Dietary application of sericite didn't affect the ammonia, hydrogen sulfide, and total mercaptans emission on d 1, 3, 5, and 7. In conclusion, dietary supplementation with 0.5 and 1.0% sericite increased the ATTD of DM and N, whereas the inclusion of 1.0% sericite reduced serum Fe concentration in growing pigs.

**Key Words:** apparent total tract digestibility, sericite, growing pigs

**1078 Effects of faba beans and faba bean hulls on the expression of selected genes in the small intestine of piglets.** A. J. M. Jansman,\* J. van Baal, H. C. A. Widjaja, J. van der Meulen, and M. A. Smits, *Wageningen UR Livestock Research, Lelystad, The Netherlands.*

In a study using the small intestinal perfusion technique in pigs, the effects were studied of intestinal perfusion of ground fava beans, fava bean hulls or saline on the intestinal net fluid absorption in intestinal segments either or not challenged with an enterotoxigenic *E. coli* (ETEC). After an 8 h perfusion test, the piglets were euthanized and small intestinal mucosa samples were taken for analyzing the expression of several selected genes, which were previously shown to be responsive toward an ETEC challenge. Samples of frozen of the jejunal mucosa were ground in liquid nitrogen and total RNA was extracted and purified. Real-time quantitative PCR (qPCR) was performed. Each sample was run in duplicate. The expression of the following genes coding for the following proteins was quantified relative to the quantity of 18S RNA: 1) apolipoprotein C3 (ApoC3), 2) metalloproteinase 1 inhibitor (TIMP1), 3) aquaporin 8 (AQP8), 4) matrix metalloproteinase 1 (MMP1), 5) mucin 13 (MUC13) and 6) pancreatitis-associated protein (PAP). There was a significant interaction between the effects of perfusion treatment (saline, fava beans or fava bean hulls) and ETEC challenge on the expression of the genes in mucosal tissue, except for MUC13. Nature of the perfusion treatment had a significant effect on the expression of AQP8 and MUC13, while the ETEC challenge had a significant effect on the expression of all selected genes, except for MUC13. The expression of APOC3 and AQP8 was increased by the ETEC challenge, while the expression of TIMP1, MMP and PAP was decreased as a result of the ETEC challenge. Overall, the expression of APOC3 and AQP8 was negatively correlated with net fluid absorption, while the expression of TIMP1, MMP1 and PAP was positively correlated with net fluid absorption. It was concluded that the expression of ETEC responsive genes in the small intestinal mucosa is affected by perfusion with fava beans and fava bean hulls and challenge with ETEC. The expression of several genes (APOC3, AQP8, TIMP1, MMP and PAP) was correlated with the net fluid absorption in the small intestine of pigs.

**Key Words:** intestinal gene expression, faba beans

**1079 Improved nutrient digestibility and retention partially explains feed efficiency gains in pigs selected for low residual feed intake.** A. J. Harris,\* J. F. Patience, S. M. Lonergan, J. C. M. Dekkers, and N. K. Gabler, *Iowa State University, Ames, IA 50011, USA.*

Residual feed intake (RFI) is a unique measure of feed efficiency (FE) and an alternative to traditional measures of gain:feed or feed:gain. It is defined as the difference between the actual feed intake of a pig and its expected feed intake based on its level of growth and backfat. Therefore, selecting for a pig with low RFI results in a more feed efficient animal for a given rate of growth. Our objective was to determine the extent to which apparent total tract nutrient digestibility (ATTD), energy utilization and retention explain FE differences between pigs divergently selected for low or high RFI. After 7 generations of selection, 12 high (HRFI) and 12 low RFI (LRFI) pigs ( $62 \pm 3$  kg BW), were randomly assigned to metabolism crates. Pigs were fed ad libitum a standard corn-soy diet containing 0.4% titanium oxide, an exogenous digestibility marker. After a 7 d acclimation period, total urine and feces collection was undertaken for 72 h. Nutrient and energy digestibility, P digestibility and N balance were then measured and calculated to determine differences between the RFI lines. As expected, ADFI was significantly lower in the LRFI pigs (2.0 vs 2.6 kg/d,  $P < 0.01$ ), ADG did not differ, and FE was significantly higher in the LRFI ( $P = 0.0003$ ) compared with the HRFI pigs. The digestibility coefficients for DM (87.3 vs 85.9%), N (88.3 vs 86.1%), and GE (86.9 vs 85.4%) were higher ( $P \leq 0.003$ ) in the LRFI versus HRFI pigs, respectively. DE (16.59 vs 16.32 MJ/kg DM) and ME (15.98 vs 15.72 MJ/kg DM) values were also significantly greater ( $P = 0.0006$ ) in the LRFI pigs. When correcting for ADFI, P digestibility did not differ between the lines. However, the LRFI pigs tended to have improved N retention compared with HRFI pigs (36.91 vs 32.12 g/d,  $P = 0.08$ ). These data suggest that differences in energy and nutrient digestibility, utilization, and retention may partially explain the superior FE seen in pigs selected for LRFI.

**Key Words:** residual feed intake, feed efficiency, nutrient digestibility

**1080 Dietary protein content does not influence calcium and phosphorus absorption and retention in the Iberian pig growing from 50 to 100 kg body-weight.** R. Nieto,\* A. Haro, C. Delgado-Andrade, I. Seiquer, and J. F. Aguilera, *Institute of Animal Nutrition, Estación Experimental del Zaidín, CSIC, Granada, Spain.*

The comparatively slower growth rate of the Iberian pig suggests lower Ca and P requirements than those reported for conventional or high-performing porcine breeds. The effects of dietary apparent-digestible protein content (ApDP) from excessive to marginally deficient (113, 93, 74 and 53 g/kg DM) and level of feeding (FL; 0.80 and 0.95 x ad libitum) upon whole-body retention of Ca and P was studied in 48 purebred Iberian barrows in the finishing stage from 50 to 100 kg BW. The diets were prepared by diluting a high-protein diet (HPC), formulated according to the ideal protein concept, with a protein-free



mixture made to match the macronutrient content of the HPC diet. The diets provided (kg<sup>-1</sup> DM) 11.6–10.7 g Ca, 6.67–6.25 g total P and 13.9–14.8 MJ ME. The ad libitum intake was calculated according to each pig's body weight, and adjusted weekly. A digestibility and balance trial was performed at approximately 75 kg BW. Average feed intake was 3104 and 2643 g/d for the 0.95 and 0.80 x ad lib. FL. Average daily gain attained a maximum value at 854 g (18.87 g/MJ ME intake) with the diet containing 74 g ApDP (5.32 g ApDLys)/kg DM. The ApDP content in the diet did not alter Ca and P fractional apparent absorption, which attained average values of 0.416 ± 0.0097 and 0.545 ± 0.0105. Correspondingly, Ca and P retention as a fraction of intake remained unaffected at 0.402 ± 0.0103 and 0.401 ± 0.0120, leading to 12.3 ± 0.34 and 7.24 ± 0.201 g Ca and P retained per day, respectively. Ca urinary losses were not enhanced by dietary protein supply in excess to requirements, remaining at 0.251 ± 0.0211 g/day. Our results fail to demonstrate in the pig a likely impact of protein intake well above requirements on Ca absorption and renal excretion, a matter of dispute in the literature (Conigrave et al., 2008). The level of feeding had a significant positive effect on the flow (g/day) of Ca and P absorbed ( $P < 0.05$ ) and on Ca and P daily retained ( $P < 0.05$ ).

**Key Words:** calcium absorption, phosphorous, protein intake

**1081 Nutrient digestibilities of degermed dehulled corn, citrus pulp and soy protein concentrate by barrows.** U. S. Ruiz<sup>\*2,1</sup>, M. C. Tomaz<sup>1</sup>, L. A. F. Pascoal<sup>3,1</sup>, P. H. Watanabe<sup>4,1</sup>, A. B. Amorim<sup>5,1</sup>, G. M. P. Melo<sup>1</sup>, and E. Daniel<sup>1</sup>, <sup>1</sup>São Paulo State University, Jaboticabal, SP, Brasil, <sup>2</sup>São Paulo State University, Dracena, SP, Brasil, <sup>3</sup>Paraíba Federal University, Bananeiras, PB, Brasil, <sup>4</sup>Ceará Federal University, Fortaleza, CE, Brasil, <sup>5</sup>São Paulo State University, Botucatu, SP, Brasil.

This study was carried out to determine ileal and total tract apparent digestibilities (AD) of dry matter (DM), crude protein (CP), gross energy (GE) and the respective digestible components (digestible DM – DDM, digestible protein – DP and digestible energy – DE) of degermed dehulled corn, citrus pulp and soy protein concentrate by pigs, by the difference approach. Thirty 2 barrows (28.1 ± 1.6 kg of BW) were fed a corn soybean meal basal diet or one of 3 diets, formulated by replacing 30% of the basal diet with 30% of one of the test feedstuffs, for 11 d. Chromic oxide (0.3%) was included in the diets for calculating nutrient digestibilities. Fecal material was collected from d 7 through d 11 by grab sampling and ileal digesta samples were collected from the ileum after the animals were slaughtered in d 12. Ileal AD of DM and total and ileal AD of GE of degermed corn (77.4%, 88.7% and 77.7%) were greater ( $P < 0.05$ ) than that observed in citrus pulp (50.3%, 86.5% and 55.8%) and in soy protein concentrate (63.5%, 85.1% and 59.4%), which did not differ ( $P > 0.05$ ). Total AD of CP, total DP and total DE of soy protein concentrate (87.5%, 500 g/kg and 3739 kcal/kg) were higher ( $P < 0.05$ ) than the values found in degermed corn (81.7%, 57.5 g/kg and 3330 kcal/kg), which were greater ( $P < 0.05$ ) than that verified in citrus pulp (60.5%, 39.5 g/kg and 3223 kcal/

kg). Total and ileal DDM, ileal AD of CP and ileal DE of degermed corn (782.1 g/kg, 673.3 g/kg, 70.7% and 2918 kcal/kg) and soy protein concentrate (778.0 g/kg, 570.1 g/kg, 78.7% and 2877 kcal/kg) were similar ( $P > 0.05$ ) and greater ( $P < 0.05$ ) than the ones observed in citrus pulp (737.0 g/kg, 436.1 g/kg, 50.6% and 2081 kcal/kg). There was no difference ( $P > 0.05$ ) between ileal DP of degermed corn (49.8 g/kg) and citrus pulp (33.0 g/kg), which were smaller ( $P < 0.05$ ) than the value found in soy protein concentrate (434 g/kg). Degermed corn presented the smallest differences between total tract and ileal digestibilities of DM and GE, and soy protein concentrate showed the smallest difference for total tract and ileal digestibilities of CP.

**Key Words:** feedstuffs, digestion, pigs

**1082 Microscopic matrix and in vitro degradation and fermentation characteristics of wheat co-products from flour milling in the pig intestine.** R. Jha<sup>\*1</sup>, A. Owusu-Asiedu<sup>2</sup>, P. H. Simmins<sup>2</sup>, A. Pharazyn<sup>3</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>Danisco Animal Nutrition, Marlborough, UK, <sup>3</sup>Nutreco Canada, Guelph, ON, Canada.

Use of co-products from wheat flour milling (WFM) in pig diets may ameliorate high feed cost. However, digestibility of WFM is lower than feed grains, with limited information about its fermentation characteristics and matrix structure. In vitro degradation and fermentation characteristics of 6 WFM samples were studied: 2 shorts, 2 millrun, 1 middlings and 1 bran; ADF, 12, 8, 13, 15, 11 and 16%; NDF, 32, 23, 34, 36, 27 and 49%, respectively. After a pepsin-pancreatin hydrolysis, WFM were incubated in a buffer solution with minerals and fresh pig feces as inoculum. Accumulated gas production, proportional to amount of fiber fermented, was measured for 72 h and modeled. Volatile fatty acid (VFA) concentration was measured in the fermented solutions. Principle component analysis indicated relations between nutrient content and fermentation characteristics of WFM. The matrix of WFM was analyzed using scanning electron microscopy. The DM degradability during fermentation ranged from 31% to 52% and correlated negatively with ADF ( $r = -0.65$ ,  $P < 0.01$ ) and positively with CP ( $r = 0.50$ ,  $P < 0.01$ ) content of WFM. Total gas production ranged from 101 to 148 mL/g DM incubated and were negatively correlated with ADF and CF ( $r = -0.70$  and  $-0.59$ , respectively;  $P < 0.01$ ). The VFA production ranged from 2.0 to 3.0 mMol/g and the fractional rate of degradation from 0.08 to 0.11/h. Microscopy indicated that nutrient content and not type of WFM influenced the fiber-starch-protein matrix: matrix of 1 millrun and 1 shorts were highly interspersed, while the matrix of the other millrun and shorts and middlings was loosely imbedded. In conclusion, the matrix structure, fiber components and CP were associated with degradability and fermentability of WFM. Thus, treatments targeted to reduce the impact of fiber and protein may increase the digestibility and fermentability of wheat co-product from flour milling.

**Key Words:** fermentation, VFA, wheat co-products



**1083 Net energy of Canadian feedstuffs in growing finishing pigs.** S. Moehn,\* R. T. Zijlstra, and R. O. Ball, *University of Alberta, Edmonton, AB, Canada.*

The objective was to determine the energy content of diets based on Canadian feedstuffs of major importance for pig production. Two sets of 8 castrated male pigs were surgically fitted with T-cannulas at the terminal ileum. Diets containing barley, wheat, corn, field pea, soybean meal, zero-tannin fava bean, canola meal or corn DDGS were formulated so that dietary methionine (pea, bean) or lysine (other feedstuffs) content limited protein deposition to similar rates to minimize its impact on dietary net energy (NE) determination. Diets contained 0.5% of Cr<sub>2</sub>O<sub>3</sub> as an indigestible marker and between 5 and 64% of a constant-ratio mix of cornstarch, sugar, canola oil and cellulose. Diets were offered twice daily at 2.5 × energetic maintenance requirement (458 kJ/kg<sup>0.75</sup> BW). Experimental periods consisted sequentially of a 7-d adaptation, 4-d N-balance and apparent total tract digestibility (ATTD) determination, 2 12 h ileal digesta collections, and 24 h of indirect calorimetry. Data were analyzed in SAS with diet and BW as main effects. Mean BW (61.2 kg SE 1.7) and feed intake (1,798 g/d SE 40.6), daily gain (631 g/d SE 23.9) and gain: feed (0.36 SE 0.013) did not differ ( $P > 0.1$ ) among diets. The ATTD of energy was lowest ( $P < 0.05$ ) for the DDGS diet (65.9% SE 2.90) and highest for the control diet (i.e., soybean meal diet without added AA, 86.7% SE 0.44). The ranking of energy content was similar for feedstuffs within the 3 energy systems. The digestible, metabolizable and net energy content was greatest ( $P < 0.05$ ) for the control diet at 14.3 (SE 0.08), 13.5 (SE 0.08) and 12.4 (SE 0.38) MJ/kg, respectively, and was lowest ( $P < 0.05$ ) for the canola meal diet at 11.3 (SE 0.50), 9.3 (SE 0.81) and 8.9 (SE 0.35) MJ/kg, respectively. Subtracting the N-free mix in the diets, the estimated NE contents were 12.4 MJ/kg (wheat), 11.7 MJ/kg (corn), 11.6 MJ/kg (barley), 11.5 MJ/kg (field pea), 10.3 MJ/kg (soybean meal), 10.1 MJ/kg (fava bean), 8.5 MJ/kg (DDGS) and 6.5 MJ/kg (canola meal). These measured NE contents ranked feedstuffs similar to NRC (1998).

**Key Words:** growing pig, feedstuff, net energy

**1084 Slowly-digestible starch influences mRNA abundance of glucose and short chain fatty acid (SCFA) transporters in the porcine distal intestinal tract.** A. D. Woodward\*<sup>1</sup>, P. R. Regmi<sup>1</sup>, M. G. Gänzle<sup>1</sup>, T. A. T. G. van Kempen<sup>2</sup>, and R. T. Zijlstra<sup>1</sup>, *<sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>North Carolina State Univ., Raleigh, NC, USA.*

The relationship between starch chemistry and nutrient transporters in the intestinal epithelium is not well known. We hypothesized that inclusion of slowly-digestible instead of rapidly-digestible starch in pig diets will decrease glucose and increase SCFA transporter expression in the distal gut. Thus, weaned barrows ( $n = 32$ ) were fed 4 diets containing 70% rapidly- to slowly-digestible starch [ranging from 0 to 63% amylose and 1.06 (rapidly) to 0.22%/min (slowly) rate of in vitro digestion] at 3 × maintenance energy requirement in a complete randomized design. Ileal and colon mucosa was collected on d 21 to quantify

mRNA abundance of Na<sup>+</sup>-dependent glucose transporter-1 (SGLT1), monocarboxylic acid transporter-1 (MCT1), and Na<sup>+</sup>-coupled monocarboxylate transporter (SMCT). Messenger RNA was extracted and cDNA manufactured before relative quantitative reverse transcription-PCR. Data were analyzed using the 2<sup>- $\Delta\Delta C_T$</sup>  method, with  $\beta$ -actin and GAPDH as reference genes, and regression analysis was performed. As in vitro rate of digestion decreased, SGLT1 increased linearly ( $P < 0.05$ ) in the ileum and quadratically ( $P = 0.08$ ) in the colon. Contrary to SGLT1, MCT1 tended to decrease linearly ( $P = 0.08$ ) in the ileum and increased quadratically ( $P < 0.001$ ) in the colon with decreasing rate of digestion. Starch digestion rate did not affect SMCT in the ileum; however, SMCT decreased quadratically ( $P < 0.01$ ) with decreasing rate of digestion. In conclusion, in contrast to our hypothesis, slowly-digestible starch increased ileal glucose and decreased ileal SCFA transporter mRNA abundance, possibly due to an increased presence of glucose in the lumen of the ileum. Effects of starch on colonic SCFA transporter mRNA abundance were inconsistent, with slowly-digestible starch increasing MCT1 but decreasing SMCT.

**Key Words:** glucose, short-chain fatty acid, transporter

**1085 Net energy of Canadian feedstuffs in pregnant sows.** S. Moehn,\* R. T. Zijlstra, and R. O. Ball, *University of Alberta, Edmonton, AB, Canada.*

The objective of this experiment was to determine dietary energy contents in diets based on Canadian-grown feedstuffs for sows, in comparison to growing pigs. Ten pregnant parity 2 or 3 sows were used to test the same feedstuffs as used in the growing-finishing pig experiment. Diets were formulated in the same manner as for growing pigs, and offered to the sows randomly to obtain 6 observations per diet. Diets contained 0.5% of Cr<sub>2</sub>O<sub>3</sub> as an indigestible marker and between 3 and 67% of a constant-ratio mix of cornstarch, sugar, canola oil and cellulose. Diets were offered twice daily according to the sow's BW and back fat at breeding. Experimental periods consisted of 7 d adaptation, 4 d apparent total tract digestibility (ATTD) determination and 24 h of indirect calorimetry. Data were analyzed in SAS with diet and BW as main effects. Mean BW (214 kg, range 172 - 277 kg), feed intake (2.62 kg/d SE 15.1), heat production (31.7 MJ/d SE 0.35) and respiratory quotient (1.07 SE 0.011) did not differ ( $P > 0.4$ ) among diets. Regressing heat production on metabolizable energy (ME) intake estimated fasting heat production as 22.5 MJ/d (402 kJ/kg<sup>0.75</sup> BW) and marginal efficiency of energy utilization for energy retention as 0.74. The ATTD of energy was lowest for the DDGS diet at 84.6% (SE 0.71) and greatest for the soybean meal diet at 95.6% (SE 0.97). The ranking of dietary energy content was similar for the digestible energy and ME: highest ( $P < 0.05$ ) found for soybean meal, field pea and fava bean diets, and lowest for the DDGS diet. Diet NE increased from 2nd to 3rd parity ( $P = 0.048$ ) and with increasing BW ( $P = 0.021$ ). Subtracting the N-free mix in the diets, the estimated NE contents were 11.9 MJ/kg (wheat), 11.6 MJ/kg (corn), 11.1 MJ/kg (corn DDGS, barley), 10.6 MJ/kg (field pea), 9.4 MJ/kg (soybean meal), 8.3 MJ/kg (fava bean) and 7.7 MJ/kg (canola meal).

These NE values were on average 3% greater than found for growing pigs. The ranking of feedstuffs in the NE system was as expected except for the comparatively high NE values found for DDGS and soybean meal.

**Key Words:** sow, feedstuffs, net energy

**1086 Effect of a supra-phytase level on post-weaning growth and stool firmness of pigs fed low or high soybean meal diets.** C. E. Zier-Rush<sup>1</sup>, S. Smith<sup>1</sup>, R. Palan<sup>1</sup>, J. Steckel<sup>1</sup>, P. Wilcock<sup>\*2</sup>, and R. D. Boyd<sup>1</sup>, <sup>1</sup>The Hanor Company, Franklin, KY, USA, <sup>2</sup>AB Vista, Marlborough, UK.

It is hypothesized that even a low level of dietary phytase is detrimental to piglet performance. This study was designed to determine if high levels of a modified *E. coli* phytase (Quantum™), when added to either a low (LSB) or high (HSB) soybean meal (SBM) feeding program, would improve post-weaning pig performance. Weaned pigs ( $n = 2550$  at  $5.53 \pm 0.23$  kg) were allotted to one of 8 dietary treatments (13 replicates/treatment) by weight in a randomized block design and fed a common diet for 1 d post-weaning. Test diets were arranged as  $2 \times 4$  factorial with either LSB or HSB and 4 levels of phytase (0, 1250, 2500 or 3750 FTU/kg). All pigs were fed a 2 phase feed program for 20 d using a feed budget allocation of 1.8 kg for phase 1 (P1) and 6.4 kg for phase 2 (P2). Diets were formulated to exceed NRC (1998) requirements including available P (P1 = 0.45%, P2 = 0.38%). The LSB treatments had SBM levels of 15% in P1 and 19% in P2 with phytate-P (PP) measured at 0.15% and 0.20% respectively. The HSB treatments had SBM levels of 25% in P1 and 29% in P2 with PP measured at 0.18% and 0.23% respectively. There was no interaction ( $P > 0.05$ ) between SBM level and phytase. There was a positive linear trend for ADG (279, 292, 295, and 292 g/d, P Linear  $< 0.07$ ) and ADFI (318, 329, 330, and 335 g/d, P Linear  $< 0.08$ ) with increasing phytase dose while G:F tended to show a quadratic response (0.88, 0.89, 0.90 and 0.87  $P < 0.09$ ) with the optimal phytase dose being at 2500 FTU/kg. Pigs fed HSB tended to have looser stools (d 1–6) than pigs fed LSB diets (1.16 vs 1.07,  $P < 0.125$ ), however, phytase numerically improved stool firmness in a dose related manner to 1.05 for the 2500 FTU/kg dose (P Linear = 0.28). The use of higher levels of a modified *E. coli* phytase tended to improve ADG, and G:F in early post-weaning pigs irrespective of SBM level resulting in a lower cost/kg. This performance benefit may be due to the phytase reducing the negative impact of dietary phytate regardless of feed phytate levels.

**Key Words:** phytase, pigs, phytate

**1087 Effect of palm kernel meal with  $\beta$ -mannanase supplementation in gestating sows' diet on nutrient digestibility.** D. H. Kim<sup>\*1</sup>, Y. D. Jang<sup>1</sup>, P. S. Heo<sup>1</sup>, Y. H. Kim<sup>2</sup>, I. C. Kim<sup>2</sup>, and Y. Y. Kim<sup>1</sup>, <sup>1</sup>School of Agricultural Biotechnology, Seoul National University, Seoul, Korea, <sup>2</sup>National Institute of Animal Science, Suwon, Korea.

The experiment was conducted to investigate the effect of palm kernel meal (PKM) and  $\beta$ -mannanase

supplementation on nutrient digestibility in gestating sows. Four multiparous sows (Yorkshire  $\times$  Landrace, F1) were arranged in a repeated  $4 \times 4$  Latin-square design. Four treatments were allotted with 2 main factors of ingredients (corn-soybean meal (SBM) basal diet or diet containing 15% PKM) and dietary enzyme (supplementation with or without 0.1%  $\beta$ -mannanase; 800,000 IU/kg, CTCbio LTD., Seoul, Korea). The diet containing 15% PKM had approximately 130 kcal of ME/kg lower energy content than that of corn-SBM diet but the other nutrients were similar. After 5 d of adaptation, feces were collected for 4 d and chromic oxide was supplemented as an indicator of initial and final sampling. Body weight and backfat thickness of gestating sows did not differ during the study. However, the average body weight gain during experimental period tended to decrease when diet containing 15% PKM was provided to gestating sows ( $P = 0.07$ ). The 2 main factors and their interaction did not affect plasma urea nitrogen and glucose level at start and end of the trial ( $P > 0.12$ ). Compared with corn-SBM treatment, there were tendencies of lower digestibilities of protein ( $P = 0.08$ ) and fiber ( $P = 0.06$ ) when sows were fed diet containing 15% PKM. Acid detergent fiber digestibility tended to increase when gestating sows were fed  $\beta$ -mannanase supplemented diet ( $P = 0.09$ ). The fat and fiber digestibility of sows tended to interact between the 2 main factors ( $P = 0.10$  and  $P = 0.10$ , respectively). Consequently, these results suggested that the nutrient digestibility of gestating sows was not changed by the high fiber and fiber fractions in diet containing 15% PKM and clear effects of  $\beta$ -mannanase supplementation were not detected.

**Key Words:** sow, palm kernel meal,  $\beta$ -mannanase

**1088 Determination of metabolizable energy contents in copra and palm kernel meal for growing pigs.** P. S. Heo<sup>\*1</sup>, Y. D. Jang<sup>1</sup>, D. H. Kim<sup>1</sup>, S. D. Lee<sup>2</sup>, J. C. Park<sup>2</sup>, and Y. Y. Kim<sup>1</sup>, <sup>1</sup>School of Agricultural Biotechnology, Seoul National University, Seoul, Korea, <sup>2</sup>National Institute of Animal Science, Suwon, Korea.

The experiment was conducted to determine the metabolizable energy (ME) and nutrient digestibility in copra meal (CM) and palm kernel meal (PKM) for growing pigs. A total of 24 growing pigs ([Yorkshire  $\times$  Landrace]  $\times$  Duroc;  $52.26 \pm 0.72$ kg of average body weight) were used to measure ME and nutrient digestibility of CM (Indonesia, solvent extracts) and PKM (Malaysia, solvent extracts). Corn-soybean meal diet was used as a basal diet and the other 2 test diets were mixed 70% of basal diet with 30% of CM or PKM. The digestibilities of dry matter (DM) and protein were higher in basal diet than the other treatment diets ( $P < 0.01$ ). Except for protein digestibility, all other nutrient digestibilities ( $P < 0.01$ ) in CM diet were higher than those of PKM diet but crude fat digestibility ( $P = 0.06$ ) tended to be lowered in CM diet. When pigs were fed CM diet, N intake was increased ( $P < 0.01$ ) but N retention was similar with those fed PKM diet. Digestible energy (DE), ME and N-corrected ME (MEn) of CM were 2,985, 2,825 and 2,741 kcal/kg as-fed basis and those values of PKM were 2,847, 2,811 and 2,768 kcal/kg, respectively. The values on a DM basis of DE, ME and MEn in CM were 3,300, 3,122,

and 3,029 kcal/kg and those in PKM were 3,043, 3,005 and 2,959 kcal/kg, respectively. As-fed basis and/or DM basis of DE, ME and MEN in CM was slightly higher than PKM when 2 ingredients were supplemented in growing pigs' diet. The ME to DE ratios of CM and PKM were calculated at 94.7 and 98.5%, respectively. Consequently, CM and PKM have similar metabolizable energy values in growing pigs; however, nutrient digestibility varied among ingredients.

**Key Words:** metabolizable energy, copra meal, palm kernel meal

**1089 High vs. low amylose starch increases methane and volatile fatty acid production and reduces energy retention in pigs.** J. L. Yanez<sup>\*1,2</sup>, S. Moehn<sup>1</sup>, R. O. Ball<sup>1</sup>, T. A. T.G. van Kempen<sup>3</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, Alberta, Canada, <sup>2</sup>Universidad Autónoma de Tlaxcala, Tlaxcala, México, <sup>3</sup>North Carolina State University, Raleigh, North Carolina, United States.

The energy contribution of starch is usually considered constant among starch types. However, starch chemistry can impact its kinetics of digestion and fermentation and thus net energy content. In a double 4 × 4 Latin square, pigs were fed 4 diets containing 70% purified starch (S1, S2, S3 and S4 with 0, 20, 28 and 63% amylose; reflected by in vitro maximal digestion rate; 1.06, 0.73, 0.38, and 0.22%/min, respectively), casein and fishmeal; TiO<sub>2</sub> was added as indigestible marker. Eight barrows (40.7 ± 2.08 kg BW) were fed 4 diets at 2.8 × maintenance of DE in 4 7-d periods. Feces were collected on d 6 and immediately stored at -20°C for digestibility or at -80°C for VFA analyses. Pigs were transferred into indirect calorimetry chambers (184 × 78 × 102 cm) configured with stabilized gas analyzers. Then, readings were obtained for 24 h on d 7 to measure O<sub>2</sub> consumption, and CO<sub>2</sub> and CH<sub>4</sub> production. Diet and achieved feed intake were included in the statistical model. The O<sub>2</sub> consumption was higher ( $P < 0.05$ ) for S3, intermediate for S4 and lowest for S1 and S2. The CO<sub>2</sub> production was higher ( $P < 0.05$ ) for S3 than S1, S2 and S4. The CH<sub>4</sub> was similar ( $P < 0.01$ ) at 0.012 L/min for S1 to S3, then higher ( $P < 0.01$ ) to 0.34 L/min for S4. Heat production was higher ( $P < 0.05$ ) 16.7 MJ/d for S3, intermediate 15.7 MJ/d for S4 and lower for S1 and S2 14.9 and 15.1 MJ/d, respectively. The ATTD of energy and DE content was similar for rapidly to moderate slowly digestible starch but was reduced ( $P < 0.05$ ) by 8% for slowly digestible starch. Reducing rate of starch digestion increased ( $P < 0.05$ ) concentration in fecal (wet) matter butyrate, valerate and caproate indicating increased starch fermentation. Increasing amylose or reducing rate of starch in vitro digestion gradually reduced ( $P < 0.05$ ) diet NE content from 12.6 MJ/kg for S1 and S2, via 11.3 for S3 to 10.8 MJ/kg for S4. In conclusion, high amylose starch increased CH<sub>4</sub> production and reduced NE content due to increased fermentation instead of digestion.

**Key Words:** energy, pig, starch

**1090 Influence on the ileal and fecal digestibility of forage inclusion in the diet.** H. Jørgensen,\* D. Carlson,

and H. N. Lærke, Aarhus University, Department of animal Science, Foulum, Denmark.

Forage, which is mainly characterized by a high content of dietary fiber, is a potential feedstuff or additive for monogastric animals to improve health and sustainability. The present study aimed to study the ileal and fecal digestibility of 3 forages (Clover grass, Clover grass silage and Pea-Barley silage) supplemented to a basal diet. A total of 24 pigs, adapted to eating forages by supplemented with clover grass silage from weaning, were fitted with a T-cannulas at the terminal ileum at approximate 30 kg LW. For each of the 3 types of forage, 2 balance trials with 4 weeks interval were carried out. Two pigs in each test were fed the basal diet while 6 others were fed the basal diet plus forage throughout the whole experiment. The forages were offered the pigs the first 40 min at each feeding thereafter removed and the basal diet supplied. After the last collection, the pigs were sacrificed and digesta collected from the digestive tract 3 h after the morning meal. The intake of forages was relative low and quite variable and accounted on average for only 10–12% of the daily dry matter intake. Ileal digestibility estimated by collection from the T-cannulas was higher than the digestibility estimated by the slaughter technique indicating some separation of the digesta collected from the T-cannulas. The forages had, as expected, a lower DM and energy digestibility than the basal diet ( $P < 0.05$ ). The fresh clover grass had a higher energy digestibility than the 2 silages (60 vs 48%,  $P < 0.05$ ). Inclusion of 10% of gross energy in the diet from clover grass reduced the rations energy digestibility relatively by 2.2%, while clover grass silage and the pea-barley silage lead to reductions of 3.4 and 5.0% ( $P < 0.05$ ), respectively. In organic pig production forages like the ones used in the present study can play an important role in satiety and rooting behavior. However, the contribution to the overall energy supply is limited.

**Key Words:** roughage, energy value, fibrous feedstuff

**1091 Digestive utilization of diets with low or high level of fibers in pigs divergently selected for residual feed intake.** L. Montagne<sup>1,2</sup>, M. Le Gall<sup>\*1,2</sup>, and H. Gilbert<sup>3,4</sup>, <sup>1</sup>Agrocampus Ouest, UMR1348 PEGASE, 35000 Rennes, France, <sup>2</sup>INRA, UMR1348 PEGASE, 35590 St-Gilles, France, <sup>3</sup>INRA, UMR1313 GABI, 78352 Jouy-en-Josas, France, <sup>4</sup>INRA, UMR444 LGC, 31326 Castanet-Tolosan, France.

Residual feed intake (RFI) is the difference between observed and theoretical daily feed intake (DFI) estimated from maintenance and production requirements. Genetic selection to lower RFI is considered to improve feed efficiency. Divergent selection on RFI was conducted for 6 generations in 2 Large White lines: the RFI+ consumed more feed than predicted compared with the RFI-. Metabolism and activity could contribute to RFI differences between the lines. Digestion has been previously reported not to differ between these lines when pigs were fed a regular diet. This study aimed to determine the digestibility coefficients of a high fiber (244



g NDF - 8.36 MJ NE/kg) and a control diets (133 g NDF - 9.69 MJ NE/kg), to evaluate the impact of the selection on the lines' ability to cope with a digestive challenge. Seven pairs of littermates were used in each line. Pigs were individually housed from 10 to 15 wk of age. At 12 wk, one pig from each pair received either the control or the high fiber diet for 3 wk. Titanium dioxide was included in the diet as an indigestible marker to determine the apparent digestibility. With the control diet, ADFI was greater in RFI+ than in RFI- pigs (1654 vs. 1336 g/d,  $P < 0.001$ ) for a similar final BW (44.75 kg for the 2 lines). With the high fiber diet, DFI was 9% lower compared with the control ( $P < 0.01$ ) and growth rate was reduced (728 vs. 866 g/d;  $P < 0.001$ ) for RFI+ pigs. The diet did not significantly affect the performances of RFI- pigs. There was no line effect on digestibility coefficients, irrespective of the digestive site and of the diet. Increasing the dietary fiber level led to decreased digestibility coefficients of nutrients and energy similarly for the 2 lines (58.4 vs. 70.2% for ileal and 70.6 vs. 80.9% for fecal N digestibility for high-fiber vs. control diet;  $P < 0.001$ ). To conclude, apparent digestibility coefficient did not contribute to explain the difference of RFI between the 2 lines, despite different line responses on DFI and growth rate when fed the high fiber diet. RFI- line seems to better valorize high fiber diet than RFI+.

**Key Words:** fiber, digestion, residual feed intake

**1092 Short-term effect of dietary yeast nucleotide supplementation on total and diurnal variation of small intestinal enzyme activities in piglets.** N. Sauer,\* M. Eklund, S. Hoerner, E. Bauer, D. Jezierny, and R. Mosenthin, *Institute of Animal Nutrition, University of Hohenheim, Stuttgart, Germany.*

A study was carried out to investigate, whether short-term supplementation of dietary yeast nucleotides affects total and diurnal variation of enzyme activities in the small intestine of weaned piglets. Twelve barrows, weaned at 18 d of age (5 kg initial BW), were fitted with a simple T-cannula at the distal ileum. Twice daily (0800 h, 2000 h), 6 piglets each received a cereal-soybean meal-based diet with or without supplementation of 1 g/kg of a yeast nucleotide product (Nucleoforce Piglets) in 2 consecutive periods. In each period, digesta samples were collected 6 times at given intervals during 24 h digesta collection. Dietary supplementation with yeast nucleotides did not affect total enzyme activities including  $\alpha$ -amylase, leucine amino peptidase (LAP), maltase and lactase ( $P > 0.05$ ). Therefore, data of both treatments were pooled to determine diurnal variations in enzyme activities. For  $\alpha$ -amylase, a diurnal variation in enzyme activity could be observed ( $P < 0.05$ , Table), in addition to a trend toward diurnal variation in maltase activity at 1330 h vs. 1630 h ( $P < 0.10$ ). There were no variations in diurnal activities of LAP and lactase (Table). It can be concluded that yeast nucleotides do not affect total small intestinal enzyme activities. Independent of diet composition,  $\alpha$ -amylase activities may vary over time, with peak flow of  $\alpha$ -amylase around 6 h postprandially.

**Table 1.** Diurnal variation of enzyme activities in ileal digesta of piglets (LSMeans; U/L)

Time point	$\alpha$ -Amylase	LAP <sup>1</sup>	Maltase	Lactase
1030 h	59713 <sup>bc</sup>	3974	21	39
1330 h	87203 <sup>ab</sup>	6091	22 <sup>A</sup>	40
1630 h	46765 <sup>c</sup>	6047	20 <sup>B</sup>	40
2230 h	44493 <sup>c</sup>	5486	20	43
0130 h	95527 <sup>a</sup>	6513	21	41
0430 h	63164 <sup>bc</sup>	4167	21	40
P-value time	0.002	0.671	0.683	0.860

<sup>a,b,c</sup>LSMeans within a column with different superscripts differ ( $P < 0.05$ ).

<sup>A,B</sup>LSMeans within a column with different superscripts tend to differ ( $P < 0.1$ ).

<sup>1</sup>Leucine aminopeptidase.

**Key Words:** enzyme activity, nucleotide, piglet

**1093 Comparative effects of five phytases on the phosphorus and calcium utilisation in the weaned piglet.** P. Guggenbuhl\*<sup>1</sup>, Y. Wache<sup>1</sup>, C. Simoes-Nunes<sup>1</sup>, and F. Fru<sup>2</sup>, <sup>1</sup>DSM Nutritional Products France, Research Centre of Animal Nutrition and Health, 68305 Saint-Louis, France, <sup>2</sup>DSM Nutritional Products Ltd., Basel, Switzerland.

The addition of phytase to the swine diets has generally increased phosphorus (P) digestibility and consequently reduced fecal excretion of P. The comparative effects on P and calcium (Ca) digestibility of the dietary inclusion of 5 different phytases were evaluated in the weaned piglet. RONOZYME HiPhos (M) a microbial 6 phytase produced by synthetic genes, mimicking a gene from *C. braakii* was compared with the *E. Coli* derived phytases Phyzyme XP10000 TPT, OptiPhos 2000 PF, MicroTech 5000 and Quantum 2500D in 2 separate trials of 112, 28-d old weaned piglets allocated to 8 equal groups of 14 animals each. In the first trial they were fed throughout a 29-d period, a vegetable-based diet without addition of mineral P (Co1(-)) or this diet supplemented with 12 g/kg of DCP (Co1(+)) or with HiPhos 1000 U/kg (R11000) and 1500 U/kg (R11500), Phyzyme 500 U/kg (P500) and 750 U/kg (P750) and OptiPhos 500 U/kg (O500) and 750 U/kg (O750). The same design was used in the second trial with the diet without addition of mineral P (Co2(-)) or this diet supplemented with 12 g/kg of DCP (Co2(+)) or with HiPhos 1000 U/kg (R21000) and 1500 U/kg (R21500), MicroTech 500 U/kg (M500) and 750 U/kg (M750) and Quantum 500 U/kg (Q500) and 750 U/kg (Q750). In comparison ( $P < 0.05$ ) to their respective non-supplemented groups, all phytases reduced the P fecal concentration and P fecal excretion and significantly increased the P digestibility and apparent P absorption. The digestible P equivalences of R11000, R11500, P500, P750, O500, O750, R21000, R21500, M500, M750, Q500 and Q750 were 0.94, 1.50, 0.67, 0.92, 0.58, 1.11, 1.36, 1.55, 0.71, 1.21, 0.95 and 1.04 g of full available P/kg of feed respectively. Ca digestibility was significantly improved and Ca excretion significantly reduced by the phytases. The 5 phytase preparations increased the digestibility and the apparent absorption of the P and Ca in the weaned piglet fed a diet containing P exclusively from vegetable origin.



**Key Words:** phytase, phosphorus digestibility, piglets

**1094 Effects of a new 6-phytase on the apparent ileal digestibility of minerals and amino acids in ileo-rectal anastomosed pigs fed on a corn-soybean meal-barley diet.** P. Guggenbuhl\*<sup>1</sup>, Y. Wache<sup>1</sup>, C. Simoes Nunes<sup>1</sup>, and F. Fru<sup>2</sup>, <sup>1</sup>DSM Nutritional Products France, Research Centre of Animal Nutrition and Health, 68305 Saint-Louis, France, <sup>2</sup>DSM Nutritional Products Ltd., 4202 Basel, Switzerland.

Phosphorus (P) of plant-based feedstuffs for monogastric animals is mainly in the form of phytic-P, which has a very low bioavailability. The non-absorbed phytic-P may contribute to P pollution. Furthermore, phytic-P may reduce the bioavailability of other minerals, inhibit digestive endogenous enzymes activity, or reduce protein digestibility. The study evaluated the effects of the microbial 6-phytase Ronozyme<sup>®</sup> HiPhos (M) on the apparent ileal digestibility of total P, phytates, calcium (Ca), total nitrogen (N), energy, and amino acids (aa) in 6 60-d old ileo-rectal anastomosed pigs. Following a double Latin square design, pigs had free access to alternatively a corn-soybean meal-barley based diet or this diet supplemented either with 500 U/kg (R500) or 1000 U/kg (R1000). All the responses were dose-dependent. Pigs receiving the diet supplemented with R500 and R1000 increased ( $P < 0.05$ ) the digestibility of P by 98 and 120%, of Ca by 19 and 20%, of Asp+Asn by 4.3 and 7.9% and that of Lys by 5.0 and 7.3%, respectively. Pigs receiving diet R1000 presented an improvement ( $P < 0.05$ ) in the digestibility of total N by 5.1%, total AA by 4.1%, essential AA by 4.3%, Glu+Gln by 4.0%, His by 5.6%, Gly by 11.1%, Ala by 8.2%, Tyr by 5.6%, Leu by 4.5%, Phe by 5.6%, Met by 5.2% and also zinc by 63% and magnesium by 64%. Similar to performance trials with increased fecal digestibility of P and Ca, phytase increased apparent ileal digestibility of these essential minerals and phytates. The new 6-phytase increased the digestibility of N and essential AA indicating a better availability of plant-based protein.

**Key Words:** phytase, apparent ileal nutrient digestibility, ileo-rectal anastomosed pigs

**1095 Bioavailability of zinc from different sources in pigs.** S. Nitrayova\*<sup>1</sup>, W. Windisch<sup>2</sup>, E. von Heimendahl<sup>3</sup>, A. Müller<sup>3</sup>, and J. Bartelt<sup>3</sup>, <sup>1</sup>Animal Production Research Centre Nitra, Institute of Nutrition, Nitra, Slovakia, <sup>2</sup>Animal Nutrition, Center of Life and Food Sciences, TU München, Munich, Germany, <sup>3</sup>Lohmann Animal Health GmbH, Cuxhaven, Germany.

In contrast to inorganic zinc, organic Zn sources are absorbed via peptide or amino acid transport systems resulting in a higher digestibility and availability. Bioavailability of organically bound Zn seems also to be influenced by the type of complex being used. 42 gilts (Large white x Landrace) with initial body weight of  $24 \pm 1.4$  kg were allotted to 6 treatments. Pigs received corn-barley-soy based diets containing either low or high zinc supplementation with ZnO (1, 2), zinc methionine 1:2 complex consisting of 1 part zinc and 2 parts DL-methionine (3), zinc glycinate (4), zinc proteonate (5) and zinc yeast (6). Diets were fed during the 10 d experimental (EP)

and the 4 d quantitative collection period (BP). The daily feed intake was restricted to 1400 g/animal. Body weight was determined at the start and end of EP and BP. Feed consumption was monitored on daily base during EP and BP. Data were analyzed using 2 way randomized block ANOVA, Scheffé multiple comparisons,  $P \leq 0.05$ . Dietary Zn addition (mg/kg feed) was 10 or 100 for ZnO and 10 for all other groups. Analyzed Zn content in feed (mg/kg) was 52, 175, 82, 53, 68 and 84 resulting in a daily Zn intake of 72.5<sup>a</sup>, 244.6<sup>d</sup>, 115.4<sup>c</sup>, 74.1<sup>a</sup>, 92.7<sup>b</sup> and 117.8<sup>c</sup> for diet 1–5. Corresponding weight gain (g/d) was 437<sup>a</sup>, 564<sup>b</sup>, 559<sup>b</sup>, 550<sup>ab</sup>, 504<sup>ab</sup>, 587<sup>b</sup>. Apparent Zn digestibility and retention (%) was highest for the Zn methionine 1:2 (51.6<sup>b</sup>, 51.0<sup>b</sup>) followed by Zn yeast (45.9<sup>ab</sup>, 45.3<sup>ab</sup>). There was a trend for lower digestibility and retention of Zn proteonate (39.3<sup>ab</sup>, 38.7<sup>ab</sup>), 100 ppm ZnO (38.2<sup>ab</sup>, 37.8<sup>ab</sup>) and Zn glycinate (27.2<sup>ab</sup>, 26.4<sup>ab</sup>). The lowest Zn digestibility and retention was observed for diet supplemented with 10 ppm ZnO (17.2<sup>a</sup>, 16.4<sup>a</sup>). This is in accordance with literature showing higher availability of organically bound zinc. Organically bound Zn in particular Zn from zinc methionine 1:2 complex and zinc yeast can replace higher dosages of zinc oxide due to better bioavailability. Furthermore, the kind of chelate can have an impact on Zn retention.

**Key Words:** zinc, pig, bioavailability

**1096 Effect of soybean meal origin on standardized ileal amino acid digestibilities in piglets.** M. Eklund\*<sup>1</sup>, N. Sauer<sup>1</sup>, F. Rink<sup>1</sup>, M. Rademacher<sup>2</sup>, and R. Mosenthin<sup>1</sup>, <sup>1</sup>Institute of Animal Nutrition, University of Hohenheim, 70593 Stuttgart, Germany, <sup>2</sup>Evonik Industries AG, 63457 Hanau-Wolfgang, Germany.

Soybean meal (SBM) is the principal protein source in diets for pigs in Western and Central Europe, although there is only limited soybean cultivation in this area. The present study with piglets was conducted to estimate standardized ileal digestibilities (SID) of AA in European Union soybean meal imports sourced from Argentina, Brazil and the United States. Twelve piglets with an average initial BW of 9 kg were fitted with a simple ileal T-cannula to determine SID of AA in 4 batches of SBM originating either from Argentina (n = 1), Brazil (n = 1) or the United States (n = 2; US1, US2). A semi-synthetic diet based on cornstarch and casein (125 g casein/kg as-fed) was supplemented with 1 of the 4 SBM batches at an inclusion rate of 235 g SBM/kg (as-fed) each. The contribution of CP and AA from casein and from each of the assay feed ingredients to the assay diet averaged approximately 50%. Each diet was fed to 6 animals according to a row-column design with 2 experimental periods. The SID of AA were calculated by means of the difference method. The chemical composition of the SBM was similar, with CP contents ranging from 458 in Argentinean to 461 g/kg (as-fed) in US1 SBM, and NDF contents ranging from 86 in US1 to 117 g/kg (as-fed) in Brazilian SBM. The Lys contents in the assay SBM ranged from 28 g/kg (as-fed) for Brazilian to 30 g/kg (as-fed) for US1 SBM. The SID of indispensable AA varied between 74% for Trp in US2 and Brazilian SBM up to 91% for Arg in US2, Brazilian and Argentinean SBM, respectively. The SID of dispensable AA ranged from 64% for Cys in US2

SBM to 87% for Glu in US2, Brazilian and Argentinean SBM. The experimental period affected SID of His, Ile and most dispensable AA, with lower SID values in period 1 compared with period 2 ( $P < 0.05$ ), but SID values did not differ between the SBM batches ( $P = 0.136$  for His to  $P = 0.975$  for Glu). In conclusion, European SBM imports from Brazil, Argentina or the United States were similar in their chemical composition, and for most AA high and uniform SID values, independent from their source of origin, were obtained.

**Key Words:** standardized ileal digestibility, soybean meal, piglet

**1097 Comparative evaluation of standardized ileal amino acid digestibilities in protein supplements for piglets.** M. Eklund\*<sup>1</sup>, N. Sauer<sup>1</sup>, S. Hörner<sup>1</sup>, M. Rademacher<sup>2</sup>, and R. Mosenthin<sup>1</sup>, <sup>1</sup>Institute of Animal Nutrition, University of Hohenheim, 70593 Stuttgart, Germany, <sup>2</sup>Evonik Industries AG, 63457 Hanau-Wolfgang, Germany.

The study was conducted to determine standardized ileal digestibilities (SID) of CP and AA in protein ingredients frequently used in piglet nutrition. Twelve piglets were removed from the sow at 19 d of age (6 kg initial BW), and were fitted with a simple ileal T-cannula between d 22 and 23 of age. A semi-synthetic diet based on cornstarch and casein was either supplemented with soy protein concentrate (SPC), soy protein (SP), fermented soybeans (FSB), fullfat soybeans (FFSB), fluid-bed dried porcine intestinal mucosa hydrolysate (FDPIMH) or spray-dried porcine intestinal mucosa hydrolysate (SDPIMH). The contribution of CP and AA from casein and from each of the assay feed ingredients to the assay diet averaged approximately 50%. Each diet was fed to 6 animals according to a row-column design with 3 experimental periods. The SID of CP and AA were calculated by means of the difference method. The experimental period affected SID of CP and AA, with lower SID values in period 1 compared with periods 2 and 3 ( $P < 0.05$ ). The SID of indispensable AA in the soy products ranged from 72% for Thr in FFSB to 92% for Arg in FSB and in SPC. The SID of CP and AA did not differ between SPC, SP, FSB and FFSB ( $P > 0.05$ ). The SID of indispensable AA in the intestinal mucosa hydrolysates ranged from 53% for His in SDPIMH to 83% for Arg in DIMH. The SID of most AA did not differ between FDPIMH and SDPIMH ( $P > 0.05$ ) except for SID of Arg, His, Asp, Glu and Ser which were up to 19 percentage units higher and SID of Gly which was 17 percentage units lower in SDPIMH compared with FDPIMH ( $P < 0.05$ ). Compared with most SID values in the soy products, SID of CP and indispensable AA were up to 19 percentage units lower in FDPIMH and SDPIMH ( $P < 0.05$ ). In conclusion, high and uniform SID values in the soy products indicate that the different processing procedures used to manufacture these products were efficient to inactivate antinutritional factors present in raw soybeans. For most AA in the porcine intestinal mucosa products, drying procedure did not affect SID of AA, but SID values were generally lower compared with the soy products.

**Key Words:** standardized ileal digestibility, amino acids, piglets

**1098 Endogenous losses and true ileal digestibility of amino acids in piglets as influenced by feed and protein intake.** M. Eklund\*<sup>1</sup>, N. Sauer<sup>1</sup>, D. Jezierny<sup>1</sup>, M. Goerke<sup>1</sup>, M. Rademacher<sup>2</sup>, and R. Mosenthin<sup>1</sup>, <sup>1</sup>Institute of Animal Nutrition, University of Hohenheim, 70593 Stuttgart, Germany, <sup>2</sup>Evonik Industries AG, 63457 Hanau-Wolfgang, Germany.

There is evidence that with increasing protein and feed intake, ileal AA digestibilities in diets for pigs decline. This reduction may be either due to reduced true ileal digestibility (TID) and (or) increased endogenous AA secretion (IAAend). Therefore, the homoarginine method was used in the present study with piglets fed soybean meal (SBM) or casein (CAS) to determine the effect of varying feed and protein intake on TID and IAAend. A total of 51 piglets (weaned at 17 d of age, 6 kg initial BW), fitted with ileal T-cannulas, were used in 4 consecutive experiments with 2 periods each. The 12 cornstarch-based diets contained 6 levels of SBM or CAS (85; 135; 185; 235; 285; 335 g CP/kg, as-fed). Half of the CP source was replaced by the corresponding guanidinated CP source. Each diet was fed at 2 levels of feed intake (30; 60 g/kg BW; in total  $n = 4$  piglets per treatment). Each period included 9 d for adaptation to the diets. Ileal digesta were collected continuously for 12 h on d 10. Using the example of Lys, the TID ( $P < 0.05$ ) but not IAAend ( $P > 0.05$ ) decreased with increasing feed intake. Moreover, TID of Lys ( $P < 0.05$ ) declined and IAAend increased ( $P < 0.05$ ) with higher CP content sourced from SBM, whereas differences in CP intake sourced from CAS did not affect ( $P > 0.05$ ) IAAend and TID of Lys. In conclusion, protein and feed intake can affect ileal AA digestibility measurements as influenced by the source of protein.

**Table 1.** Effect of protein source (PS) and feeding level (FL, g/kg as-is) on IAA<sub>end</sub> and TID of Lys

	PS	FL	Protein level (PL; g/kg as-is)					P-value				
			85	135	185	235	285	335	PS	PL	FL	PSxPL
IAA <sub>end</sub> , Lys, g/kg DMI	CAS	60	0.6	0.7	0.7	0.7	1.1	1.5	<0.05	<0.05	0.60	<0.05
	SBM	30	0.8	0.7	0.9	0.8	0.7	1.3				
	SBM	60	1.5 <sup>a</sup>	1.8 <sup>a</sup>	2.6 <sup>ab</sup>	3.4 <sup>cb</sup>	4.6 <sup>c</sup>	4.5 <sup>c</sup>				
		30	1.7 <sup>a</sup>	2.8 <sup>ac</sup>	2.2 <sup>ab</sup>	3.5 <sup>cb</sup>	5.5 <sup>d</sup>	4.0 <sup>c</sup>				
TID, Lys, %	CAS	60	99.7	99.1	100.4	97.8	99.3	99.1	<0.05	<0.05	0.05	<0.05
	SBM	30	99.5	99.8	100.5	99.7	99.2	99.5				
	SBM	60	94.8 <sup>d</sup>	90.7 <sup>bc</sup>	82.5 <sup>cb</sup>	73.7 <sup>a</sup>	76.0 <sup>ab</sup>	74.2 <sup>ab</sup>				
		30	94.5 <sup>c</sup>	92.0 <sup>cb</sup>	89.7 <sup>cb</sup>	84.3 <sup>ab</sup>	77.0 <sup>a</sup>	77.5 <sup>a</sup>				

<sup>a-d</sup>Within a row, Lsmeans with different superscripts differ ( $P < 0.05$ ).

**Key Words:** true ileal digestibility, feed intake, piglet

**1099 An increased ratio of dietary tryptophan to lysine post weaning improves feed conversion efficiency and elevates plasma tryptophan and kynurenine in the absence of antimicrobials and regardless of infection with enterotoxigenic *E. coli*.** M. M. Capozzalo\*<sup>1</sup>, J. C. Kim<sup>2</sup>, J. K. Htoo<sup>3</sup>, C. F. M. de Lange<sup>4</sup>, B. P. Mullan<sup>2</sup>, J. W. Resink<sup>5</sup>, P. A. Stumbles<sup>1</sup>, and J. R. Pluske<sup>1</sup>, <sup>1</sup>Murdoch University, Murdoch, Western Australia, Australia, <sup>2</sup>Department of Agriculture and Food Western Australia, South

Perth, Western Australia, Australia, <sup>3</sup>Evonik Industries AG, Hanau, Wolfgang, Germany, <sup>4</sup>University of Guelph, Guelph, Ontario, Canada, <sup>5</sup>Nutreco, Boxmeer, The Netherlands.

This experiment examined if a higher ratio of dietary TRP to LYS (TRP:LYS), in the absence of antimicrobials, would improve feed conversion efficiency (FCE) and modulate diarrhea in weaner pigs infected or not infected with enterotoxigenic *E. coli* (ETEC). Effect of the TRP:LYS ratio on plasma levels of TRP and its metabolite kynurenine (KYN) were also examined, as KYN levels can increase during inflammation states such as during disease challenge. Individually housed pigs ( $n = 72$ ) weaned at 21 d (Landrace x Large White, mixed sex, mean  $\pm$  SEM body weight  $6.3 \pm 0.32$  kg) were stratified into one of 6 treatments ( $n = 12$ ) according to a 2x3 factorial arrangement of (i) infection or no infection with ETEC and (ii) 3 levels of standard ileal digestible (SID) TRP:LYS ratios of 0.17, 0.21 or 0.25, in a randomized complete block design. Pigs were fed diets (10.4 MJ NE, 1.24% SID LYS, 19.5% CP) ad libitum for 3 weeks after weaning. Pigs were infected with ETEC (6, 8 and 10 mL of  $2.12 \times 10^8$  cfu/mL, serotype O149:K98:K88) at 72, 96 and 120 h after weaning and then bled on d 11. A TRP:LYS ratio of 0.25 improved ( $P = 0.024$ ) FCE over the study period compared with other ratios (1.48, 1.48 and 1.35 for 0.17, 0.21 and 0.25, respectively), without an infection effect. Treatments did not affect daily gain or feed intake ( $P > 0.05$ ). Infection increased diarrhea index ( $P = 0.039$ ) and deteriorated fecal consistency (FC;  $P = 0.025$ ). Time and infection interacted for FC ( $P = 0.001$ ) and ETEC shedding as assessed by fecal swabs (FS;  $P = 0.034$ ), with differences greatest on d 7 for FC and d 5 for FS. Plasma TRP and KYN were lower in pigs fed 0.17 TRP:LYS than those fed ratios of 0.21 and 0.25 ( $P = 0.001$ ), without an infection effect. In conclusion, in the absence of antimicrobials, increasing the dietary TRP:LYS ratio enhanced plasma levels of TRP and KYN and a ratio higher than 0.21 TRP:LYS improves FCE in the period after weaning.

**Key Words:** tryptophan, performance, *E. coli*

**1100 Phytase improves apparent fecal P and Ca digestibility of piglet diets with adequate or reduced P content.** I. Kühn<sup>\*1</sup> and K. Partanen<sup>2</sup>, <sup>1</sup>AB Vista, Darmstadt, Germany, <sup>2</sup>MTT Agrifood Research, Hyvinkää, Finland.

The effect of a thermo-tolerant phytase (Quantum Blue) on performance and apparent fecal phosphorus (P) and calcium (Ca) digestibility was evaluated in 192 weaned piglets (randomized block design, 16 replicates, 2 piglets each). Wheat, barley, oat, soybean meal and whey-protein based diets with adequate (PC) or reduced (NC) Ca and P levels were fed 46 d after weaning. PC and NC diets contained Ca 8.0 and 6.4 g/kg and digestible P 2.9 and 1.9 g/kg, respectively. Pelleted diets contained 0, 500 or 1000 FTU/kg of phytase. Growth performance and feed conversion ratio were measured during starter (25 d) and weaner (21 d) periods. Apparent fecal Ca and P digestibilities were determined by spot-sampling at the end of the weaner period (8 pens per treatment over 5 consecutive days). The data was analyzed using a mixed model with random block effect and fixed effect of dietary P

level and phytase addition and their interaction. Dietary P level did not affect growth performance or feed conversion ratio of piglets over the entire feeding period ( $P > 0.10$ ) whereas phytase improved feed conversion ratio ( $P < 0.05$ ). During starter period, phytase linearly enhanced ( $P < 0.05$ ) growth performance (258, 266, and 292 g/d) and feed conversion ratio (1.55, 1.45, 1.45 kg dry matter/kg gain) but no differences were detected during the weaner period ( $P > 0.10$ ). Phytase and P level interacted for apparent fecal P digestibility ( $P < 0.05$ ), so that phytase improved apparent fecal P digestibility was more distinct in NC (48, 61, 68%) than in PC diets (52, 62, 61%). The apparent fecal Ca digestibility was higher in PC than in NC diets (68 vs. 58%), and it was increased quadratically by phytase addition (61, 65, 63%). In conclusion, dietary phytase enhances piglet performance during immediate post-weaning period, and increased apparent fecal P and Ca digestibility.

**Key Words:** piglet, phytase, phosphorus

**1101 Phytase inclusion in pig diets improves zinc status but its effect on copper availability is inconsistent.** P. Bikker<sup>\*</sup> and A. W. Jongbloed, Wageningen UR Livestock Research, Lelystad, The Netherlands.

We conducted 2 studies in young growing pigs (8–40 kg) to estimate the effect of dietary phytase on their zinc (Zn) and copper (Cu) requirements. In each of the studies one dietary treatment was included with and without inclusion of 500 FTU of microbial phytase (Natuphos® 5000G, BASF) per kg to determine the effect of dietary phytase on availability of the trace elements. Complexation of dietary phytate with cations is a major cause of reduced bioavailability of Zn and possibly Cu in pig diets. Inclusion of phytase is expected to improve their availability and reduce the required dietary inclusion. Each treatment comprised 10 pens with 8 pigs each as experimental units. Diets were based on cereal grains, SBM and RSM, contributing 30 mg Zn and 7 mg Cu per kg to the basal diet. In experiment 1, 500 FTU/kg phytase was added to a diet containing 15 mg Zn from zinc sulfate and 160 mg/kg Cu from copper sulfate in addition to Cu and Zn from feed ingredients. In experiment 2, 500 FTU phytase/kg was added to a diet containing 45 mg Zn from zinc sulfate, without added copper sulfate. At the end of an 8 week experimental period, feces were collected to determine nutrient digestibility, blood was collected and pigs were sacrificed to determine Cu and Zn in the liver. In both experiments phytase inclusion increased zinc digestibility (+10%,  $P < 0.001$ ), serum zinc level (+0.4 mg/L,  $P < 0.001$ ) and liver Zn content (+129 mg/kg DM,  $P < 0.001$ ). In exp. 1 phytase slightly increased copper digestibility (+6%,  $P = 0.03$ ) but reduced liver Cu content (–35 mg/kg DM,  $P = 0.04$ ). In exp. 2 phytase reduced Cu digestibility (–16%,  $P < 0.001$ ) without significant effect on liver Cu content. Results suggest that the effect of phytase on copper availability depend on the dietary copper and zinc content and the response parameters studied. The consistent effects of phytase on parameters of Zn status allow a reduction of zinc inclusion in phytase-enriched diets. We suggest that 500 FTU of phytase may replace inclusion of 30 mg Zn per kg of diet. The inconsistent effects of phytase on Cu status require further attention.



**Key Words:** phytase, copper, zinc

**1102 Copper induced reductions in cellular proliferation and changes in membrane integrity in porcine epithelial intestinal cells (IPEC-J2) and mouse macrophage cells (RAW264.7).** B. E. Aldridge<sup>\*1</sup>, Y. Liu<sup>2</sup>, J. S. Radcliffe<sup>1</sup>, and Y. Wang<sup>2</sup>, <sup>1</sup>Purdue University, Department of Animal Science, West Lafayette, IN 47905, USA, <sup>2</sup>Zhejiang University, Key Laboratory of Animal Nutrition and Feed Science, Ministry of Agriculture, Institute of Feed Science, Hangzhou 310058, Zhejiang, People's Republic of China.

Current requirements of dietary Cu range from 3 to 6 ppm Cu with industry feeding 25 ppm and growth promoting levels fed between 125 and 250 ppm Cu. However, Cu is potentially toxic to cells and little is known about levels which may stimulate cell proliferation, or induce membrane damage. The objective was to examine Cu-induced cytotoxicity by measuring cell proliferation (WST1 assay) and membrane integrity (LDH release assay) in mouse macrophage (RAW264.7) and porcine epithelial intestinal (IPEC-J2) cell lines. Cells were seeded at  $1 \times 10^5$  cells/well in 100  $\mu$ L of culture medium and incubated for 12 h on a 96 well plate. IPEC-J2 and RAW264.7 cells were incubated in duplicate or triplicate wells containing 5, 15, 25, 35, 45, 55 or 65  $\mu$ g/ml of Cu from  $\text{CuSO}_4$ , to measure LDH release ( $n = 3$  and  $n = 5$ , respectively). For the WST1 assay, IPEC-J2 and RAW264.7 cells were incubated in duplicate or triplicate wells containing 1, 2, 4, 8, 16, 32, 64 and 128  $\mu$ g/ml Cu from  $\text{CuSO}_4$  ( $n = 4$  and  $n = 3$ , respectively). The GLM procedure of SAS was used to determine the effects of Cu, and linear and quadratic contrasts were used to determine the dose response to Cu. Plate run was the experimental unit. Cellular proliferation quad decreased ( $P < 0.001$ ) by a total of 41 and 94% as Cu concentration increased from 1 to 128  $\mu$ g/ml Cu in IPEC-J2 and RAW264.7 cells, respectively. Membrane damage (% cytotoxicity) in RAW264.7 cells (% of Triton-X-100 control) linearly increased ( $P < 0.001$ ) by 136% as Cu concentration increased from 5 to 65  $\mu$ g/ml Cu exposure. In contrast, LDH release in IPEC-J2 cells linearly decreased ( $P < 0.001$ ) as Cu concentration increased from 5 to 65  $\mu$ g/ml, indicating a 71% decrease in membrane damage. These data begin to elaborate on the potential benefits (cell proliferation) and/or hazards (membrane damage) of digestion and absorption of supplemental Cu in various cells. In conclusion, increasing Cu in culture medium for 12 h decreases cell proliferation in both macrophage and intestinal cells, yet inversely affects membrane integrity between cell lines.

**Key Words:** IPEC-J2, RAW264.7, copper

**1103 Metabolic profiling of plasma from sows before parturition and during lactation.** M. S. Hedemann<sup>1</sup>, C. Flummer<sup>1</sup>, N. B. Kristensen<sup>1,2</sup>, and P. K. Theil<sup>\*1</sup>, <sup>1</sup>Dept. of Animal Science, Aarhus University, Foulum, DK-8830 Tjele, Denmark, <sup>2</sup>Syddansk Kvæg, Billundvej 3, DK-6500 Vejens, Denmark.

During transition, the sow undergoes large and sudden metabolic changes to adapt from anabolic to catabolic metabolism to produce milk. Little is known about changes

in nutrient uptake and intermediary metabolism during this transition. This study was undertaken to screen the metabolic profile for qualitative changes in nutrient uptake and metabolism during transition. Four sows were fitted with permanent catheters in artery femoralis (A), and in portal (P) and hepatic (H) veins (sampling sites). Sows were fed a standard lactation diet from 15 d before parturition for 42 d. Blood samples were taken 1.5 h after feeding on d-10, d-3, d3, and d17 relative to parturition and plasma metabolites were analyzed by an LC-MS based approach using a MicrO-TOF Q II mass spectrometer. Principal components analysis was performed to visualize the metabolic profiles and to screen for intermediary metabolites altered during the transition period. The metabolic profile of sows on d3 after parturition was distinct from other days. Plasma betaine and 7 unidentified plasma lipid compounds contributed to the separation on d3, and betaine was lowered by 32% at d-3 compared with other time points ( $P < 0.001$ ). Plasma choline, 3 unidentified lipid compounds and another metabolite contributed to the separation due to sampling sites. Plasma choline was lowest in H (25%), intermediate in A (39%) and highest in P (100%;  $P < 0.001$ ) plasma, indicating net absorption from the GI-tract (P-A) and liver metabolism (H-P), while choline was comparable among days ( $P = 0.33$ ). Interactions between day and sampling site were found for 2 unidentified lipid compounds. The majority of unidentified metabolites (10 of 11) found using the loadings plot and affected by day or sampling site or both were revealed as lipid compounds, i.e., either bile acid-, cholesterol-, glycerol-, phosphatidyl-, sphingomyelin-, or acylglycerol derivatives. In conclusion, the intermediary metabolism of sows, especially the fat metabolism, changed during the transition period, and a deeper understanding and detection of involved metabolites are necessary to optimize sow feeding during transition.

**Key Words:** metabolites, pig, transition period

**1104 Influence of high levels of dietary zinc oxide on performance and small intestinal gene expression in weaned piglets.** L. Martin,<sup>\*</sup> R. Pieper, W. Vahjen, and J. Zentek, Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany.

High levels of dietary zinc oxide (ZnO) can enhance performance and improve health of weaned piglets. Besides an influence on intestinal microbial communities, possible reasons could be an effect on digestion and absorption. Whether short (one week) or longer (4 weeks) ZnO supplementation has similar effects is still unclear. This study investigated the effects of dietary ZnO fed to piglets for 1, 2, 3, and 4 weeks after weaning. A total of 126 piglets weaned at  $26 \pm 1$  d of age ( $7.6 \pm 1.1$  kg body weight) were allocated into 3 groups fed 57 (low level), 164 (optimal level) or 2425 (high level) mg zinc/kg diet supplied as analytical grade ZnO. After 1, 2, 3 and 4 weeks, 6 piglets per group were euthanized and total mRNA was extracted from jejunal tissue for gene expression analysis of lactase-phlorizin hydrolase (LPH), sucrase-isomaltase (SUC), aminopeptidase-N (APN), intestinal alkaline phosphatase (IAP), proliferating cell nuclear antigen (PCNA) and caspase 3 (CASP). Activity of IAP was also determined in



jejunal brush border membranes. Data were analyzed by ANOVA following LSD post-hoc test using SPSS (version 19.0). Average daily gain (22 and 25%) and feed intake (23 and 24%) were higher ( $P < 0.05$ ) in piglets fed high vs. the 2 other ZnO levels during the first week, but did not differ thereafter. Gene expression analysis did not reveal clear effects of dietary zinc level on transcript abundance for digestive enzymes (LPH, SUC, APN), markers for cell turnover (PCNA, CASP) and IAP. However, the activity of IAP was 39 and 50% higher ( $P < 0.05$ ) in piglets fed high vs. the 2 other ZnO levels. In conclusion, high dietary levels of zinc from ZnO can increase early post-weaning performance but this cannot be clearly linked to intestinal expression and activity of digestive enzymes.

**Key Words:** zinc oxide, performance, gene expression

**1105 Pharmacological levels of zinc oxide change the expression of zinc transport proteins ZIP4 and ZnT1 and metallothionein but not DMT 1 and ZnT2 in the jejunum of weaned piglets.** R. Pieper,\* L. Martin, W. Vahjen, and J. Zentek, *Institute of Animal Nutrition, Freie Universität Berlin, Berlin, Germany.*

Intestinal zinc uptake is facilitated through members of zinc transporter families SLC30 (ZnT) and SLC39 (ZIP). In rodents, low or adequate zinc supply alters regulation of these transporters; however, such mechanisms are unclear for pigs. Fifty-four piglets were fed diets containing 57 (low), 164 (optimal) or 2425 (high) mg/kg DM dietary zinc. The zinc level was adjusted using analytical grade zinc oxide (Sigma). After 4 weeks, 30 animals (10 per group) were euthanized and jejunal tissues were sampled for mRNA extraction. Primers for zinc transporters ZnT1, ZnT2, ZIP4, divalent metal transporter 1 DMT1 and metallothionein (MT) were generated using public available gene sequences. Data were analyzed by ANOVA following post-hoc Tukey-test using SPSS 19.0. The zinc concentration in jejunal contents increased ( $P < 0.05$ ) with increasing dietary zinc ( $550 \pm 54$ ,  $647 \pm 110$  and  $8178 \pm 839$  mg/kg for low, optimal and high supplemented groups, respectively). Increasing intestinal zinc concentration increased ( $P < 0.05$ ) expression of ZnT1 (0.59, 0.65 and 0.88, for low, optimal and high supplemented groups, respectively) and decreased ( $P < 0.05$ ) expression of ZIP4 (1.78, 1.63 and 0.92 for low, optimal and high supplemented groups, respectively), whereas expression of ZnT2 and DMT1 were not affected. High levels of dietary and intestinal zinc increased the expression of MT (0.87, 0.95 and 1.74 for low, optimal and high supplemented groups, respectively). In conclusion, high levels of dietary and intestinal zinc can influence the expression of zinc transporters ZIP4 and ZnT1 and increase the expression of MT. Thus, high dietary zinc concentrations increase intracellular zinc, promote increased zinc export from intestinal tissues into extracellular compartments and decrease the zinc uptake from the gut lumen.

**Key Words:** zinc oxide, zinc transport, absorption

**1106 Ileal digestibility of soybean meal, sunflower meal, pea, rape seed cake and lupine in pigs.** J. V.

Nørgaard,\* J. A. Fernández, and H. Jørgensen, *Dept. of Animal Science, Aarhus University Foulum, Tjele, Denmark.*

The use of European-grown protein sources is an important factor in organic pig production, since only organically produced feedstuffs are allowed from 2012. Especially pea, rape seed cake, and lupine are interesting, because they can also be produced in Northern Europe. The objective of this experiment was therefore to ascertain the standardized ileal digestibility (SID) of protein and amino acids in soybean meal, sunflower meal, rape seed cake, field pea (*Pisum sativum*), and lupine (*Lupinus angustifolius*), with 508, 417, 356, 244 and 316 g crude protein/kg dry matter, respectively. Pigs were fitted with either a T-cannula or a steered ileo-cecal valve (SICV)-cannula. After surgery at 35 kg, pigs were allowed to recover for 14 d. Diets were formulated to contain from 170 to 186 g crude protein/kg dry matter by diluting the test feedstuffs with a N-free diet based on wheat starch and sugar. Endogenous losses of protein (15.1 g/kg DM) and amino acids were estimated by feeding the N-free diet. Diets were supplemented with both chromic oxide and titanium oxide as indigestible markers. Results are presented as means across type of cannula and marker. Soybean meal, sunflower meal, rape seed cake, and pea were evaluated in 10 pigs and lupine in 7 pigs. The apparent digestibility of organic matter in soybean meal (80%) was greater ( $P < 0.05$ ) compared with sunflower meal (71%) and rape seed cake (71%), but not different than pea (76%). Lupine had the lowest ( $P < 0.05$ ) with 64% apparent organic matter digestibility. The SID of crude protein was 85% for soybean meal, 77% for sunflower meal, 78% for rape seed cake, 89% for pea, and 79% for lupine, with greater SID for soybean meal and pea compared with sunflower meal, rape seed cake and lupine ( $P < 0.05$ ). Sunflower meal had lowest ( $P < 0.05$ ) SID for lysine and histidine, and lupine had lowest ( $P < 0.05$ ) SID for methionine and valine. These results imply soybean meal and pea to be high-digestible protein source relative to sunflower meal, rape seed cake, and especially lupine, although all tested feedstuffs seem appropriate for inclusion in diets for organic pigs.

**Key Words:** amino acids, protein, standardized ileal digestibility

**1107 Effect of microbial phytase on phosphorus digestibility in non-heat-treated and heat-treated wheat-barley pig diets.** K. Blaabjerg,\* J. V. Nørgaard, and H. D. Poulsen, *Aarhus University, Faculty of Science and Technology, Department of Animal Science, P.O. Box 50, 8830 Tjele, Denmark.*

Microbial phytase increases the digestibility of phytate phosphorus (P) resulting in reduced need for feed phosphate and improved P utilization. The effect of microbial phytase on the P digestibility may depend on the processing of the feed due to inactivation of plant phytase. A wheat-barley diet without feed phosphate was ground and half of the batch was steam-pelleted at approximately 81°C and crumbled. Subsequently, both non-heat-treated and heat-treated diets were divided in 3 portions and phytase was added at 0, 250 and 500 FTU/kg as-fed (*Aspergillus niger*).

The experiment comprised 36 pigs, 6 litters of 6 female littermates weighing about 43 kg. From each litter, the pigs were randomly assigned to the 6 treatments. The pigs were housed in metabolism crates and fed one of the 6 diets for 12 d, 5 d for adaptation and 7 d for total collection of feces. Heat-treatment reduced the plant phytase activity from 450 to 340 FTU/kg DM whereby the P digestibility decreased ( $P \leq 0.01$ ) from 57 to 49% (without microbial phytase). The added phytase increased ( $P \leq 0.001$ ) the P digestibility to 60%, whether the diets were heat-treated or not. Thus, the increase in the P digestibility by additions of phytase was 8 percent units greater for heat-treated compared with non-heat-treated diets. 500 FTU/kg as-fed did not improve the P digestibility further compared with 250 FTU/kg as-fed. The phytase supplementation increased ( $P \leq 0.001$ ) the digestible P content with 0.2 and 0.4 g/kg as-fed diet in the non-heat-treated and heat-treated diets, respectively. In conclusion, microbial phytase increased the P digestibility to a maximum of 60% independent of processing, but the magnitude of the increase was greater in heat-treated compared with non-heat-treated diets showing that assessments of effects of microbial phytases on the P digestibility depend on the processing of the diet. Thus, steam pelleting of feed should be considered when supplementing phytase to avoid over- or underestimation of the effect of microbial phytase.

**Key Words:** phosphorus, phytase, heat-treatment

**1108 Environmental consequences of feeding high fiber diet to growing pigs.** A. Woldeghebriel\*<sup>1</sup>, S. Smith<sup>1</sup>, T. Barios<sup>1</sup>, B. Pope<sup>1</sup>, and S. Gebrelul<sup>2</sup>, <sup>1</sup>North Carolina A&T State University, Greensboro, NC, USA, <sup>2</sup>Southern University, Baton Rouge, LA 70809.

The study was conducted to estimate the concentration of carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) in pigs using a ruminant animal model currently under validation using CO<sub>2</sub> and CH<sub>4</sub> analyzer. Pigs were randomly assigned to pens (6/pen) and pens assigned to 1 of 4 diets (4/diet). Diets include a corn-soybean meal based diet as the control (CON, 8.3% NDF), and 3 high fiber diets (D1, D2 and D3; 23.3, 23.9 and 20.0% NDF, respectively) each containing 5% sugar beet pulp and an oats to barley ratios of 1:2, 1:1, and 2:1, respectively. Diets contain similar amount of protein (18% CP) and energy (3.415 Mcal/kg of feed). Pigs had free access to their diets for 70 d. Three pigs of comparable weights from each treatment were selected and kept without feed for 18 h (abattoir requires overnight fasting) before slaughter. Digesta samples from the stomach, cecum, and colon were taken for the determination of short chain fatty acid (SCFA) concentration and values obtained were used to predict CO<sub>2</sub> and CH<sub>4</sub> concentration. Data collected were analyzed using SAS Glimmix procedure, where animals were considered random effects, and diet means were used to compare treatment effects. The highest ( $P < 0.05$ ) total and individual SCFA concentration (except isobutyrate) was found in pigs fed D3 and CON diets. The average molar concentration of isobutyrate in pigs fed high fiber diets was lower (31%;  $P < 0.05$ ) than CON diet fed pigs. Similarly, pigs fed high fiber diets on the average were 25.6 and 24.2% lower ( $P < 0.05$ ) in CO<sub>2</sub> and CH<sub>4</sub> concentrations

respectively, compared with pigs fed CON diet. Pigs fed the highest oats to barley ratio showed higher ( $P < 0.05$ ) concentrations of CO<sub>2</sub> (8.3%) and CH<sub>4</sub> (5.1%) compare with the averages of CO<sub>2</sub> (5.3%) and CH<sub>4</sub> (3.3%) in the lower oats to barley ratios. Molar proportions of SCFA, CO<sub>2</sub> and CH<sub>4</sub> in gut contents were in the order of SCFA > CO<sub>2</sub> > CH<sub>4</sub>, at 53.0%, 28.6% and 18.4%, respectively and CO<sub>2</sub> and CH<sub>4</sub> were 47% of the total volume of gas in the digestive tract of the pigs.

**Key Words:** methane, carbon dioxide, short-chain fatty acids

**1109 The effect of live yeast utilization and dietary fibre on growth performance, nutrient utilization and gut microbiology in the weaning pig.** R. Lizardo\*<sup>1</sup>, A. Perez-Vendrell<sup>1</sup>, I. Badiola<sup>3</sup>, R. D'Inca<sup>2</sup>, E. Auclair<sup>2</sup>, and J. Brufau<sup>1</sup>, <sup>1</sup>IRTA - Institut de Recerca i Tecnologia Agroalimentaries, Constantí, Tarragona, Spain, <sup>2</sup>LFA - Lesaffre Feed Additives, Marquette-Lez-Lille, France, <sup>3</sup>CRSA - Centre de Recerca en Sanitat Animal, Bellaterra, Barcelona, Spain.

The digestive microflora of piglets undergoes major changes after weaning. Since the EU ban of antimicrobial growth promoters, inclusion of live yeasts in diets became usual due to their probiotic effects. Moreover, due to increasing availability of cereal fiber-rich by-products, swine feeds tend to contain more fiber, even for piglets. Information on the use of live yeast on high-fiber diets is lacking. In total, 144 weaning piglets were distributed in a 2x2 factorial arrangement. Treatments correspond to low and high fiber diets (11.3 vs 13.8% NDF) supplemented or not with 5\*10<sup>9</sup>cfu/kg of live *Saccharomyces cerevisiae* Sc47 yeasts (Actisaf). Wheat bran was used as the additional fiber source. Productive parameters were evaluated after 5 weeks. Then, 32 piglets were slaughtered and cecum content was sampled for VFA determinations and gut microbiology. In a 2nd similar trial, 36 piglets of around 15-kg were used for digestibility measurements using celite as indigestible marker. During the 1st 2 weeks after weaning, effects were not observed. However, during the subsequent 3 weeks, piglets fed low fiber and those fed yeast diets consumed more feed ( $P < 0.05$ ) and tended to gain more weight ( $P = 0.08$ ). A synergistic association of yeast and high-fiber diets is also observed for overall daily weight gain ( $P < 0.05$ ) and final liveweight ( $P = 0.08$ ). Nitrogen ( $P = 0.08$ ), NDF and ADF digestibility ( $P < 0.05$ ) increased with fiber level whereas that of dry matter, nitrogen ( $P < 0.05$ ), energy ( $P = 0.10$ ), NDF and ADF ( $P < 0.01$ ) increased with yeast inclusion in diets. Although some tendencies were observed only acetate concentration was increased with both fiber level and inclusion of yeast (57.4, 60.6;  $P < 0.01$ ). Dendograms of the similarity degree of RFLP profiles of intestinal microbiota clearly indicated the existence of clusters related with diets in cecum content but not in feces. In conclusion, utilization of live yeast in high fiber diets may influence the digestive environment affecting nutrient digestion and piglet productive variables after weaning.

**Key Words:** piglet, live yeast, digestion

**1110 Histamine and PGE<sub>2</sub>-induced chloride secretion and the epithelial catabolism of histamine in the colon of piglets is influenced by diets high in fermentable protein.** S. Kroeger\*<sup>1</sup>, R. Pieper<sup>1</sup>, H. G. Schwelberger<sup>3</sup>, J. Wang<sup>2</sup>, J. F. Richter<sup>4</sup>, J. R. Aschenbach<sup>5</sup>, A. G. Van Kessel<sup>2</sup>, and J. Zentek<sup>1</sup>, <sup>1</sup>Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany, <sup>2</sup>Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, <sup>3</sup>Department Operative Medizin, Universitaetsklinik Innsbruck, Innsbruck, Austria, <sup>4</sup>Clinical Physiology, Charité Univeritaetsmedizin, Berlin, Germany, <sup>5</sup>Veterinary Physiology, Freie Universitaet Berlin, Berlin, Germany.

We studied the influence of dietary fermentable protein (fCP) and fermentable carbohydrate level (fCHO) on the epithelial response to histamine and prostaglandin E<sub>2</sub> (PGE<sub>2</sub>), as protein- or inflammation-derived secretagogues, in the colon of pigs. Furthermore, the capacity for histamine inactivation through the enzymes diamine oxidase (DAO) and histamine N-methyltransferase (HMT) was determined. Thirty-two weaned piglets were fed 4 diets for 21–23 d in a 2 × 2 factorial design, with low vs. high fCP (15 or 20% CP) and low vs. high fCHO (14.5 or 17.3% TDF). High fCP was achieved by the addition of autoclaved soybean meal (200 g/kg) and high fCHO by wheat bran and sugar beet pulp (80 or 50 g/kg). Pigs were euthanized and mucosa from the proximal colon was mounted in Ussing chambers. Histamine or PGE<sub>2</sub> was applied and the change of short-circuit current ( $\Delta$ Isc) and tissue conductance ( $\Delta$ Gt) was measured. Gene expression of DAO and HMT was determined by RT-qPCR in RNA extracts from colon tissue. DAO activity was measured radiometrically and HMT activity by transmethylated histamine. Histamine concentration in colon digesta was analyzed by ion-exchange chromatography. Generalized linear model procedures in SPSS (version 19.0, Chicago, IL, USA) were used to analyze data. The  $\Delta$ Isc in response to histamine was lower ( $P < 0.05$ ) and  $\Delta$ Gt was higher ( $P < 0.05$ ) for tissue taken from the high fCP groups. The  $\Delta$ Isc tended to be lower after the addition of PGE<sub>2</sub> in groups which were fed high fCP diets. The HMT gene expression ( $P < 0.05$ ) and the activities of DAO and HMT were higher ( $P < 0.05$ ) in pigs receiving the high fCP diets. Histamine concentration in the colon digesta was increased by dietary fCP ( $P < 0.05$ ). All effects were irrespective of fCHO treatment. In conclusion, epithelial histamine and PGE<sub>2</sub> sensitivity and histamine inactivation through DAO and HMT are modified through diets high in fCP in weaned piglets, thus suggesting adaptation to increased histamine levels.

**Key Words:** histamine, fermentable protein, secretory response

**1111 Digestible energy values of feed ingredients with or without addition of enzymes complex in growing pigs.** P. Cozannet\*<sup>1</sup>, A. Preynat<sup>1</sup>, and J. Noblet<sup>2</sup>, <sup>1</sup>Adisseo France SAS, CERN, F-03600 Malicorne, France, <sup>2</sup>INRA, UMR1348 Pegase, F-35590 Saint Gilles, France.

Digestible energy (DE) values and digestible nutrients content of 6 diets were measured in 60 kg male growing

pigs fed restricted amount of feed. Diets were prepared from 5 ingredients (wheat, corn, barley, wheat bran and soybean meal; inclusion levels of ingredients being independent) with or without Rovabio Excel AP (3,300 endo- $\alpha$ -1,4-xylanase visco units and 300 endo-1,3(4)- $\beta$ -glucanase units/kg of feed; 150 g/ton of feed) according a 6 × 2 factorial arrangement; dietary NDF ranged from 12 to 20% of DM. Pigs (5 per treatment) were placed in metabolism cages that allowed total collections of feces and urine for 10 d after a 11 d adaptation period. Samples were analyzed for GE, ash and N. Digestibilities of GE, N and organic matter (OM) and N balance were calculated. The effects of diet and enzyme were evaluated by ANOVA. In addition, the DE and digestible nutrient contents of ingredients were calculated by regression of nutritive values of diets on levels of ingredients inclusions. Apparent total tract digestibilities of OM, N and GE of diets were affected by diet characteristics ( $P < 0.001$ ) in connection with a negative effect of NDF content ( $R = -0.97$ ;  $P < 0.001$ ) and were increased ( $P < 0.05$ ) by enzyme addition (Enz) with +0.69, +1.68 and +0.76% units for OM, N and GE digestibilities, respectively. Increases in DE value due to Enz averaged 0.12 MJ per kg DM (15.11 vs 14.99 MJ/kg DM;  $P < 0.001$ ). The ADG (878 vs. 834 g/day;  $P < 0.05$ ) and N balance were also increased by Enz addition, suggesting that it may overcome limiting amino acid contents. The calculated DE content per ingredient averaged 16.0, 16.6, 15.0, 10.6 and 16.7 MJ/kg DM for wheat, corn, barley, wheat bran and soybean meal, respectively. The Enz addition increased the DE value of diets similar to the ingredients (+0.12 MJ/kg DM). Considered per ingredient, tendencies for a better response was observed for wheat and soybean meal (0.48 and 1.25 MJ/kg DM, respectively). In conclusion, apparent total tract digestibility for energy of diets or raw materials can be increased by Enz addition.

**Key Words:** digestible energy, enzyme, pig

**1112 Effects of fibers with different fermentation characteristics on feeding motivation in adult pigs.** C. Souza Da Silva\*<sup>1,2</sup>, J. E. Bolhuis<sup>1</sup>, W. J. J. Gerrits<sup>2</sup>, B. Kemp<sup>1</sup>, and J. J. G. C. van den Borne<sup>2</sup>, <sup>1</sup>Adaptation Physiology Group, Wageningen University, Wageningen, The Netherlands, <sup>2</sup>Animal Nutrition Group, Wageningen University, Wageningen, The Netherlands.

Dietary fibers can be fermented in the colon, resulting in production of short-chain fatty acids (SCFA) and secretion of satiety-related peptides such as GLP-1 and PYY. Recently, we have shown that a diet containing 40% native potato starch reduced feeding motivation in adult pigs up to 7 h after feeding. The aim of the current study was to assess the effects of fibers with varying fermentation characteristics on feeding motivation in adult pigs. Sixteen pair-housed gilts (250 kg BW) received 4 diets: inulin (INU), guar gum (GG), retrograded tapioca starch (RS), and control (C), in 4 periods in a Latin square design. Each period, pigs were fed a low fiber (L) followed by a high fiber (H) diet (7 d each). Fiber levels were 7% and 14% for INU, 5% and 10% for GG, 17% and 34% for RS. Fibers were exchanged for starch from the C diet based on gross energy. Pigs received 1050 g of feed twice daily.



At 1 h, 3 h and 7 h after feeding, feeding motivation was assessed in an operant test, where turning a wheel yielded multiple feed rewards, and in a runway test, where walking a fixed U-shaped track yielded one feed reward. An ad libitum feed intake test was conducted at 3 h after feeding. In the operant test, at 7 h after feeding the number of wheel turns tended to be lower ( $P < 0.1$ ) for RS-fed (502) than for INU-fed pigs (592, SEM = 122). In the runway test, at 1 h (H: 2.0 km/h, L: 2.7 km/h, SEM = 0.2,  $P < 0.05$ ) and 3 h (H: 1.5 km/h, L: 2.5 km/h, SEM = 0.2,  $P < 0.001$ ) H-fed pigs walked slower for food than L-fed pigs. Pigs had a lower voluntary feed intake (fiber type  $\times$  level effect,  $P < 0.05$ ) in the ad libitum feed intake test when fed RS-H (2.4 kg) compared with most of the other diets, including the RS-L (3.1 kg, SEM = 0.3). In conclusion, increasing the dietary fiber content enhanced satiety at 1 h and 3 h after feeding, despite a reduction in metabolizable energy supply. RS was the most satiating fiber, possibly due to its slow rate of fermentation and high production of butyrate, which may result in reduced long-term energy intake.

**Key Words:** dietary fiber, satiety, pigs

**1113 Effects of formic acid and phytase supplementation on digestibility and utilization of phosphorus and zinc in growing pigs.** R. Blank<sup>1</sup>, M. Naatjes<sup>1</sup>, P. Ader<sup>\*2</sup>, U. Roser<sup>2</sup>, and A. Susenbeth<sup>1</sup>, <sup>1</sup>University of Kiel, Institute of Animal Nutrition, Kiel, Germany, <sup>2</sup>BASF SE; GBU Animal Nutrition, Lampertheim; Germany.

Addition of organic acids to microbial phytase (PHY) containing diets can increase the effectiveness of PHY and therewith the utilization of phosphorus (P) and probably other minerals. The hypothesis is that lower digesta pH will reduce phytate complex building. The study aimed to quantify that effect on digestibility of P and zinc (Zn) in growing pigs fed a pelleted diet based on wheat, barley and soybean meal. The complete study consisted of 2 experiments. For each experiment, 12 barrows (35–40 kg) were assigned to a triplicate 4  $\times$  4 Latin square design. Dietary treatments in Exp. I consisted of 1) control diet (CON), designed to be marginal deficient in P and Zn, 2) CON supplemented with 4.7 g/kg of a 85% formic acid (FA) formulation (BASF, Germany) to reduce feed pH by 1 unit, 3) CON supplemented with 500 FTU/kg fungal 3-PHY (BASF) and 4) CON supplemented with both, FA and PHY at same dosage as in 2) and 3). Dietary treatments in Exp. II were exactly the same, except that the microbial PHY supplementation was increased to 1000 FTU/kg. Total feces and urine were collected quantitatively. Feed, feces and urine were analyzed for P and Zn to calculate digestibility and their retention. The statistical model included supplementation of FA, PHY, their interaction and period as fixed effects. In both experiments, PHY supplementation decreased fecal P excretion ( $P < 0.05$ ) and improved P digestibility and retention ( $P < 0.05$ ), whereas FA supplementation did not affect P retention at present conditions. The PHY and FA supplementation interacted ( $P < 0.05$ ) for P utilization so that in comparison to CON P digestibility was improved ( $P < 0.05$ ) by 31 and 50% (3)) and by 50 and 63% (4)) in Exp. I and II, respectively. Effects on Zn utilization followed a similar pattern. In conclusion,

the present study indicated that FA supplementation to fungal 3-PHY containing diets increase P and Zn utilization and therewith improve environmental sustainability of pig production.

**Key Words:** fungal-3-phytase, formic acid, digestibility

**1114 Effect of supplementing alternating ratios of laminarin and fucoidan in the diet of the weanling piglet on performance, nutrient digestibility and selected faecal microbial populations and volatile fatty acid concentrations.** A. M. Walsh,<sup>\*</sup> T. Sweeney, C. J. O'Shea, D. N. Doyle, B. Flynn, and J. V. O'Doherty, University College Dublin, Lyons Research Farm, Newcastle, Co. Dublin, Ireland.

A 3  $\times$  2 factorial experiment was conducted to investigate the effects of alternating ratios of dietary laminarin and fucoidan on growth performance and markers of gastrointestinal tract function in newly-weaned piglets. At weaning, one hundred and 68 piglets (24 d of age, 6.8 kg live-weight) were assigned to one of 6 dietary treatments (n = 14/treatment): (1) control diet, (2) control diet + 240 ppm fucoidan, (3) control diet + 150 ppm laminarin, (4) control diet + 150 ppm laminarin and 240 ppm fucoidan, (5) control diet + 300 ppm laminarin, (6) control diet + 300 ppm laminarin and 240 ppm fucoidan. Pigs offered 300 ppm laminarin supplemented diets had a significantly higher average daily gain (0.374 v. 0.346 kg/day, s.e.  $\pm$  0.0094,  $P < 0.05$ ) throughout the entire experimental period (d 0–35) compared with pigs offered diets without laminarin. There was a significant interaction between laminarin and fucoidan supplementation on gain to feed ratio ( $P < 0.05$ ) during the entire experimental period. Pigs offered the 300 ppm laminarin supplemented diet had a higher gain to feed ratio than pigs offered the control diet. However, there was no effect of the high level laminarin when combined with fucoidan. There was a significant interaction between laminarin and fucoidan supplementation on the apparent total tract digestibility (ATTD) of gross energy (GE) ( $P < 0.05$ ). Pigs offered the 150 ppm and 300 ppm laminarin diet had an increased ATTD of GE compared with pigs offered the control diet. However, there was no effect of laminarin when combined with fucoidan. Pigs offered the 150 ppm and 300 ppm laminarin supplemented diets had increased the ATTD of nitrogen (N) (0.806, 0.806 respectively v. 0.776, s.e.  $\pm$  0.0091,  $P < 0.05$ ) compared with pigs offered diets without laminarin supplementation. In conclusion, the inclusion of laminarin singularly increased the ATTD of diet components and improved growth performance of pigs after weaning.

**Key Words:** laminarin, fucoidan, performance

**1115 Digestibility of canola meal from 2 species (*Brassica juncea* and *Brassica napus*) fed to ileal-cannulated grower pigs.** M. H. A. Le<sup>\*1</sup>, A. D. G. Buchet<sup>1,2</sup>, E. Beltrana<sup>1,3</sup>, W. J. J. Gerrits<sup>2</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>Wageningen University, The Netherlands, <sup>3</sup>Alberta Agriculture and Rural Development, Edmonton, AB, Canada.



**1110 Histamine and PGE<sub>2</sub>-induced chloride secretion and the epithelial catabolism of histamine in the colon of piglets is influenced by diets high in fermentable protein.** S. Kroeger\*<sup>1</sup>, R. Pieper<sup>1</sup>, H. G. Schwelberger<sup>3</sup>, J. Wang<sup>2</sup>, J. F. Richter<sup>4</sup>, J. R. Aschenbach<sup>5</sup>, A. G. Van Kessel<sup>2</sup>, and J. Zentek<sup>1</sup>, <sup>1</sup>Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany, <sup>2</sup>Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, <sup>3</sup>Department Operative Medizin, Universitaetsklinik Innsbruck, Innsbruck, Austria, <sup>4</sup>Clinical Physiology, Charité Univeritaetsmedizin, Berlin, Germany, <sup>5</sup>Veterinary Physiology, Freie Universitaet Berlin, Berlin, Germany.

We studied the influence of dietary fermentable protein (fCP) and fermentable carbohydrate level (fCHO) on the epithelial response to histamine and prostaglandin E<sub>2</sub> (PGE<sub>2</sub>), as protein- or inflammation-derived secretagogues, in the colon of pigs. Furthermore, the capacity for histamine inactivation through the enzymes diamine oxidase (DAO) and histamine N-methyltransferase (HMT) was determined. Thirty-two weaned piglets were fed 4 diets for 21–23 d in a 2 × 2 factorial design, with low vs. high fCP (15 or 20% CP) and low vs. high fCHO (14.5 or 17.3% TDF). High fCP was achieved by the addition of autoclaved soybean meal (200 g/kg) and high fCHO by wheat bran and sugar beet pulp (80 or 50 g/kg). Pigs were euthanized and mucosa from the proximal colon was mounted in Ussing chambers. Histamine or PGE<sub>2</sub> was applied and the change of short-circuit current ( $\Delta$ Isc) and tissue conductance ( $\Delta$ Gt) was measured. Gene expression of DAO and HMT was determined by RT-qPCR in RNA extracts from colon tissue. DAO activity was measured radiometrically and HMT activity by transmethylation of histamine. Histamine concentration in colon digesta was analyzed by ion-exchange chromatography. Generalized linear model procedures in SPSS (version 19.0, Chicago, IL, USA) were used to analyze data. The  $\Delta$ Isc in response to histamine was lower ( $P < 0.05$ ) and  $\Delta$ Gt was higher ( $P < 0.05$ ) for tissue taken from the high fCP groups. The  $\Delta$ Isc tended to be lower after the addition of PGE<sub>2</sub> in groups which were fed high fCP diets. The HMT gene expression ( $P < 0.05$ ) and the activities of DAO and HMT were higher ( $P < 0.05$ ) in pigs receiving the high fCP diets. Histamine concentration in the colon digesta was increased by dietary fCP ( $P < 0.05$ ). All effects were irrespective of fCHO treatment. In conclusion, epithelial histamine and PGE<sub>2</sub> sensitivity and histamine inactivation through DAO and HMT are modified through diets high in fCP in weaned piglets, thus suggesting adaptation to increased histamine levels.

**Key Words:** histamine, fermentable protein, secretory response

**1111 Digestible energy values of feed ingredients with or without addition of enzymes complex in growing pigs.** P. Cozannet\*<sup>1</sup>, A. Preynat<sup>1</sup>, and J. Noblet<sup>2</sup>, <sup>1</sup>Adisseo France SAS, CERN, F-03600 Malicorne, France, <sup>2</sup>INRA, UMR1348 Pegase, F-35590 Saint Gilles, France.

Digestible energy (DE) values and digestible nutrients content of 6 diets were measured in 60 kg male growing

pigs fed restricted amount of feed. Diets were prepared from 5 ingredients (wheat, corn, barley, wheat bran and soybean meal; inclusion levels of ingredients being independent) with or without Rovabio Excel AP (3,300 endo- $\beta$ -1,4-xylanase visco units and 300 endo-1,3(4)- $\beta$ -glucanase units/kg of feed; 150 g/ton of feed) according a 6 × 2 factorial arrangement; dietary NDF ranged from 12 to 20% of DM. Pigs (5 per treatment) were placed in metabolism cages that allowed total collections of feces and urine for 10 d after a 11 d adaptation period. Samples were analyzed for GE, ash and N. Digestibilities of GE, N and organic matter (OM) and N balance were calculated. The effects of diet and enzyme were evaluated by ANOVA. In addition, the DE and digestible nutrient contents of ingredients were calculated by regression of nutritive values of diets on levels of ingredients inclusions. Apparent total tract digestibilities of OM, N and GE of diets were affected by diet characteristics ( $P < 0.001$ ) in connection with a negative effect of NDF content ( $R = -0.97$ ;  $P < 0.001$ ) and were increased ( $P < 0.05$ ) by enzyme addition (Enz) with +0.69, +1.68 and +0.76% units for OM, N and GE digestibilities, respectively. Increases in DE value due to Enz averaged 0.12 MJ per kg DM (15.11 vs 14.99 MJ/kg DM;  $P < 0.001$ ). The ADG (878 vs. 834 g/day;  $P < 0.05$ ) and N balance were also increased by Enz addition, suggesting that it may overcome limiting amino acid contents. The calculated DE content per ingredient averaged 16.0, 16.6, 15.0, 10.6 and 16.7 MJ/kg DM for wheat, corn, barley, wheat bran and soybean meal, respectively. The Enz addition increased the DE value of diets similar to the ingredients (+0.12 MJ/kg DM). Considered per ingredient, tendencies for a better response was observed for wheat and soybean meal (0.48 and 1.25 MJ/kg DM, respectively). In conclusion, apparent total tract digestibility for energy of diets or raw materials can be increased by Enz addition.

**Key Words:** digestible energy, enzyme, pig

**1112 Effects of fibers with different fermentation characteristics on feeding motivation in adult pigs.** C. Souza Da Silva\*<sup>1,2</sup>, J. E. Bolhuis<sup>1</sup>, W. J. J. Gerrits<sup>2</sup>, B. Kemp<sup>1</sup>, and J. J. G. C. van den Borne<sup>2</sup>, <sup>1</sup>Adaptation Physiology Group, Wageningen University, Wageningen, The Netherlands, <sup>2</sup>Animal Nutrition Group, Wageningen University, Wageningen, The Netherlands.

Dietary fibers can be fermented in the colon, resulting in production of short-chain fatty acids (SCFA) and secretion of satiety-related peptides such as GLP-1 and PYY. Recently, we have shown that a diet containing 40% native potato starch reduced feeding motivation in adult pigs up to 7 h after feeding. The aim of the current study was to assess the effects of fibers with varying fermentation characteristics on feeding motivation in adult pigs. Sixteen pair-housed gilts (250 kg BW) received 4 diets: inulin (INU), guar gum (GG), retrograded tapioca starch (RS), and control (C), in 4 periods in a Latin square design. Each period, pigs were fed a low fiber (L) followed by a high fiber (H) diet (7 d each). Fiber levels were 7% and 14% for INU, 5% and 10% for GG, 17% and 34% for RS. Fibers were exchanged for starch from the C diet based on gross energy. Pigs received 1050 g of feed twice daily.

J. J. Mallo<sup>\*1</sup>, A. Balfagon<sup>2</sup>, M. I. Gracia<sup>3</sup>, M. Puyalto<sup>1</sup>, and P. Honrubia<sup>1</sup>, <sup>1</sup>Norel S.A., Madrid, Spain, <sup>2</sup>SCA Iberica S.A., Mequinenza, Aragon, Spain, <sup>3</sup>Imasde Agroalimentaria S.L., Madrid, Spain.

The objective of these 2 tests was to compare 2 forms of butyric acid (BA) protection on the liberation of BA along the gastrointestinal tract (GIT) in piglets. The 2 forms of BA were: vegetable fat-encapsulated sodium butyrate (SBE) and monoglyceride of butyric acid (MB). In the first trial, 528 piglets were weaned at 21 d of age, divided and assigned to 3 diets in 8 replicate pens of 22 piglets per pen for 39 d. The 3 diets were 1) pre-starter and starter (C), 2) C+SBE, and 3) C+MB. Piglets fed C or C+SBE tended to show higher body weight than piglets fed C+MB (18.74 or 18.66 vs. 17.82 kg;  $P = 0.0995$ ) and average daily gain (331 or 331 vs. 309 g/d;  $P = 0.0512$ ). Feed intake and gain/feed were not different among diets. In the second trial, 8 pens of 4 piglets each (4 pens/diet), weaned at 21 d, were given either a standard post-weaning program with SBE (2 g/kg) or MB (2 g/kg) for 28 d. Piglets received the same amount of BA. At the end of the trial, one animal per pen was euthanized and the concentration of BA and volatile fatty acids (VFA) in duodenum, jejunum, ileum, colon and cecum were quantified with HPLC. There were no statistical differences in growth, feed intake, or gain/feed. However, piglets fed SBE had higher concentration of VFA in colon than those MB fed animals (8.24 vs 5.11 mmol/g of BA;  $P = 0.032$ ; 19.26 vs 11.49 mmol/g of propionic acid;  $P = 0.12$ ; 31.25 vs 15.42 mmol/g of acetic acid;  $P = 0.054$ ; 29.44 vs 17.22 mmol/g of lactic acid;  $P = 0.027$  and 58.75 vs 32.02 mmol/g of total VFA;  $P = 0.0477$ ). There were relevant numerical but non-statistically significant differences in the rest of the GIT sections. It is concluded that the addition of sodium butyrate encapsulated with vegetable fat allows more BA to reach the distal sections of the GIT than MB. The higher levels of VFA in the intestine may be related to a negative correlation with enterobacteria populations and a positive correlation with lactic acid-producing bacteria.

**Key Words:** butyric, coated, VFA

**1119 Artificial sweeteners do not all increase glucose absorption at the same level in piglets.** A. Moran<sup>1</sup>, D. Batchelor<sup>1</sup>, S. Shirazi-Beechey<sup>1</sup>, D. Bravo<sup>2</sup>, and C. Oguey<sup>\*2</sup>, <sup>1</sup>University of Liverpool, Liverpool, United Kingdom, <sup>2</sup>Pancosma SA, Geneva, Switzerland.

Early weaning in piglets generates many intestinal disorders such as impaired nutrient absorption, diarrhea or dehydration. Various strategies were developed to minimize these issues. It was previously shown that low levels of a high intensity sweetener based on saccharin and NHDC (SUCRAM<sup>®</sup>, Pancosma) was detected by intestinal sweet taste receptor, T1R2/T1R3 present in enteroendocrine cells. This activated a pathway resulting in the upregulation of intestinal Na<sup>+</sup>/glucose co-transporter (SGLT1). As a consequence, glucose absorption was increased. The objective of this study was to evaluate if other artificial sweeteners had the same effect on SGLT1 expression. A total of 40 weaned piglets (28 d old) were fed

a diet free of any sweetener and allocated to one of the 5 treatments (n = 8). Animals were offered water containing either no sweetener, sucralose (2 mM), cyclamate (10 mM), aspartame (1 mM) or acesulfame K (10 mM). All groups consumed the same amount of feed and water. After 3 d they were humanely euthanized. Levels of intestinal SGLT1 mRNA abundance were measured. Results showed that SGLT1 mRNA abundance was not modulated by acesulfame K addition. However, SGLT1 expression was increased for animals supplemented with sucralose (2.73 folds,  $P = 0.003$ ), cyclamate (3 folds,  $P \leq 0.001$ ) and aspartame (2.8 folds,  $P \leq 0.001$ ) when compared with unsupplemented piglets. These results demonstrate the specificity of piglets sweet taste perception and that artificial sweeteners do not induce the same physiological response in the intestine. Consequently the lowest concentrations of other artificial sweeteners able to promote glucose absorption must be assessed before considering them as feed supplements.

**Key Words:** artificial sweeteners, glucose absorption, piglets

**1120 Expression of the small intestinal Na-neutral amino acid co-transporter B0AT1 (SLC6A19) in early-weaned pigs.** Z. Wang<sup>1</sup>, C. Yang<sup>2</sup>, T. Archbold<sup>3</sup>, M. Hayhoe<sup>\*3</sup>, K. Lien<sup>4</sup>, and M. Fan<sup>3</sup>, <sup>1</sup>Henan Agricultural University, Zhengzhou, Henan Province, China, <sup>2</sup>Lucta-Guangzhou Flavours Co., Ltd., Guangzhou, Guangdong Province, China, <sup>3</sup>University of Guelph, Guelph, Ontario Canada, <sup>4</sup>University of Alberta, Edmonton, Alberta, Canada.

System-B0 Na-neutral AA co-transporter B0AT1 (SLC6A19) plays a dominant role for intestinal apical uptake of neutral AA. The objective of this study was to examine changes in the gut B0AT1 expression in early-weaned compared with suckling piglets. Yorkshire piglets (12 barrows and 12 gilts) at 10 d of age were obtained from 20 different sows and used in this study. The weaning group of 12 piglets (6 barrows and 6 gilts) was fed on a corn and SBM-based weaning diet, formulated according to NRC (1998), for 12 d. The other 12 piglets, including 6 barrows and 6 gilts as a suckling control, were allowed to suckling with their sows for 12 d. Proximal jejunal samples were collected at age of 23 d. The jejunal tissue samples were partitioned into apical membrane and cytosolic fractions by differential centrifugation. Target gene protein abundances were analyzed by Western blotting while their gene mRNA relative abundances were measured by qRT-PCR with the SYBR Green kit. Except Met, there were no differences ( $P > 0.05$ ) in the jejunal free neutral AA concentrations (nmol/mg tissue protein) between the 2 groups. When expressed by using  $\beta$ -actin as a housekeeping control, there were no differences ( $P > 0.05$ ) in B0AT1 protein abundances in the jejunal homogenate, the apical membrane and the cytosolic fraction between the weaning and the suckling pigs. However, B0AT1 protein abundances in the jejunal homogenate and the apical membrane were higher ( $P < 0.05$ ) in the barrows than in the gilts. Although real time RT-PCR analyses showed no difference ( $P > 0.05$ ) in the SLC6A19 mRNA abundance relative to  $\beta$ -actin between the weaning and the suckling pigs, the SLC6A19 mRNA

abundance was higher ( $P < 0.05$ ) in the barrows than in the gilt. Our results suggest that the apical Na-neutral AA co-transporter B0AT1 expression is reserved during the weaning in pigs. These observations provide cellular mechanism for promoting dietary supplementation of crystalline neutral AA to improve gut growth and performance in weaning pigs with barrows likely being more responsive.

**Key Words:** early-weaned pigs, gene expression, sodium-neutral amino acid co-transporter B0AT1

**1121 Cocoa husks in diets of Italian heavy pigs.** D. Magistrelli,\* L. Malagutti, G. Galassi, and F. Rosi, *University of Milan, Milan, Italy.*

According to their nutritional composition, some wastes from the agroindustry may have a potential for use in livestock production. In particular, by-products derived from chocolate production can be considered worth of interest for animal nutrition. Cocoa husks have a high concentration of lignin, but also a high content of proteins, lipids and NDF. Cocoa is also rich in antioxidants. To verify the possibility of using cocoa-derived products in pig nutrition, the effect of cocoa husks administration on liver composition of Italian heavy pigs was studied. Eight finishing pigs (Duroc x Large White) were divided into 2 homogeneous groups: a control group (C) fed a traditional pelleted diet, based on cereals, and a treatment group (T) fed a diet obtained by substitution of 10% of the control diet with coarsely-ground cocoa husks. Animals were kept into individual steel boxes, under identical condition for light and temperature. All the pigs were fed twice a day (8:00 a.m. and 5:00 p.m.) and water was always available. During the experimental period, individual dry matter intake was recorded daily, body weight was recorded weekly. Experimental diets were analyzed for nutritional composition and gross energy. After 6 weeks, all the pigs were slaughtered. Body, carcass, and liver weights were recorded and hot dressing percentage was calculated. Backfat thickness was determined using the Fat-O-Meter and liver samples were taken and analyzed for dry matter (DM), ether extract and total cholesterol. Data were analyzed by a one-way ANOVA, using the GLM procedure of SAS. Cocoa husks diet reduced individual dry matter intake by 10% ( $P < 0.01$ ) and energy intake by 8% ( $P < 0.01$ ). Neither body weight ( $P = 0.90$ ) nor backfat thickness ( $P = 0.63$ ) was affected by cocoa diet. Treatment did not influence carcass weight ( $P = 0.83$ ) and dressing percentage ( $P = 0.72$ ). Cocoa husks reduced liver weight ( $P < 0.05$ ) and dry matter percentage ( $P < 0.01$ ), but increased ether extract (% DM) ( $P < 0.01$ ), without affecting liver cholesterol (mg/g DM) ( $P = 0.79$ ).

**Key Words:** cocoa, liver, heavy pigs

**1122 Microscopic matrix and in vitro pig model fermentation of wheat and corn distillers dried grains with solubles with supplemental carbohydrases and protease.** R. Jha\*<sup>1</sup>, J. Li<sup>1</sup>, M. R. Bedford<sup>2</sup>, C. R. Christensen<sup>3</sup>, T. Vasanthan<sup>1</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>AB Vista Feed Ingredients, Wilts, UK, <sup>3</sup>University of Saskatchewan, Saskatoon, SK, Canada.

Digestibility of distillers dried grains with solubles (DDGS) by porcine enzymes is lower than that of grains. The physico-chemical basis for the difference is poorly understood. Thus, 3 DDGS samples (2 wheat DDGS, wDDGS1 and wDDGS2 and a corn DDGS, cDDGS) were pre-digested with pepsin and pancreatin. Residues were then subjected to in vitro fermentation in a pig large intestine model, using buffered mineral solution inoculated with fresh pig feces. The fermentation was carried out with or without enzymes, carbohydrases (C) or carbohydrases + protease (C+P). In a 3 × 3 factorial arrangement, gas production during in vitro fermentation was determined up to 72 h. The fermentation broth was analyzed for volatile fatty acid (VFA) content. The matrix of native DDGS and their residues after fermentation was analyzed using confocal laser scanning electron microscopy (CLSM) and scanning electron microscopy (SEM). Total gas production was higher ( $P < 0.05$ ) for cDDGS than wDDGS, and was higher ( $P < 0.05$ ) for C than control and C+P. Total VFA production was similar in pattern as total gas; but DDGS and enzymes interacted ( $P = 0.003$ ). Total VFA production was highest ( $P < 0.05$ ) for cDDGS either control or C, and lowest for wDDGS2 with C+P (6.5, 6.2, and 4.0 mMol/g, respectively). Principle component analysis revealed that total gas and VFA produced correlated negatively with ADF and CP, and positively with starch of DDGS. Using CLSM and SEM, the fiber-starch-protein matrix of wDDGS2 was highly interspersed and less degraded; even after fermentation with C or C+P. In contrast, the matrix of cDDGS was loosely imbedded. In conclusion, C unlocked the fiber-starch-protein matrix better for fermentation than C+P, indicating that the substrate for C hinders degradation of the DDGS matrix. The matrix of cDDGS is less imbedded and hence more fermentable than wDDGS.

**Key Words:** DDGS, enzymes, fermentation

**1123 Microbial fermentation in the hindgut—Energy contribution to sows fed diets differing in dietary fibre source with and without addition of a live yeast.** N. Canibe\*<sup>1</sup>, E. C. Soto<sup>2</sup>, H. Jørgensen<sup>1</sup>, K. E. Bach Knudsen<sup>1</sup>, and B. B. Jensen<sup>1</sup>, <sup>1</sup>Aarhus University, Blichers Allé 20, 8830 Tjele, Denmark, <sup>2</sup>Estación Experimental del Zaidín (CSIC), Alameda, Granada, Spain.

Microbial fermentation in the hindgut supplies the host with energy as short-chain fatty acids (SCFA). The contribution made by fermentation to the total energy economy of the animal is not clear. The amount and fermentability of substrates entering the hindgut depends to a great extent on the dietary fiber level and source. Live yeasts have been reported to stimulate growth and/or activity of fibrolytic bacteria and thereby potentially influence the degradation of dietary fiber. The aim of the present study was to measure the digestibility and assess, using an in vivo-in vitro methodology, the available energy from hindgut fermentation to sows fed diets differing in dietary fiber source amended or not the live yeast *Saccharomyces cerevisiae* ssp. *boulardii* CNCM I-1079 (SB). Sixteen sows were fitted with a simple T-shaped cannula at the terminal ileum and offered 4 diets: a wheat bran diet with and without SB, and a sugar beet pulp diet with and without SB.



Freeze-dried ileal samples were incubated anaerobically with fecal slurry in an in vitro batch system for 48 h at 38°C. The pH was automatically adjusted to 6.0. Available energy from hindgut fermentation was calculated from the amount of SCFA produced in vitro and excreted in vivo, and the in vivo ileal energy digestibility. The ileal digestibility of non-starch polysaccharides (NSP) (16% vs. -13%) and the fecal digestibility of DM (81.3% vs. 75.5%), gross energy (81.6 vs. 75.5%) and NSP (80.8 vs. 56.3) of the sugar beet pulp-containing diets was higher than that of those containing wheat bran ( $P \leq 0.01$ ). The energy available from hindgut fermentation was between 13 and 16% of the total energy without differences between diets. Feeding diets based on the 2 fiber sources and supplemented or not SB did not affect the energy available from hindgut fermentation.

**Key Words:** hindgut, fermentation, energy

**1124 Effect of immune system stimulation and divergent selection for residual feed intake on digestive capacity of the small intestine in growing pigs.** A. Rakhshandeh<sup>\*1</sup>, T. E. Weber<sup>2</sup>, J. C. M. Dekkers<sup>1</sup>, B. J. Kerr<sup>2</sup>, J. English<sup>1</sup>, and N. K. Gabler<sup>1</sup>, <sup>1</sup>Iowa State University, Ames, IA, USA, <sup>2</sup>USDA-ARS, Ames, IA, USA.

Residual feed intake (RFI) is a measure of feed efficiency that reflects differences in the efficiency of the use of feed for maintenance and growth. The consequences of genetic selection for RFI on intestinal nutrient digestion capacity, particularly during immune system stimulation (ISS), are poorly documented. Our objective was to evaluate the impact of ISS and genetic selection for RFI on apparent ileal digestibility (AID) of nutrients, and intestinal nutrient transport and barrier function. Twenty 8 gilts (BW 63 ± 4 kg) from lines of Yorkshire pigs selected for low RFI ( $n = 14$ ) and high RFI ( $n = 14$ ) were randomly selected from the Iowa State University RFI herd and used in the current study. Following adaptation, 8 pigs in each line were injected intramuscularly and every 48 h, for 7 d, with increasing amounts of *E. coli* lipopolysaccharide (ISS+). Remaining pigs were injected with saline (ISS-). Pigs were then euthanized, ileal digesta collected for measuring nutrient digestibility, and jejunum used to measure glucose transport (GLU) and transepithelial resistance/barrier integrity (TER) by Ussing chambers. As expected, ISS increased eye temperature (ISS- vs. ISS+; 37.6 vs. 38.4°C, SE 0.04), plasma levels of haptoglobin (2.6 vs. 3.5 g/L, SE 0.38) and interleukin-1 $\beta$  (1 vs. 152 ng/L, SE 35), indicating effective ISS ( $P < 0.05$ ). No effects of line or its interaction with ISS on AID of crude protein (CP) and organic matter (OM), TER and active glucose (GLU) transport were observed ( $P > 0.10$ ). However, ISS decreased and tended to decrease AID of CP (ISS- vs. ISS+; 83 vs. 74%, SE 3;  $P < 0.05$ ) and OM (88 vs. 79%, SE 4;  $P < 0.08$ ), respectively. No effect of ISS on TER was observed ( $P > 0.10$ ). Relative to ISS-, active GLU transport was greater in ISS+ pigs (7 vs. 11 A/cm<sup>2</sup>, SE 1.5;  $P < 0.05$ ), indicating increased intestinal GLU absorption during ISS. Collectively, these results suggest that intestinal digestive capacity is affected by ISS but not by genetic selection for RFI. Supported by USDA-AFRI grant# 2011-68004-30336.

**Key Words:** residual feed intake, immune system stimulation, intestinal digestive capacity

**1125 Post-weaning evolution of plasma levels of zinc from different sources and doses in a commercial farm.**

R. Davin<sup>\*1</sup>, E. G. Manzanilla<sup>1</sup>, S. Durosoy<sup>2</sup>, and J. F. Perez<sup>1</sup>, <sup>1</sup>Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain, <sup>2</sup>Animine, SILLINGY, France.

Post-weaning diarrhea could be related to a Zn deficiency. Plasma level of Zn in weaned pigs is lower than in unweaned littermates at the same age. Therapeutic levels of in-feed ZnO re-establish pre-weaning levels of plasma Zn. We studied different sources and doses of Zn to check their ability to maintain plasma levels of Zn after weaning. A total of 200 pigs were weaned at 26 d of age and allocated to 20 pens. Pens were randomly allocated to 10 dietary treatments. Treatments were: a commercial diet including colistin and 3100 ppm of ZnO (COM); an experimental diet without any source of zinc other than the ingredients (33 ppm of Zn) considered zinc deficient compared with NRC recommended levels (100 ppm of Zn) (DEFIC); DEFIC supplemented to NRC levels of Zn with either ZnO (NRCZnO) or ZnSO<sub>4</sub> (NRCZnS); DEFIC supplemented to 150 ppm of Zn (EU maximum inclusion level) with either ZnO (150ZnO) or ZnSO<sub>4</sub> (150ZnS); DEFIC supplemented to 250ppm and 700 ppm of Zn with ZnSO<sub>4</sub> (250ZnS and 700ZnS); DEFIC supplemented to 2500 ppm of Zn with ZnO (2500ZnO); and an extra treatment using NRCZnO but fasting animals for 24 h hours after weaning to increase deficiency (FAST). Two animals per pen were bled on days -1, 1, 2, 3, and 5 post weaning and plasma was analyzed for Zn. Plasma levels of Zn on day -1 were 0.82 mg/L. Most animals (75%) showed plasma levels of Zn considered deficient (<0.60 mg/L) in the first 2 d after weaning with a slight recovery after d 3 post weaning. Animals on DEFIC and FAST diets did not show lower plasma levels of Zn compared with animals on NRC diets even when a strong decrease was expected. The Zn source of choice for diarrhea treatment in humans (ZnSO<sub>4</sub>) was expected to be better absorbed by the animal than ZnO; however none of the treatments including ZnSO<sub>4</sub> increased plasma levels of Zn compared with ZnO. Both treatments including therapeutic levels of Zn, COM and 2500ZnO, reached pre-weaning plasma levels of Zn on d 2 or 3 post-weaning. Early weaning reduces plasma levels of Zn acutely in pigs. Currently used therapeutic levels of ZnO were the only treatments able to bring plasma levels of Zn close to pre-weaning levels.

**Key Words:** zinc, plasma, diarrhea

**1126 Dynamic changes in digestive capability may contribute to compensatory growth following a nutritional insult in newly weaned pigs.** C. L. Levesque,<sup>\*</sup> L. Skinner, J. Zhu, and C. F. M. de Lange, University of Guelph, Guelph, Ontario, Canada.

Using low complexity diets may reduce feeding costs but can result in reduced starter pig growth performance. We have previously demonstrated that feeding low complexity diets compromises growth performance of pigs during the



first 3 weeks post-weaning and induces compensatory growth and improved feed efficiency thereafter. A study was undertaken to explore physiological mechanisms involved in compensatory growth following a nutritional insult. Fifty-six pigs were weaned at  $21 \pm 2$  d of age and fed high (H) or low (L) complexity diets for 6 wk. All pigs received the same grower diet thereafter. Pigs were killed at wk 2, 4, and 8 post-weaning and proximal jejunum and distal ileum were sampled for evaluation of histology and enzyme activity. In the proximal jejunum gut morphology was affected by diet at wk 2 and 4, but not at wk 8. Villus height was lower ( $P = 0.03$ ) at wk 2 in pigs on L than H (356 vs 427  $\mu\text{m}$ ) but not different at wk 4 (527 vs 492  $\mu\text{m}$ ). There was no effect of diet on crypt depth; villus height: crypt depth ratio increased ( $P = 0.02$ ) from wk 2 to wk 4 (2.1 vs 2.8) in pigs on L, but was not changed (2.3 vs 2.5) in pigs on H. Diet did not impact gut morphology at the distal ileum. Intestinal alkaline phosphatase (IAP) substrate affinity ( $\text{IAP}_{\text{Km}}$ ) was higher at wk 2 than wk 4 or wk 8 (2.70 vs 1.65 or 1.84  $\text{mmol/L}$ ,  $P < 0.05$ ) but was not affected by diet. Within week, maximal specific activity of IAP ( $\text{IAP}_{\text{Vmax}}$ ) was not affected by diet but was higher at wk 2 than wk 4 (0.157 vs 0.134  $\mu\text{mol/mg protein}\cdot\text{min}^{-1}$ ,  $P < 0.005$ ) in pigs on H and was not different at wk 4 (0.154 vs 0.138  $\mu\text{mol/mg protein}\cdot\text{min}^{-1}$ ,  $P = 0.17$ ) in pigs on L.  $\text{IAP}_{\text{Vmax}}$  was higher at wk 2 than wk 8 (0.155 vs 0.137  $\mu\text{mol/mg protein}\cdot\text{min}^{-1}$ ,  $P < 0.09$ ) regardless of diet. There was no effect of diet on  $\text{IAP}_{\text{Vmax}}$  or  $\text{IAP}_{\text{Km}}$  in the ileum. Compensatory growth observed in pigs following a nutritional insult after weaning may be due in part to improvement in digestive capability.

**Key Words:** digestive capability, nutritional insult, newly weaned pigs

**1127 Standardized ileal amino acid digestibility in egg from hyperimmunized-hens fed to nursery pigs.** J. M. Heo,\* E. Kiarie, R. Kahindi, T. A. Woyengo, and C. M. Nyachoti, *University of Manitoba, Winnipeg, MB, Canada.*

The aim of the study was to determine the apparent (AID) and standardized (SID) ileal AA digestibilities in whole egg from hens hyperimmunized with *E. coli* K88 antigens (EGG) fed to nursery pigs. Spray dried porcine plasma (SDPP) was included for comparison. Eight barrows (Yorkshire-Landrace  $\times$  Duroc; initial BW =  $17 \pm 1$  kg) fitted with a T-cannula at the distal ileum were fed 2 diets in a completely randomized design to give 4 observation per diet. The diets were cornstarch-based with either EGG or SDPP as the sole source of protein, and were formulated to contain 13% CP. At the end of the study, a 5% casein diet was fed to all pigs ( $n = 8$ ) to quantify endogenous N and AA losses to determine SID. Titanium dioxide (3 g/kg) was included in the diets as an indigestible maker. Each period lasted for 7 d. Pigs were acclimatized to their respective diets for 5 d followed by 12 h of continuous ileal digesta collection on d 6 and 7. Daily feed allowance was set a 4% BW at the beginning of each period and offered in 2 equal portions at 08:00 and 16:00 h as a dry mash. Pigs had unlimited access to water via low pressure nipple drinkers at all times. The AID (%) of all measured AA and CP were lower ( $P < 0.05$ ) in EGG compared with SDPP. The SID (%) of CP (82 vs. 96), Arg (80 vs. 100), His (71 vs. 94), Ile (75 vs. 95), Leu (74 vs.

94), Lys (71 vs. 95), Met (75 vs. 96), Phe (68 vs. 93), Thr (74 vs. 91) and Val (74 vs. 93) for indispensable AA and Ala (75 vs. 95), Asp (72 vs. 93), Cys (66 vs. 93), Glu (77 vs. 97), Ser (68 vs. 96) and Tyr (66 vs. 89) for dispensable AA were lower ( $P < 0.05$ ) in pigs fed EGG compared with SDPP. The average SID of indispensable AA between EGG and SDPP was 73% and 95%, respectively, thus suggesting that the SID of indispensable AA in EGG are approximately 23% lower than in SDPP.

**Key Words:** amino acid, digestibility, pig

**1128 High-moisture airtight storage of barley and wheat improves nutrient digestibility.** H. D. Poulsen,\* J. V. Nørgaard, and K. Blaabjerg, *Aarhus University, Department of Animal Science, Foulum, P.O. Box 50, Tjele, Denmark.*

Barley (B) and wheat (W) are often stored dry at a humidity not higher than 14%, which during rainy periods requires that the grains are dried after harvest. However, it is hypothesized that air tight storage of B and W with high moisture contents will result in higher nutrient digestibility due to chemical conversions taking place before feeding. The objective of this study was to evaluate the effect of high-moisture compared with dry storage of B and W on the digestibility of phosphorus (P) and protein. The crops were grown on the same field keeping all other factors constant. Half of the grains was harvested in the morning after a rainy day and stored in airtight silos (DM: B 85.2%; W 82.8%) and the other half was harvested later the same day (windy and sunny) and stored dry (DM: B 89.8%; W 88.3%). After 6 mo of storage, a low and a high moisture diet was prepared with a B:W ratio of 1:1 mixed with soybean meal and rape seed cake to produce a normal compound diet without inorganic P and microbial phytase. Sixteen pigs (45 kg) housed in metabolism crates were fed either the low or the high moisture diet for 5 d for adaptation and 7 d for total collection of feces. The P digestibility was 41 in the low and 46% in the high-moisture diet ( $P < 0.01$ ). Similarly, the protein digestibility was 78 and 81% ( $P = 0.10$ ). The phytase activity of the dry was lower than the high-moisture stored grain (870 vs. 990 FTU/kg DM). This suggests that high-moisture storage of grain was superior in maintaining the activity of phytase. Overall, the high-moisture storage increased the digestibility of phosphorus and protein when the grain was fed to finishing pigs. Thus, high-moisture air tight storage saved energy (no drying) and at the same time enhanced the availability of P and protein and improved the nutritional value of grains probably through enzymatic activity during storage.

**Key Words:** high-moisture storage, phosphorus, protein

**1129 Dose response of a new phytase on dry matter, calcium and phosphorus digestibility in weaned piglets.** M. H. L. Bento\*<sup>1</sup>, C. Pedersen<sup>2</sup>, P. W. Plumstead<sup>1</sup>, L. Salmon<sup>3,1</sup>, C. M. Nyachoti<sup>4</sup>, and P. Bikker<sup>5</sup>, <sup>1</sup>*Danisco Animal Nutrition, Marlborough, Wiltshire, United Kingdom*, <sup>2</sup>*Livestock Feed Consultancy Ltd., Wilton, Wiltshire, United Kingdom*, <sup>3</sup>*Premier Nutrition, Rugeley, Staffordshire, United Kingdom*, <sup>4</sup>*University of Manitoba, Department of Animal*

Science, Winnipeg Manitoba, Canada, <sup>5</sup>Wageningen UR Livestock Research, Lelystad, The Netherlands.

When fed to pigs, phytase increases the availability of phytate bound phosphorus (P) in plant feedstuffs resulting in a reduced requirement for additional dietary inorganic P. Therefore, the total P content in the diet can be reduced, which reduces feed cost and also results in reduced P excretion which is important for environmental reasons. The present study evaluated the dose response of a new phytase (*Buttiauxella* expressed in *Trichoderma reesei*, Danisco Animal Nutrition, Marlborough, UK) in weaned piglets. Experiments were conducted at 2 different locations. In both trials, piglets were fed a commercial post weaning diet, followed by an experimental diet for a period of 12 to 14 d. Piglets were fed one of the following experimental diets during the experimental period: a positive control (PC) diet, a negative control (NC) diet with reduced P and calcium (Ca), or the NC diet + graded doses of 250, 500, 750, 1000, and 2000 FTU phytase/kg feed (for Trial A) or NC diet + graded doses of 250, 500, 1000, and 2000 FTU phytase/kg feed (for Trial B). Fecal sampling took place over the last 4 d of the experimental period. Apparent total tract digestibility of dry matter (DM), Ca and P was evaluated. In Trial A, digestibility of P was (%): 57.2 for PC, 32.5 for NC, 59.4 for 250 FTU, 62.0 for 500 FTU, 63.8 for 750 FTU, 66.0 for 1000 FTU, and 67.3 for 2000 FTU. In Trial B, digestibility of P was (%): 45.2 for PC, 28.4 for NC, 58.7 for 250 FTU, 64.1 for 500 FTU, 67.9 for 1000 FTU, and 70.9 for 2000 FTU. In both studies, the reduction in P in the NC diets resulted in poorer digestibility of P when compared with the PC diets ( $P < 0.001$ ). Phytase supplementation improved ( $P < 0.001$ ) P digestibility at all inclusion levels to the NC control diet. Furthermore, these responses to increasing phytase dose were linear and quadratic ( $P < 0.001$ ). The improvement in P digestibility at 250 FTU/kg averaged 74% of the response found at 2000 FTU/kg.

**Key Words:** *Buttiauxella* phytase, piglets, P digestibility

**1130 Hypophosphatemia during refeeding with corn-soy-blends is prevented by addition of milk or permeate.** A. Hother<sup>1</sup>, M. Lykke<sup>1</sup>, T. Martinussen<sup>2</sup>, C. Mølgaard<sup>1</sup>, P. T. Sangild<sup>1</sup>, C. F. Hansen<sup>3</sup>, H. Friis<sup>1</sup>, K. F. Michaelsen<sup>1</sup>, and T. Thymann<sup>\*1</sup>, <sup>1</sup>Department of Human Nutrition, University of Copenhagen, DK-1958 Frederiksberg C, Denmark, <sup>2</sup>Basic Sciences and Environment, DK-1958 Frederiksberg C, <sup>3</sup>Large Animal Sciences, DK-1870 Frederiksberg C.

Corn-Soy-Blends (CSB) may not meet the requirement during recovery from acute malnutrition. A recent reformulation to include more phosphorus (CSB+) and skim milk powder (CSB++) was therefore introduced. We tested the hypothesis that inclusion of skim milk powder or addition of permeate, a cost-effective phosphorus-rich by-product from the dairy industry, would prevent hypophosphatemia during refeeding in a pig-model of acute child malnutrition. Weaned pigs were nutritionally depleted for 7 weeks (wks) by feeding a pure maize diet. They were then allocated to 4 groups given either pure maize (n = 8), CSB+ (n = 9), CSB+ added permeate (n = 9) or CSB++ (n = 10) for 3 wks. During the initial nutritional depletion period, there was no change

in body weight. Average BW before refeeding was  $7.6 \pm 1.4$  kg (mean  $\pm$  sd). Relative to maize-fed pigs, refeeding with CSB+, CSB+ added permeate or CSB++ showed, similar increments in BW (2.42 kg; 95%CI:1.75;3.08), and bone mineral density (0.03 g/cm<sup>2</sup>; 95% CI: 0.01;0.05). However, refeeding with CSB+ created transient hypophosphatemia during the first week of refeeding (25% reduction in serum inorganic phosphate (S-Pi) level relative to maize-fed pigs, 95%CI: 9–37%) but returned to pre-refeeding levels after 2 wks. In contrast, refeeding with CSB+ added permeate or CSB++ prevented transient hypophosphatemia during the first wk of refeeding and after 3 wks S-Pi was 21% (95%CI: 2–42%) higher in CSB++ fed pigs relative to CSB+ fed pigs. The effect of refeeding with CSB+ added permeate on S-Pi was at no time point during the 3 wks different from the effect of CSB++. The content of phosphate in milk products, including permeate seems to be effective to prevent a transient decline in S-Pi and resulted in higher S-Pi levels after 3 wks. This effect is likely due to the higher bioavailability of phosphorus from milk products. We conclude that addition of milk products to vegetable-based refeeding diets may be important for malnourished patients susceptible to hypophosphatemia during refeeding.

**Key Words:** malnutrition, refeeding, phosphate

**1131 Severe acute malnutrition (SAM) in early life reduces gut function and structure.** M. Lykke, A. Hother, P. T. Sangild, K. F. Michaelsen, H. Friis, C. F. Mølgaard, and T. Thymann,\* Department of Human Nutrition, University of Copenhagen, DK-1958 Frederiksberg C, Denmark.

Malnutrition is known to affect multiple organ systems including the liver, heart, kidney and brain. However, relatively little is known about gastrointestinal structure and function during malnutrition, and most evidence is derived from cross sectional studies. Our objective was to investigate effects of malnutrition in a prospective study using a piglet model. We hypothesized that a uniform maize flour diet, resembling a diet commonly ingested in developing countries, would induce symptoms of malnutrition and reduce gut structure and function. Four-week old pigs were weaned and given ad libitum access to either maize flour (MAIZE, n = 12) or a nutritionally optimized diet (CONTROL, n = 12). Weekly blood samples and anthropometric measurements were collected. All pigs were euthanized after 7 weeks and organ dimensions were determined. Relative to control, maize-fed pigs displayed very clear symptoms of malnutrition as indicated by reduced body weight ( $8.3 \pm 0.6$  vs  $32.4 \pm 1.2$  kg;  $P < 0.001$ ) and reduced hemoglobin ( $P < 0.01$ ), hematocrit ( $P < 0.05$ ) and mean cell volume ( $P < 0.01$ ) from wk 3 and onwards. Villous height in both the proximal and distal small intestine was significantly reduced in MAIZE relative to CONTROL (proximal:  $286 \pm 17$   $\mu$ m, vs  $623 \pm 49$   $\mu$ m and distal:  $268 \pm 12$   $\mu$ m vs  $421 \pm 11$   $\mu$ m, both  $P < 0.001$ ). However, the difference in villous height was only to a minor degree associated with a functional change in brush-border enzyme activity, where sucrase was increased ( $2.16 \pm 0.23$  vs  $1.60 \pm 0.15$  U/g,  $P < 0.05$ ) and aminopeptidase A was decreased ( $2.29 \pm 0.21$  vs  $3.18 \pm 0.27$  U/g,  $P < 0.05$ ) in MAIZE versus CONTROL. No differences in maltase, lactase aminopeptidase N and dipeptidylpeptidase IV were

observed. Feeding a uniform maize diet induces symptoms characteristic of severe acute malnutrition and significantly reduces intestinal villous height. Increased sucrase activity in maize-fed pigs may indicate increased crypt cell activity to regenerate normal gut structure. We conclude that the intestine is significantly affected by malnutrition. This may be important to consider during treatment or nutritional rehabilitation.

**Key Words:** malnutrition, intestine, atrophy

**1132 Evolution of zinc, iron, and copper concentrations along the gastrointestinal tract of pigs weaned with or without in-feed high doses of zinc oxide compared to unweaned littermates.** R. Davin<sup>\*1</sup>, E. G. Manzanilla<sup>1</sup>, K. C. Klasing<sup>2</sup>, and J. F. Perez<sup>1</sup>, <sup>1</sup>Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain, <sup>2</sup>University of California - Davis, Davis, CA, USA.

High doses of Zn are used to treat diarrhea in piglets but are an environmental concern. Mechanisms of action of Zn against diarrhea are still not well understood. Solubilized Zn, interaction of Zn with Fe and Cu, and concentration of these metals in the gastrointestinal tract (GIT) of nursing pigs are key data to understand its mechanism of action and optimize its use. Eight litters were used and 3 piglets were selected within each litter. Two of pigs from each litter were weaned at 21 d of age and fed 2 different diets; a commercial control diet (Ct) and Ct diet + 2000 ppm of ZnO (dZn). The third pig was kept unweaned (Uw) with the rest of the litter. All 24 selected pigs were killed at 28 d of age and GIT contents were sampled. Soluble and insoluble fractions of the GIT content were separated, and Zn, Fe, and Cu concentrations were analyzed. Soluble fraction of the GIT content represented 20–50% less of the total GIT content in Uw pigs than in weaned pigs, except for the ileum. Total concentration of metals increased along the GIT in all animals. Concentration of Zn in the insoluble fraction increased 3–5 fold for weaned pigs fed dZn compared with Ct and Uw pigs ( $P < 0.01$  in all cases). Percentage of solubilized Zn was 4–10 folds higher in jejunum, ileum, and cecum of Uw animals than in weaned ones. Concentration of soluble Fe along the GIT was higher for unweaned pigs than for weaned ones ( $P < 0.05$  in all cases) even when the total amount of Fe was lower for these animals in stomach ( $P = 0.001$ ) and jejunum ( $P = 0.028$ ). Unweaned pigs showed lower concentrations of Cu along the GIT compared with weaned littermates ( $P < 0.05$  in all cases). Surprisingly, animals on dZn showed a 5–10 fold increase of Cu solubilized in distal parts of the GIT ( $P < 0.001$ ). High variations and interactions were found among GIT sections and treatments that could modify metal absorption and effects on microbiota. Levels found in weaned animals are very different from physiological levels found in Uw animals. These differences could indicate possible imbalances due to weaning.

**Key Words:** zinc, copper, diarrhea

**1133 Characterization of digestion discrepancy between in vitro and in vivo for co-products using spectroscopy.** L. F. Wang<sup>\*1</sup>, M. L. Swift<sup>1,2</sup>, and R. T.

Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>Alberta Agriculture and Rural Development, Lacombe, AB, Canada.

In vitro methods accurately predicted in vivo apparent total tract digestibility (ATTD) of energy for cereal grains ( $R^2 \leq 0.97$ ) but not for co-products ( $R^2 < 0.10$ ; in vitro vs. in vivo apparent ileal digestibility (AID) or ATTD). To explore, we scanned 496 samples of digesta, feces and in vitro digestion residues (*ivR*) from co-products on a Fourier transform mid-infrared instrument with a single-bounce attenuated total reflectance attachment. For corn distillers dried grains with solubles (DDGS), spectral intensity of the carbonyl ester peak at  $1744 \text{ cm}^{-1}$  was higher in *ivR* than in feces (0.020 vs. 0.004,  $P < 0.001$ ), indicating poor enzymatic digestion of unsaturated fat. In support, *ivR* spectra had a strong olefinic C-H peak at  $3008 \text{ cm}^{-1}$ . With acetone instead of water filtration, the carbonyl ester peak intensity dropped to 0.007. However, in vitro ATTD of energy of corn DDGS was still lower than in vivo (61.5 vs. 76.7%;  $P < 0.001$ ). Peak intensities of both C-OH at  $1033 \text{ cm}^{-1}$  and  $\beta$ -(1,4)-glycosidic linkage at  $897 \text{ cm}^{-1}$  were higher in *ivR* than in feces (0.055 vs. 0.029, 0.017 vs. 0.011, respectively;  $P < 0.001$ ), indicating that the in vitro assay poorly simulated fiber digestion. In contrast, the intensities of amide I peak at  $1641 \text{ cm}^{-1}$  and amide II at  $1535 \text{ cm}^{-1}$  of *ivR* spectra were lower than in vivo (0.014 vs. 0.021 and 0.010 vs. 0.027, respectively;  $P < 0.001$ ), suggesting that protein digestion of corn DDGS was not a major issue. Conversely, peak intensities of protein in *ivR* for canola cake were higher than in feces (Amide I area: 1.043 vs. 0.660;  $P = 0.001$ ), indicating that in vitro protein digestion was a major issue for canola cake. Similarly, principal component analysis of spectra indicated poor in vitro enzymatic digestion of fat and fiber for canola meal, canola seed, extruded flaxseed, and wheat millrun. In conclusion, the improvement of in vitro assay for co-products should focus on the simulation of fat and fiber digestion, and only in the sole case of canola cake on protein digestion.

**Key Words:** digestion, in vitro, spectroscopy

**1134 The effect of alkaline phosphatase in nursery pig diets containing dried distillers grains with solubles on performance and active intestinal glucose and phosphate absorption.** J. S. Radcliffe<sup>\*1</sup>, Z. Rambo<sup>1</sup>, B. E. Aldridge<sup>1</sup>, J. Ferrel<sup>2</sup>, D. Anderson<sup>2</sup>, D. Kelly<sup>1</sup>, and B. T. Richert<sup>1</sup>, <sup>1</sup>Purdue University, West Lafayette, IN, USA, <sup>2</sup>ChemGen Corporation, Gaithersburg, MD.

Individually housed, crossbred barrows (BW =  $5.70 \pm 0.04$  kg; 26 d age) were used to evaluate the effect of adding alkaline phosphatase (AP, 0.066 MU/kg) to corn-soybean meal-dried distillers grains with solubles (DDGS) based diets on active nutrient absorption using intestinal sections mounted in modified Ussing chambers. Pigs were blocked by BW, and allotted to the following diets (9 or 10 pigs/diet): 1) Positive Control (PC); 2) Negative Control (NC; ME and aP reduced 100 kcal/kg and ~1 g/kg, respectively); 3) NC+AP; 4) NC+AP+P (aP same as PC); and 5) NC+AP+Fat (ME same as PC). Pigs were fed a common phase 1 diet for 7d post-wean. Experimental diets were fed in 2 phases (d



0 to 5 and d 5 to 19) with 10 and 20% DDGS, respectively. At the end of the experiment, all pigs fed diets 1–4 were euthanized and a section of the jejunum was removed for use in modified Ussing chambers. Overall (d 0–19), ADG was numerically higher for PC and NC+AP+P over all other treatments (443, 409, 415, 438, 406 g/d, respectively). There was a tendency ( $P < 0.10$ ) for improved G:F for PC and NC+AP+P over NC (0.730, 0.664, 0.675, 0.726, 0.689, respectively). Active glucose absorption, estimated based on changes in short circuit current was 9.78, 18.55, 23.89 and 25.05  $\mu\text{A}/\text{cm}^2$  for the NC, PC, NC+AP+P, and NC+AP, respectively ( $P = 0.39$ , pooled SEM = 17). Active phosphate absorption, based on changes in short circuit current following phosphate addition to the serosal chamber, was highest ( $P < 0.05$ ) for pigs fed the NC diet. The addition of AP to the NC diet resulted in a 26% reduction in active phosphate absorption ( $P < 0.05$ ). Pigs fed the PC or the NC+AP+P had further reductions in active phosphate absorption of 53 and 64%, respectively, relative to the NC. The addition of Alkaline Phosphatase plus phosphorus recovered pig performance equal to the positive control. These data indicate an increase in luminal phosphate resulting in decreased active phosphate absorption with the addition of alkaline phosphatase.

**Key Words:** swine, alkaline phosphatase, nutrient absorption

**1135 The effects of  $\beta$ -mannanase and  $\beta$ -glucanase on nursery pig growth performance, intestinal morphology and active nutrient absorption.** Z. Rambo<sup>\*1</sup>, B. E. Aldridge<sup>1</sup>, B. T. Richert<sup>1</sup>, J. Ferrel<sup>2</sup>, D. Anderson<sup>2</sup>, and J. S. Radcliffe<sup>1</sup>, <sup>1</sup>Purdue University, West Lafayette, IN, USA, <sup>2</sup>ChemGen Corporation, Gaithersburg, MD, USA.

Forty-eight, crossbred pigs were weaned at ~19 d of age, fed a starter diet for 7 d and then moved to individual pens, where they were randomly allotted to treatments for a 21 d experiment (Phase 1: d7–14, 10% DDGS; phase 2: d14–28, 20% DDGS) to investigate the effects of  $\beta$ -mannanase or  $\beta$ -mannanase +  $\beta$ -glucanase on growth performance, intestinal morphology and active nutrient transport. Diets were 1) Positive control (PC), 2) Negative control (NC, reduced ME by 80 kcal/kg), 3) NC +  $\beta$ -mannanase (M), and 4) NC +  $\beta$ -mannanase +  $\beta$ -glucanase (M+G). At the end of the experiment, pigs were euthanized, intestines were weighed and measured, and a section of the jejunum was removed for histological examination and for use in modified Ussing chambers as an indicator of active nutrient absorption. Overall (d 7–28) ADG was 406, 406, 462, 455 g/d, for PC, NC, M, M+G, respectively. Overall ADFI decreased ( $P = 0.05$ ) for PC over M and G:F tended ( $P < 0.10$ ) to be higher for PC over NC while all others were intermediate (0.706, 0.635, 0.660, 0.674, respectively). The small intestine was 11% longer ( $P < 0.05$ ) in M+G fed pigs compared with all other diets. Stomach and intestinal weights, large intestine lengths, villus height, crypt depth and the villus:crypt did not differ. Basal short circuit current was greater ( $P < 0.01$ ) for M fed pigs compared with all other diets. Active glucose and

glutamine absorption, measured by a change in short-circuit current, were greater ( $P < 0.05$ ) in NC (83% increase) and M (73% increase) fed pigs than PC or M+G fed pigs. Active phosphate absorption was 87% greater ( $P < 0.05$ ) for PC fed pigs than M or M+G fed pigs, with NC fed pigs being intermediate. Active Gly-Sar absorption, basal resistance, and carbachol induced chloride ion secretion did not differ. The addition of M improved ADG and ADFI in phase 2 with numerical improvements in performance observed for the overall period and for G:F with the enzyme combination (M+G). These data suggest that the inclusion of M and G in nursery pig diets containing 20% DDGS has the potential to improve performance and modify nutrient uptake.

**Key Words:** swine,  $\beta$ -mannanase,  $\beta$ -glucanase

**1136 Effects of dietary true digestible Ca to P ratio on growth performance and efficiency of Ca and P utilization in growing pigs.** M. Fan,<sup>\*</sup> C. de Lange, and T. Archbold, University of Guelph, Guelph, Ontario, Canada.

Objectives of this study were to determine effects of dietary true digestible Ca to true digestible P ratio on growth performance and efficiency of Ca and P utilization in growing pigs fed corn-SBM based diets. Experiment 1 was carried out to measure true fecal digestibility of Ca and P as well as the fecal gastrointestinal endogenous outputs of these nutrients associated with a corn-SBM based diet in Yorkshire growing pigs by the substitution method. True fecal digestibility (% ,  $\pm$  SEM,  $n = 6$ ) of Ca ( $53.6 \pm 12.7$ ) and P ( $43.8 \pm 16.7$ ) as well as the endogenous outputs (g/kg DMI,  $\pm$  SEM,  $n = 12$ ) of Ca ( $0.91 \pm 0.20$ ) and P ( $1.31 \pm 0.15$ ) associated with the diets were determined. Experiment 2 was conducted with 36 Yorkshire barrows of an average initial BW of 24.2 kg and the pigs were fed 6 diets according to a completely randomized block design. The 6 diets were corn and SBM-based with diet 1 containing 0.2% true digestible Ca and 0.3% true digestible P and were formulated to contain 6 total Ca to total P ratios based on analyzed dietary Ca and P contents (diet 1, 0.6:1; diet 2, 0.7:1; diet 3, 0.8:1; diet 4, 1.3:1; diet 5, 1.0:1; and diet 6: 1.3:1) by supplementing gradient levels of limestone with dietary P level for meeting the recommended requirement. Changes in the dietary Ca to P ratio had no effects ( $P > 0.05$ ) on the average ADFI. Changes in the dietary Ca to P ratio had a linear effect ( $P < 0.05$ ) on the ADG with optimal responses occurred in diets 2 to 4. Changes in the dietary Ca to P ratio had linear, quadratic and cubic effects ( $P < 0.05$ ) on the feed conversion ratio with optimal responses also occurred in diets 2 to 4. However, due to a large variability, changes in the dietary Ca to P ratio had no effects ( $P > 0.05$ ) on dietary Ca and P digestibility and their efficiency of retention. Efficiency of P retention was numerically high in diets 2 and 3 but very low in diet 6. We conclude that changes in dietary Ca to P ratio have effects on growth performance in grower pigs.

**Key Words:** calcium to phosphorus ratio, endogenous Ca and P loss, grower pigs



## **Session III: Mucosal Immunity and Pathogenesis**

**2000 Promoting mucosal immunity—Developing new efficacious probiotics.** D. Kelly,\* *RINH, Institute of Medical Sciences, University of Aberdeen, Foresterhill, Aberdeen AB25 2ZD, Scotland.*

The gastrointestinal tract contains large numbers of microorganisms, collectively known as the gut microbiota. The early microbiota is derived from both maternal and environmental sources and is affected by factors such as genotype, antibiotics and nutrition. The early microbiota is heterogeneous and dynamic, reflecting the mixture of microbial populations associated with the environment. Recent studies have shown that the first period of postnatal life is characterized by fluctuating microbial diversity until convergence toward a stable adult microbiota. The microbiota has several important physiological properties including promoting pathogen resistance and immune development. The ability to limit pathogen colonization is either due to competition for similar micro-niches within the gut or to the production of antimicrobial factors. The immune modulatory effects of the gut microbiota are immense and a mechanistic understanding of how bacteria influence immune development and regulation is emerging. In the healthy animal a delicate balance is maintained between beneficial and potentially harmful bacteria. Imbalances between health promoting commensal bacteria and pathogens drives a wide range of mucosal and systemic immune responses that can be costly to health, growth and performance. Supplementing beneficial microorganisms in the gastrointestinal tract to improve intestinal function and boost animal growth and performance is considered an important and desirable alternative to antibiotic use. Probiotics which, by definition are 'live microorganisms which when administered in adequate amounts confer a health benefit on the host' provide an important opportunity to beneficially manipulate the gut microbiota. A large number of studies have failed to consistently demonstrate efficacy of current probiotics. However, new rigorous scientific screening approaches designed to select bacterial strains with robust biological efficacy provide an exciting opportunity for the development and exploitation of new generation of probiotics with proven ability to promote healthy immune function and limit enteric infections.

**2001 Effects of capsicum and turmeric oleoresins on performance, diarrhea, gut morphology, immune and inflammatory status of weaned pigs infected with a pathogenic *E. coli*.** Y. Liu<sup>1</sup>, M. Song<sup>1</sup>, JA Soares<sup>1</sup>, D. Bravo<sup>2</sup>, C. M. Maddox<sup>1</sup>, J. E. Pettigrew<sup>1</sup>, and C. Oguey<sup>\*2</sup>, <sup>1</sup>University of Illinois, Urbana, Illinois, USA, <sup>2</sup>Pancosma SA, Geneva, Switzerland.

Plant extracts are known to positively impact gut function and immune modulation. The objective of this trial was to evaluate if capsicum (CAP) and turmeric (TUR) oleoresins could affect performance, diarrhea, gut morphology, immune and inflammatory status of weaned piglets infected with a pathogenic F-18 *E. coli*. Weaned pigs (6.3 kg BW, 21 d old) were housed in disease containment chambers for 15 d and allocated to treatments according to a factorial arrangement (8 animals/treatment). First factor was with or without a F-18 *E. coli* challenge with 10<sup>10</sup> cfu/mL daily oral

dose for 3 d from d 0. Second factor was the diet type: control diet (CON), 10 ppm CAP or TUR. Performance parameters were measured at d 0, 5 and 11. On d 5 and 11, one-half of the pigs were euthanized to collect intestine to measure villi height (VH), crypt depth (CD), and their ratio (VH:CD). Diarrhea (DS) was daily scored individually (1: normal, to 5: watery diarrhea). Frequency of diarrhea (FD) was the percentage of pig days with DS  $\geq$  3. Blood was collected on d 0, 5, and 11 to measure white blood cell (WBC) counts, serum TNF- $\alpha$  and haptoglobin. The infection reduced overall performance and VH and increased DS and FD as expected. It increased ( $P \leq 0.05$ ) lymphocytes, TNF- $\alpha$  and haptoglobin on d 5, and WBC, neutrophils, lymphocytes, monocytes, and haptoglobin on d 11. In sham group, plant extracts improved ( $P \leq 0.05$ ) ADG from d 0 to 5 and reduced average DS from d 0 to 5 and FD. On d 5, CAP and TUR decreased ( $P \leq 0.05$ ) haptoglobin. In challenged group, plant extracts reduced ( $P \leq 0.05$ ) DS from d 3 to 5 and d 9 to 11, and overall FD. Plant extracts increased ileal VH on d 5 ( $P \leq 0.05$ ), jejunum VH ( $P \leq 0.1$ ) and VH:CD ( $P \leq 0.1$ ), without affecting growth performance. CAP decreased ( $P \leq 0.05$ ) TNF- $\alpha$  (-22.8%) and haptoglobin (-41.2%) on d 5, and WBC (-32.9%) and neutrophils (-39.4%) on d 11. TUR decreased ( $P \leq 0.05$ ) TNF- $\alpha$  (-20.7%) on d 5 and neutrophils (-40%) on d 11. This demonstrated that CAP and TUR positively affected performance, gut health humoral and cellular immune responses of pigs infected with *E. coli*.

**Key Words:** plant extracts, *E. coli*, disease resistance

**2002 Influence of the feed physical form (grinding intensity/compaction) on the incidence of immune cells, the mannose content in the mucus and the in vitro adhesion of *Salmonella Typhimurium* in the porcine intestine.** S. J. Sander\*<sup>1</sup>, A. Callies<sup>1</sup>, A. Beineke<sup>2</sup>, J. Verspohl<sup>1</sup>, and J. Kamphues<sup>1</sup>, <sup>1</sup>Institute for Animal Nutrition, University of Veterinary Medicine, Hannover, Germany, <sup>2</sup>Institute for Pathology, University of Veterinary Medicine, Hannover, Germany.

Former studies showed an influence of the feed structure on the secretion pattern of intestinal mucins (neutral/acid). The aim of the following studies was to evaluate further potential effects of feed physical form on the intestinal immune response of young pigs; first by evaluating numbers of IgA-secreting plasma cells (IgA-SC) and mast cells, second by determining the density of mannose in the intestinal mucus as a receptor for *Salmonellae* and third the in vitro adhesion of *Salmonellae* without the digesta as influencing factor. Forty-eight pigs (45  $\pm$  3 d, 14.2  $\pm$  2.35 kg BW) were fed identical diets as a coarse meal (CM) or a finely ground pellet (FP). After 6 wk, tissue from the duodenum, jejunum, ileum, cecum and colon were fixed in formaldehyde or Carnoy's solution. The first were stained immunohistologically for IgA-SC and mast cells; counts were expressed as cells/10,000 $\mu$ m<sup>2</sup> lamina propria. The second were stained with the lectin GNA (binds specifically to mannose). The GNA-stained secreted mucus was scored by 1 = < 25%, 2 = 25–50%, 3 = 50–75%, 4 = > 75% of the whole mucus. Ileal and cecal mucosa were incubated with *S. Typhimurium*, washed and diluted to count

*Salmonellae* adhering to the mucus/mucosa. Throughout the whole intestine, lower numbers of IgA-SC were found after feeding the CM compared with the FP with significant differences in the ileum and cecum (ileum:  $17.7 \pm 4.74$  vs.  $22.9 \pm 6.90$ ,  $P = 0.04$ ; cecum:  $20.9 \pm 4.14$  vs.  $25.6 \pm 5.71$  IgA-SC/10,000 $\mu\text{m}^2$ ,  $P = 0.03$ ). In contrast, mast cells varied on a low level with  $\sim 1.2$  cells/10,000 $\mu\text{m}^2$  without differences between the groups. Lectin histochemistry did not reveal differences in the mannose density in the mucus with scores varying between 3.6 and 3.9 in the ileum as well as in the cecum. In the in vitro model *Salmonella* counts were about 7.1 lg cfu/g tissue in the ileum for both groups. In the cecum counts of  $6.7 \pm 0.30$  (CM) and  $6.8 \pm 0.21$  (FP) lg cfu/g were obtained; results were not significantly different ( $P = 0.63$ ). Although the number of IgA-SC was lower after feeding the CM diet, perhaps due to higher protective properties of the intestinal mucus layer (higher amounts of acid mucins), feed structure had neither an influence on the in vitro adhesion of *Salmonellae* nor on the mannose density in the mucus as a receptor for *Salmonellae*.

**Key Words:** particle size, Salmonella, immune cells

**2003 Heat stress reduces barrier function and alters intestinal metabolism in growing pigs.** S. C. Pearce<sup>\*1</sup>, V. Mani<sup>1</sup>, R. L. Boddicker<sup>1</sup>, J. S. Johnson<sup>1</sup>, T. E. Weber<sup>1,2</sup>, J. W. Ross<sup>1</sup>, L. H. Baumgard<sup>1</sup>, and N. K. Gabler<sup>1</sup>, <sup>1</sup>Department of Animal Science, Iowa State University, Ames, IA, USA, <sup>2</sup>USDA-ARS, Ames, IA, USA.

High ambient temperature exposure can cause major reductions in intestinal function, pig performance and if severe enough, mortality. Therefore, our objective was to examine how acute heat stress (HS) alters growing pig intestinal integrity and metabolism. Individually penned crossbred gilts and barrows ( $46 \pm 6$  kg BW) were exposed to either thermal neutral (TN, 21°C; 35–50% humidity;  $n = 8$ ) or HS conditions (35°C; 24–43% humidity;  $n = 8$ ) for 24 h. All pigs had ad libitum access to feed and water. Rectal temperature (Tr), respiration rates (RR), body weight (BW) and feed intake (FI) were measured. Pigs were sacrificed after 24 h of environmental exposure and freshly isolated ileum and colon samples were mounted into modified Ussing chambers. Segments were analyzed for glucose and glutamine nutrient transport and barrier integrity (transepithelial electrical resistance (TER), and fluorescein isothiocyanate (FITC)-labeled dextran transport). Additionally, circulating blood concentrations of glucose and endotoxin were measured along with ileal lactase, maltase, sucrase and L-alanine aminopeptidase activities. As expected, pigs exposed to HS had an increase in Tr ( $39.3$  vs.  $40.9^\circ\text{C}$ ,  $P < 0.01$ ) and RR ( $52$  vs.  $119$  bpm,  $P < 0.05$ ). Heat stress decreased FI (53%;  $P < 0.05$ ) and BW ( $-2.2$  kg;  $P < 0.05$ ) compared with TN pigs. Compared with TN pigs, mucosal heat shock protein 70 increased (101%,  $P < 0.05$ ), while intestinal integrity was compromised in the HS pigs (ileum and colon TER decreased 52 and 24%, respectively;  $P < 0.05$ ). Furthermore, serum endotoxin concentrations increased 200% due to HS ( $P = 0.05$ ). Intestinal glucose transport and blood glucose were elevated due to HS ( $P < 0.05$ ). However, ileal sucrase and maltase activities decreased in HS pigs (30 and 24%, respectively;  $P < 0.05$ ).

There were no differences ( $P = 0.09$ ) in intestinal glutamine transport or ileal aminopeptidase activity ( $P = 0.17$ ). Altogether, these data indicate that high ambient heat loads reduce intestinal integrity and increase circulating endotoxin and stress in pigs. Furthermore, glucose transport and digestive capacity are altered during acute HS. This work was supported by USDA NIFA grant #2011–67003–30007.

**Key Words:** heat stress, Intestine

**2004 Effects of supplementation with *Laminara hyperborea*, *Laminara digitata* and *Saccharomyces cerevisiae* on the IL17 pathway in the porcine colon.** M. T. Ryan<sup>1</sup>, C. J. O'Shea, C. B. Collins<sup>1</sup>, J. V. O'Doerty<sup>2</sup>, and T. Sweeney<sup>\*1</sup>, <sup>1</sup>School of Veterinary Medicine, College of Life Sciences, University College Dublin, Belfield, Dublin 4, Ireland, <sup>2</sup>School of Agriculture and Food Science, College of Life Sciences, University College Dublin, Belfield, Dublin 4, Ireland.

$\beta$ -glucans are natural biomolecules which have been shown to have immunomodulatory activity in the colon. These glucose polymers vary widely in their biochemical properties depending on their source. Seaweed  $\beta$ -glucans have been shown to induce reduced expression of the signature  $T_H17$  cytokine IL17a in the porcine colon. The  $T_H17$  cells are a distinct lineage of CD4<sup>+</sup> T cells characterized by the secretion of cytokines IL17 and IL22 and which serve to protect the host from bacterial and fungal infections, particularly at mucosal surfaces. The aim of this study is to investigate the effect of supplementing feeds with  $\beta$ -glucans derived from *Laminara hyperborea*, *Laminara digitata*, and *Saccharomyces cerevisiae* on several cytokines, receptors and signal transducing molecules relevant to the IL17 pathway in the porcine colon. Weaned 49-d-old pigs were allocated to one of the following 4 dietary groups ( $n = 8$  per group) for 28 d: Basal Diet (BD), BD +  $\beta$ -glucans from *L. hyperborea*, BD +  $\beta$ -glucans from *L. digitata* and BD +  $\beta$ -glucans from *S. cerevisiae*. The  $\beta$ -glucans were included at 250 mg/kg in the diets. The RNA was purified from the colon tissues of euthanised pigs. Real-time PCR was used to quantify cytokines (*IL5*, *IL6*, *IL12*, *IL17a*, *IL17F*, *IL21*, *IL22*, *IL23*), transcription factors (*ROR c/γ* and *STAT3*) and receptors (*IL23Ra*, *IL17R*). Expression of the transcription factors *ROR c/γ* and *STAT3*, the *IL17a* receptor and *IL21* genes were not changed in any of the supplemented groups in comparison to BD. All other cytokine genes were downregulated in the *S. cerevisiae* supplemented group in comparison to BD. Supplementation with *L. digitata* resulted in a downregulation of targets; *IL17a* ( $P = 0.01$ ), *IL22* ( $P = 0.01$ ), *IL12b* ( $P = 0.1$ ) and *IL6* ( $P = 0.016$ ). Supplementation with *L. hyperborea* resulted in a downregulation of targets; *IL17a* ( $P = 0.02$ ), *IL17F* ( $P = 0.05$ ), *IL22* ( $P = 0.01$ ), *IL23RA* ( $P = 0.04$ ) and *IL6* ( $P = 0.014$ ). The results indicate that  $\beta$ -glucans from all 3 sources have an immunosuppressing effect on  $T_H17$  cell types in the gut, most probably mediated through the downregulation of their key activator *IL6*.

**Key Words:**  $\beta$ -glucans, colon,  $T_H17$

**2005 The influence of dietary locust bean gum and live yeast on some digestive immunological parameters of**

**piglets experimentally challenged with *Escherichia coli*.** R. Badia<sup>1,2</sup>, R. Lizardo<sup>1</sup>, P. Martinez<sup>2</sup>, I. Badiola<sup>3</sup>, and J. Brufau<sup>\*1</sup>, <sup>1</sup>IRTA - Institut de Recerca i Tecnologia Agroalimentaries, Constantí, Tarragona, Spain, <sup>2</sup>IBB - UAB Institut de Biotecnologia i Biomedicina - Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain, <sup>3</sup>CRESA - Centre de Recerca en Sanitat Animal, Bellaterra, Barcelona, Spain.

Gums and yeast cells are natural mannose-rich products that can be used as substrates for adhesion of Gram-negative bacteria. Moreover, live yeast has beneficial effects in the prevention and treatment of intestinal disorders. The aim of the study was to investigate the role of dietary locust bean gum (LBG, Salmosan, ITPSA, Spain) or live yeast (*Saccharomyces cerevisiae* SC47, Actisaf, Lesaffre, France) as immunological enhancers of the intestinal epithelium of piglets. Treatments included a non-infected group fed with a control diet and 4 other groups orally challenged with  $1 \times 10^8$  cfu of *Escherichia coli* K99. These 4 groups corresponded to animals fed a control diet or supplemented with colistin, LBG or yeast. Twenty-five Landrace  $\times$  Duroc piglets weaned at 4 wk were used. They were housed in groups and fed experimental diets for 2 wk before the challenge and euthanized 3 d later. Blood, bile, ileum and mesenteric lymph node (MLN) were sampled for analysis of C-reactive protein (CRP), secretory immunoglobulin A (sIgA) and toll-like receptors 2 (TLR2) and 4 (TLR4). C-reactive protein of control fed piglets increased after the challenge ( $P < 0.001$ ). However, piglets previously fed with LBG and yeast diets showed CRP levels similar to the non-challenged group. Bile sIgA levels increased for all the challenged groups and particularly for the pigs fed the yeast diet ( $P < 0.01$ ). Compared with non-challenged pigs, both receptors in MLN and ileal TLR4 were upregulated in control group after the challenge ( $P < 0.05$ ). Pigs fed yeast diet showed similar expression of TLR2 and TLR4 to unchallenged pigs in both tissues, whereas pigs fed LBG diets showed intermediate results. It appears that piglets fed yeast diet were protected against an *E. coli* infection. In conclusion, live yeast *S. cerevisiae* and locust bean gum may reduce the risk of *E. coli* infection and may be suitable alternatives to antibiotic growth promoters for the weaned piglet.

**Key Words:** piglet, immunity, *E. coli* challenge

**2006 Effects of feeding capsicum oleoresin, garlison, or turmeric oleoresin on gene expression of ileal mucosa of pigs experimentally infected with a pathogenic *E. coli*.** Y. Liu<sup>\*1</sup>, M. Song<sup>1</sup>, T. M. Che<sup>1</sup>, J. A. Soares-Almeida<sup>1</sup>, J. J. Lee<sup>1</sup>, D. Bravo<sup>2</sup>, C. W. Maddox<sup>1</sup>, and J. E. Pettigrew<sup>1</sup>, <sup>1</sup>University of Illinois, Urbana, IL, USA, <sup>2</sup>Pancosma SA, Geneva, Switzerland.

This study characterized the effects of 3 plant extracts on gene expression in ileal mucosa of weaned pigs experimentally infected with a pathogenic *E. coli*. Weaned pigs ( $n = 64$ , 6.3 kg BW, 21 d old) were housed in individual pens for 15 d: 4 d before and 11 d after the first inoculation (d 0). Treatments were in a  $2 \times 4$  factorial arrangement: with or without an F-18 *E. coli* challenge and 4 diets (a nursery basal diet (CON), 10 ppm of capsicum oleoresin

(CAP), garlison (GAR), or turmeric oleoresin (TUR)). Total RNA (4 pigs/treatment) was extracted from ileal mucosa of pigs at d 5. Double-stranded cDNA was amplified, labeled, and further hybridized to the Affymetrix GeneChip Genome Array. Microarray data were analyzed in R using packages from the Bioconductor project. Bioinformatics analysis was conducted by DAVID Bioinformatics Resources. Pairwise comparisons tested 4 different effects of interest. The *E. coli* infection altered the expression of 240 genes of pigs fed the CON. Compared with the infected CON, feeding CAP, GAR, and TUR affected the expression of 52 (18 up, 34 down), 117 (34 up, 83 down), and 84 (16 up, 68 down) genes, respectively. The *E. coli* infection upregulated ( $P < 0.05$ ) the expression of genes related to the activation of immune response, but downregulated ( $P < 0.05$ ) the expression of genes involved in protein synthesis and accumulation; in most of cases the plant extracts counteracted these effects of *E. coli*. Compared with the infected CON, feeding CAP and GAR increased ( $P < 0.05$ ) the expression of genes related to membrane, suggesting enhanced gut mucosa health. Moreover, feeding all 3 plant extracts reduced ( $P < 0.05$ ) the expression of genes associated with antigen presentation or other biological processes of immune responses, indicating attenuation of overstimulation of immune responses caused by *E. coli*. In conclusion, plant extracts regulated the expression of genes in ileal mucosa of *E. coli*-infected pigs, perhaps providing benefits by enhancing the gut mucosa health and attenuating the overstimulation of the immune system.

**Key Words:** *Escherichia coli*, pigs, plant extracts

**2007 Butyrate relieves weaning diarrhea by promoting repair of pig intestinal barrier.** X. Ma,<sup>\*</sup> S. Hu, and D. Li, State Key Laboratory of Animal Nutrition, China Agricultural University, No.2 Yuanmingyuan West Road, Beijing, P. R. China.

Post-weaning diarrhea is one of the most common causes of morbidity and mortality for weanling piglets. Our previous research suggested that feeding butyrate to weanling piglets decreased the incidence of post-weaning diarrhea. However, the mechanism through which this is achieved has not been fully elucidated. The present study was carried out to evaluate the effect of butyrate on diarrhea in relation to intestinal mucosal barrier function using IPEC-J2 porcine intestinal epithelial cells. Cultured IPEC-J2 cells were scratched to serve as an intestinal damage model. Supplementation of the cells in vitro with butyrate caused significant repair of the mucosal barrier, accompanied by enhanced expression of laminin and fibronectin ( $P < 0.05$ ). In addition, butyrate increased the mRNA and protein expression of the intestinal mucosal tight junction proteins occludin and zonula occluden protein-1 ( $P < 0.05$ ), which suggests protective effects of butyrate on the intestinal barrier. Furthermore, in the butyrate treated group, intestinal tSOD ( $P < 0.05$ ) and GSH-Px ( $P < 0.05$ ), 2 of the main antioxidant enzymes, as well as GSH ( $P < 0.01$ ), one of the non-enzymatic anti-oxidant components, were enhanced, whereas the MDA level, a marker of free radical mediated lipid peroxidation injury, was decreased ( $P < 0.01$ ) compared with the control group. Collectively, these



results indicate that dietary butyrate functions, at least partly, to relieve weaning diarrhea by repairing damage to the intestine and improving antioxidant indices.

**Key Words:** butyrate, weaning diarrhea, damage repair

**2008 Influence of grain type (wheat/barley), grinding intensity (coarse/fine) and fibre content on the incidence of epithelial alterations of the gastric pars oesophagea in fattening pigs.** S. J. Sander\*<sup>1</sup>, M. Wintermann<sup>1</sup>, A. Moessler<sup>1</sup>, C. Schulze Langenhorst<sup>2</sup>, G. Stal-johann<sup>3</sup>, and J. Kamphues<sup>1</sup>, <sup>1</sup>*Institute for Animal Nutrition, University of Veterinary Medicine Hannover, Hannover, Germany*, <sup>2</sup>*Haus Düsse, Centre for Agriculture, Bad Sas-sendorf, Germany*, <sup>3</sup>*Chamber of Agriculture of North Rhine-Westphalia, Münster, Germany*.

Epithelial alterations of the pars esophagea in the stomach are an ongoing problem in swine production, regarding fattening as well as reproduction units. Although it is well known that a finely ground diet favors the incidence of gastric ulcers in pigs it is also accepted as a multifactorial disease, especially pushed by various stress factors. Therefore the aim of this study was to evaluate the incidence of epithelial alterations of the pars esophagea in fattening pigs housed under high standard conditions (including a short distance to the abattoir) fed diets differing in their grinding intensity and the crude fiber content. A total of 253 pigs were distributed to 4 feeding groups and fattened to an average body weight of 120 kg. The animals were fed either a wheat-based, finely ground (Wf), a wheat-based, coarsely ground (Wc), a barley-based, finely ground (Bf) or a wheat-based, finely ground diet supplemented with beet pulp (Wf+). A 2-phase feeding system was applied with diets identical in energy and protein content. At the abattoir stomachs of 77 pigs were taken and evaluated using a macroscopic score differentiating the degree of hyperkeratosis (0 = none up to 3 = high-grade), erosion (4) and ulceration (5). Furthermore, performance data and carcass traits were obtained. Neither performance data (daily gain: 813 g; FCR: 2.53) nor carcass traits differed between the feeding groups. But major differences were seen in terms of gastric health: the coarsely ground diet Wc resulted in the significantly lowest macroscopic score (Wc:  $0.955 \pm 0.449^a$ ; Wf:  $1.78 \pm 1.01^b$ ; Bf:  $1.37 \pm 0.441^b$ ; Wf+:  $1.47 \pm 0.423^b$ ). Additionally only after feeding the Wf diet, 17.7% of the animals had ulcerations at slaughter. Numerically lower scores than in the Wf group were obtained after feeding the diets with higher crude fiber content (Bf and Wf+). It can be concluded that a coarse feed structure is more efficient in maintaining gastric health of fattening pigs than elevated crude fiber contents. Furthermore, the coarsely ground diet did not result in reduced performance or carcass traits.

**Key Words:** feed structure, gastric ulcer, particle size

**2009 The effect of yeast cell walls on performance and innate immunity of weaned piglets.** R. Gerritsen\*<sup>1</sup>, G. Klaassen<sup>2</sup>, G. Schutter<sup>2</sup>, S. Rouwers<sup>2</sup>, and H. K. Parmen-tier<sup>3</sup>, <sup>1</sup>*Schothorst Feed Research, Lelystad, The Nether-lands*, <sup>2</sup>*Sloten B.V., Deventer, The Netherlands*, <sup>3</sup>*Wagenin-gen University, Wageningen, The Netherlands*.

Positive effects of yeast concentrate on immunity and performance of weaned piglets have been reported. However, the effects on innate immunity were never examined. Natural antibodies (NAb) are part of innate immunity and have been related to health and survival in fish, poultry, rodents and man. Possibly, yeast cell walls may also affect innate immunity of weaned piglets. Also positive effects of Nuklospray, a spray dried blend of dairy-based feed ingredients and vegetable fats, were reported. We studied the effect of Nuklospray ProHealth containing specially processed yeast cell walls as protein source on NAb levels and performance of weaned piglets. A total of 120 piglets weaned at 28 d of age were assigned 2 treatments comprising: a control diet; and an experimental diet with the test product. Piglets were housed in groups of 6 during the first 4 weeks post-weaning. Blood samples of 20 healthy non-medicated piglets per treatment were taken at d 0, 14 and 28 post-weaning and analyzed for NAb levels binding keyhole limpet hemocyanin (KLH) by an indirect ELISA procedure. Also performance parameters were determined. Overall, the experimental diet significantly improved feed intake (574 g/d vs. 522 g/d;  $P < 0.01$ ), average daily gain (449 g/d vs. 412 g/d;  $P < 0.01$ ) and final body weight (21.4 kg vs. 20.3 kg;  $P < 0.01$ ) compared with the control diet. No differences were found in feed conversion ratio or fecal score. At d 0, no differences in NAb levels were found, but on d 14 post-weaning, NAb levels of piglets fed the experimental diet were significantly higher than of piglets fed the control diet (2.05 vs. 1.70;  $P < 0.05$ ). On d 28 post-weaning no differences were found. These results indicate that levels of NAb as a parameter of innate immunity, and post weaning performance of piglets fed the yeast-enriched diet (Nuklospray ProHealth) were positively affected.

**Key Words:** yeast cell walls, weaned piglet, natural antibodies

**2010 Dietary oxidative stress-induced yellow fat and lipofuscin accumulation in the digestive tract of swine.** J. J. Dibner\*<sup>1</sup>, C. D. Knight<sup>1</sup>, M. Vazquez-Anon<sup>1</sup>, T. Lu<sup>2</sup>, M. L. Kitchell<sup>1</sup>, and J. Zhao<sup>1</sup>, <sup>1</sup>*Novus International, Inc, St. Charles, MO, USA*, <sup>2</sup>*Virginia Polytechnic Institute, Blacks-burg, VA, USA*.

A syndrome characterized by a yellow pigmentation of adipose tissue has been reported in many species, including swine. Yellow fat (YF) emerged as a serious commercial problem in China in 2008 at a time when Vitamin E (VitE) prices tripled, reducing supplementation. Yellow fat is often only detected at processing as it is rarely associated with a performance decline although in this case, pigs affected by YF were also observed to have dark stools, suggesting intestinal bleeding. Microscopically, YF is characterized by extensive adipose cell degeneration, with inflammation, fibrosis and accumulation of lipofuscin. Lipofuscin is generated during oxidative stress. It has been reported that high dietary unsaturated fatty acids and deficiency of VitE or other antioxidants (AOX) is responsible for YF. The objective of this trial was to develop a model system for YF in swine. Sixteen 11-kg nursery pigs (in 4 pens) were fed a commercial nursery diet for the first 10 d post-weaning. On d 11 the challenge diet was started which had

5% oxidized soybean oil (225 Meq/kg), 3.5% long-chain polyunsaturated fat (PUFA), and no added VitE (8 IU/kg in basal). Back fat biopsy was taken on d 45 and 65 for gross and histological evaluation. Accumulation of lipofuscin in the adipose was observed on d 65 and in the lamina propria of the small intestine on d 115. A second study (25 11-kg pigs/diet) and a similar diet (5% oxidized soybean oil and 10% PUFA with or without both VitE (11IU/kg) and a feed grade AOX (AGRADO Ultra, 0.025%) was conducted at Virginia Polytechnic Institute. Morphological evaluation of the digestive system of challenged 40-kg pigs on d 55 revealed lipofuscin deposition in the small intestine, liver, and adipose of pigs fed the challenge diet in the absence of VitE and AOX. In this case, a significant reduction ( $P < 0.001$ ) in BW and ADG suggests that the oxidative damage in the intestine may lead to growth performance reduction in addition to product quality consequences.

**Key Words:** lipofuscin, oxidative stress, yellow fat

**2011 Effects of an *Allium* botanical on performance, diarrhea, gut morphology, immune and inflammatory status of weaned pigs infected with a pathogenic *E. coli*.** Y. Liu<sup>1</sup>, M. Song<sup>1</sup>, T. M. Che<sup>1</sup>, J. A. Soares<sup>1</sup>, D. Bravo<sup>2</sup>, C. M. Maddox<sup>1</sup>, J. E. Pettigrew<sup>1</sup>, and C. Oguey<sup>\*2</sup>, <sup>1</sup>University of Illinois, Urbana, Illinois, USA, <sup>2</sup>Pancosma SA, Geneva, Switzerland.

Plant extracts are known to positively impact gut function and immune modulation. The objective of this trial was to evaluate if a standardized extract of *allium* (GAR) could affect performance, diarrhea, gut morphology, immune and inflammatory status of weaned piglets infected with a pathogenic F-18 *E. coli*. Weaned pigs (6.3 kg BW, 21 d old) were housed in disease containment chambers for 15 d and allocated to treatments according to a factorial arrangement (8 pigs/treatment). First factor was with or without an F-18 *E. coli* challenge with  $10^{10}$  cfu/mL daily oral dose for 3 d from d 0. Second factor was the diet type: control diet (CON) or 10 ppm GAR. Performance parameters were measured at d 0, 5 and 11. On d 5 and 11, one-half of the pigs were euthanized to collect intestine to measure villi height (VH), crypt depth (CD), and their ratio (VH:CD). Diarrhea (DS) was daily scored individually (1: normal, to 5: watery diarrhea). Frequency of diarrhea (FD) was the percentage of pig days with DS  $\geq 3$ . White blood cell (WBC) counts, cytokines and haptoglobin were measured at d 0, 5 and 11. Feces culture scores were performed at d 3, 5, 8 and 11. The infection reduced global performance and VH and increased DS and FD as expected. It increased ( $P \leq 0.05$ ) lymphocytes, TNF- $\alpha$  and haptoglobin on d5, and WBC, neutrophils, lymphocytes, monocytes and haptoglobin on d 11. Results showed that GAR never affected feces culture scores. In sham group, GAR improved ( $P \leq 0.05$ ) ADG from d 0 to 5, reduced average DS from d 0 to 5 and FD. Feeding GAR decreased ( $P \leq 0.05$ ) haptoglobin on d5 and TGF- $\beta$  on d11. In challenged group, GAR did not affect performance but it reduced ( $P \leq 0.05$ ) DS from d3 to 5 and d9 to 11 and overall FD. Ileum VH at d 5 and VH:CD at d11 were increased ( $P \leq 0.05$ ) by GAR supplementation. Supplemented pigs exhibited reduced WBC and haptoglobin on d 5 and 11, and lower lymphocytes at d 11 ( $P \leq 0.05$ ). This confirms

the anti-inflammatory effect of GAR in case of infection. This demonstrated that this *allium* botanical has the ability to limit the negative impact of *E. coli* infection in weaned piglets.

**Key Words:** allium extract, *E. coli*, disease resistance

**2012 in vitro test on the ability of a yeast cell wall product to inhibit the *Escherichia coli* F4ac adhesion on the brush border of porcine intestinal villi.** P. Trevisi<sup>\*1</sup>, D. Priori<sup>1</sup>, G. Gandolfi<sup>1</sup>, M. Colombo<sup>1</sup>, T. Goossens<sup>2</sup>, and P. Bosi<sup>1</sup>, <sup>1</sup>University of Bologna, Bologna, Italy, <sup>2</sup>Nutriad, Dendermonde, Belgium.

The ability of a yeast cell wall (YCW) based product (SENTIGUARD<sup>®</sup>C, Nutriad, Belgium) to inhibit the *E. coli* F4 adhesion on the brush border of porcine intestinal villi was tested. In 2 trials, different batches of product (I and II) were pre-incubated with *E. coli* F4, and then were incubated with intestinal villi collected from already weaned piglets. In trial 1 and 2, we used 4 and 6 sub-sets of villi respectively. The YCW treatments were tested as follows: trial 1, 2 mL of *E. coli* F4 solution were pre-incubated with: batch I (SENT\_I10); batch II (SENT\_II10), both at 10% w/v; trial 2, 2 mL of *E. coli* F4 solution were pre-incubated with: batch I (SENT\_I0.5) and batch II (SENT\_II0.5), at 0.5% w/v; batch I (SENT\_I5) and batch II (SENT\_II5), at 5% w/v. In both trials we added also a treatment pre-incubated with egg yolk immunized against *E. coli* F4, to assess the maximum inhibition of the adhesiveness, and a negative control with villi incubated directly with *E. coli* F4, to verify the maximum potential adhesiveness of the pathogen. For each experimental group at least 20 different villi were observed, brush border length measured and the adherent pathogen counted. Finally the data was reported as number of adherent bacteria along 250  $\mu$ m length of villous brush border. Data were analyzed by ANOVA and all the treated groups were compared by the multiple Dunnett test against the negative control as a reference. In trial 1, both batches of SENTIGUARD C and immunized egg yolk, significantly reduced the pathogen adhesion on the villi ( $P < 0.001$ ) than the negative control group. In trial 2, the tested additive, SENT\_I 0.5% did not significantly reduce the *E. coli* F4 adhesion. At the same concentration, the SENT\_II tended to reduce the pathogen adhesion ( $P = 0.073$ ), while immunized egg yolk and both additives significantly reduced the *E. coli* F4ac adhesion at the concentration of 5% ( $P < 0.001$ ). Taken into account the experimental set-up, our results indicate the ability of the SENTIGUARD C to contain the intestinal infection from *E. coli* F4 in young pigs.

**Key Words:** yeast cell wall, brush border, *E. coli* F4ac

**2013 Diarrhea-like condition and intestinal mucosal responses in susceptible homozygous and heterozygous F4R+ pigs under challenge.** S. Sugiharto, M. Hedemann, B. Jensen, and C. Lauridsen,\* Aarhus University, Foulum, Denmark.

Enterotoxigenic *E. coli* (ETEC) expressing F4 fimbriae are a major cause of diarrhea in neonatal and recently

weaned pigs. The F4 fimbriae must bind to F4 receptors on intestinal enterocytes in order diarrhea to occur, thus only pigs having F4 receptors are susceptible. Positive pigs may be homo- or heterozygous carriers of the gene encoding intestinal F4 receptors. Among positive pigs, no difference between genotypes has been seen regarding spontaneous *E. coli* postweaning diarrhea occurrence, but there is a lack of information regarding intestinal mucosal responses to ETEC. This study investigated a diarrhea-like condition and intestinal mucosal responses in F4-homo- and -heterozygous susceptible weaners. Sixteen weaned pigs (28 d of age, 5 to 10 kg BW) were used in a 2 × 2 factorial study with genotype (homo- or heterozygous F4R+) and inoculation with *E. coli* F4 or not as the 2 factors. Within genotype, 4 pigs were inoculated with *E. coli* F4 and the other 4 pigs received saline buffer on d 7 and 8 after weaning. Fecal score and DM, and bacterial enumeration were conducted from d 7 (prior inoculation) until 12 after weaning. Plasma was obtained at 4 d prior and 2 d after challenge, and at the time of killing. Four pigs (1 per treatment) were killed per day at 6, 7, 8 and 9 d after challenge. Small intestine (SI) was divided into 3 parts of equal length (proximal, mid and distal). From the middle of each part, a 10 cm section was removed for measurement of intestinal weight and mucosa. Total percentage of mucosa was reduced ( $P = 0.05$ ) by *E. coli* challenge, with more pronounced in the mid-part of SI ( $P < 0.05$ ). No influence of genotype was seen on mucosal responses, metabolomic profile and immune responses of the plasma. Although all pigs in our study had no history of diarrhea from birth, O-seroagglutination test performed at the day prior- and at 2 d after inoculation showed that *E. coli* F4 existed before inoculation and lasted thereafter. This study provided no evidence for different diarrhea susceptibility or intestinal mucosal responses between F4-homo- and heterozygous susceptible pigs to *E. coli* F4.

**Key Words:** genotype, F4 fimbriae, metabolomic

**2014 Impact of *Bacillus cereus* var. Toyoi on the infection with *Salmonella* Typhimurium DT104 in weaned piglets.** L. Scharek-Tedin<sup>\*1</sup>, R. Pieper<sup>1</sup>, W. Vahjen<sup>1</sup>, S. Kinzinger<sup>2</sup>, A. Mueller<sup>2</sup>, and J. Zentek<sup>1</sup>, <sup>1</sup>*Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany*, <sup>2</sup>*Lohmann Animal Health, Cuxhaven, Germany*.

Bacterial spore formers are coming more into focus to promote intestinal health in pigs. This study was conducted to determine the impact of *Bacillus cereus* var. Toyoi on the shedding and translocation of *Salmonella* Typhimurium and on the immune response in weaned piglets. Six landrace sows received  $5 \times 10^5$  cfu/g *B. cereus* var. Toyoi from 28 d before parturition until weaning of the piglets. Piglets ( $n = 24$ ) from these sows received creep feed supplemented with *B. cereus* from d 12 of life with  $1 \times 10^6$  cfu/g and a starter diet containing  $7 \times 10^5$  cfu/g after weaning (on d 26). A control group with 6 sows and 24 piglets was managed and fed equally but without supplementation of *B. cereus*. Three days after weaning, all piglets of the treatment group (TG) and the control Group (CG) were infected orally with  $3 \times 10^9$  cfu *S. Typhimurium* DT104 (ST). Feces consistency was monitored daily. Shedding of ST was determined on d 1, 3, 7,

and weekly until 28 d post infection (p.i.). On d 1, 3, 7 and 28 p.i. Six piglets per group were euthanized to determine the translocation of ST into mesenteric lymph nodes (MLN) and tonsils. Phenotypic analysis of intraepithelial lymphocytes and peripheral blood mononuclear cells was performed via flow cytometry. Results show that piglets in the CG had a higher occurrence of diarrhea (43.2%) than piglets in the TG (8.1%,  $P < 0.05$ ). Shedding of ST tended to be higher in the CG 28 d p.i. as compared with the TG. No clear differences were observed for translocation of ST. Gamma-delta ( $\gamma\delta$ ) T cells were less frequent in the blood of the TG 1 d p.i.. Differences were observed for CD8+  $\gamma\delta$ T cells ( $P = 0.032$ ) as well as for CD8-  $\gamma\delta$ T cells ( $P = 0.027$ ). Treated piglets showed lower numbers of  $\gamma\delta$ T cells in the jejunal epithelium 7 and 28 d. p.i. ( $P < 0.02$ ). In conclusion, treatment of sows and piglets had a positive impact on the health status of the piglets. As the  $\gamma\delta$ T cells were less frequent in the blood of the TG 24 h p.i. it can be assumed that this difference was present at the time of infection. Whether the lower numbers of  $\gamma\delta$ T cells in the TG are associated with improved health has to be further elucidated.

**Key Words:** intraepithelial lymphocytes, probiotic, Salmonella

**2015 Effect of  $\beta$ -glucans on net fluid absorption in enterotoxigenic *E. coli*-infected small intestinal segments of weaned piglets.** J. van der Meulen<sup>1</sup>, A. J. M. Jansman<sup>\*1</sup>, J. J. Mes<sup>2</sup>, I. M. van der Meer<sup>3</sup>, and M. M. Hulst<sup>1</sup>, <sup>1</sup>*Wageningen UR Livestock Research, Lelystad, The Netherlands*, <sup>2</sup>*Agrotechnology & Food Sciences Group of Wageningen University and Research Centre, Wageningen, The Netherlands*, <sup>3</sup>*Plant Sciences Group of Wageningen University and Research Centre, Wageningen, The Netherlands*.

$\beta$ -Glucans are known as immunostimulants. In the pig,  $\beta$ -glucans are not enzymatically hydrolysed in duodenum and jejunum but may be fermented in the ileum and hindgut. In this way, they may modulate the gut flora and its fermentation activity, ultimately possibly influencing gut morphology and mucosal immune response.  $\beta$ -Glucans may also have antiviral and antibacterial properties. Enterotoxigenic *E. coli* (ETEC) infection is a major cause of diarrhea in early-weaned piglets. This study investigated whether  $\beta$ -glucans isolated from *Lentinus edodis* (lentinan), *Ganoderma lucidum* (ganoderma), *Alcaligenes fecalis* (curdlan) and *Avena sativa* (oats) are able to reduce ETEC-induced loss in fluid absorption in the small intestinal segment perfusion (SISP) model. In four 5-wk-old anaesthetized piglets, 4 pairs of jejunal segments (a non-infected and an adjacent ETEC-infected) were perfused over 8 h with 4 g/L  $\beta$ -glucans from lentinan, ganoderma, curdlan and oats with saline as control in another pair of segments. After perfusion mucosal tissue samples were taken for analysing pancreatitis-associated protein (PAP) expression as a biomarker for infection. Net fluid absorption was calculated from the difference between the volumes of inflow and outflow divided by the surface area of the segments. Absorption of net fluid, sodium, potassium and chloride in non-infected segments was significantly higher ( $P < 0.05$ ) than in ETEC-infected segments. There was



no effect of any of the tested  $\beta$ -glucans on net fluid and electrolyte absorption in ETEC-infected segments. In ETEC-infected segments PAP expression was increased. Perfusion with any of the  $\beta$ -glucans did not affect PAP expression in the intestinal mucosa. The results indicate that  $\beta$ -glucans do not promote net fluid absorption in piglets affected by post weaning diarrhea. The lack of effect of the  $\beta$ -glucans in the present study may be related to the amount and nature of  $\beta$ -glucans used, to the way they were extracted or to the duration of administration.

**Key Words:**  $\beta$ -glucans, ETEC, post weaning digestive problems

**2016 Impact of plant extracts on the adhesion of enterotoxigenic *Escherichia coli* on the porcine intestinal epithelial cell line IPEC-J2.** A. Mader, W. Vahjen, and J. Zentek,\* *Institute of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany.*

It was shown that the adherence of enterotoxigenic *E. coli* strains (ETEC) to intestinal epithelial cells (IEC) is regarded as an important initial step for colonization and infection of piglets. The colonization with ETEC is primarily mediated by fimbriae; one of the most common adhesins of porcine ETEC is F4 (K88). Plant extracts may interfere with the adherence of pathogens. The properties of water extracts (WE) from plant byproducts of the pharmaceutical and the food industry to reduce the binding of ETEC 147:K89:K88, stained with CDFA-SE, to IPEC-J2 were investigated in vitro. *Cucurbita pepo* L. (pulp and peel), *Cynara scolymus* L. (pomace of aerial part press juice production), *Daucus carota* L. (pomace of root press juice production), *Mangifera indica* L. (peel), *Salix alba* L. (pomace of bark ethanol extraction), and *Thymus vulgaris* L. (pomace of leaf ethanol extraction) were used. The ratio of bacteria to IPEC-J2-cells was 100:1. Cell suspension was counted using flow cytometry, which detected attached *E. coli* due to the increased fluorescence intensity of the cells. Data were analyzed by one factorial ANOVA and posthoc Scheffé-test with a minimum of 4 replicates per WE, WE concentration and incubation condition. Probability (*P*)-values <0.05 were taken as significant (SPSS 15.0, SPSS Inc. Chicago, Illinois, USA). The method proved as suitable test system to determine anti-adhesive capacities of the plant residues. It could be shown that the concentration (WE to medium 1:100 and 1:1000) and the protocol of incubation WE, bacteria and cells (WE and bacteria for 90 min on cells, WE for 180 min and bacteria for 90 min on cells, preincubation of WE and bacteria for 90 min and thereafter incubation on cells for 90 min) can have a significant impact. The WE of *Thymus vulgaris* L. (thyme) decreased the adhesion of *E. coli* most effectively. The mechanisms of bacterial adhesion on IEC and the mode of action of the interfering mechanisms need to be characterized. The proposed method might be useful as prescreening tool in the development of feed additives improving piglet health after weaning.

**Key Words:** *Escherichia coli*, adhesion, plant extracts

**2017 Lipopolysaccharide and n-3 fatty acids alter intestinal toll-like receptor 4 (TLR4) recruitment and**

**function.** V. Mani\*<sup>1,5</sup>, J. D. Spencer<sup>2</sup>, J. Hollis<sup>3,5</sup>, T. E. Weber<sup>4</sup>, and N. K. Gabler<sup>1,5</sup>, <sup>1</sup>*Department of Animal Science, Interdepartmental Toxicology Program,, <sup>2</sup>JBS United Inc., Sheridan, IN, USA, <sup>3</sup>Department of Food Science and Human Nutrition,, <sup>4</sup>USDA-ARS, Ames, Iowa, USA, <sup>5</sup>Iowa State University,, Ames, Iowa, USA.*

Previously we reported that dietary n-3 fatty acids (FA) decrease intestinal lipopolysaccharide (LPS) transport (LT) and serum endotoxin in pigs. Endotoxin or LPS is recognized by TLR4 to initiate an innate immune response. Localization of TLR4 to lipid raft (LR) membrane micro domains is critical for cellular LT and signaling in numerous cells. Our objective was to examine the effects of n-3 FA and LPS on intestinal TLR4 LR recruitment and LT. Twenty pigs (22  $\pm$  2.4 kg) were fed 2 diets: 1) control (CON); 2) CON plus 0.5% Gromega (GRO, JBS United Inc.), high in docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) n-3 FA. After 8 weeks, the CON and GRO pigs were challenged (n = 5 pigs/trt) with either an I.M. injection of *E. coli* LPS (CH; 10  $\mu$ g/kg BW) or saline (SAL). Four hours after CH or SAL, pigs were euthanized and ileum and colon segments mounted into Ussing chambers to measure ex vivo FITC-LPS apparent permeability coefficient (Papp) as a marker of LT. Ileum and colon mucosa were assessed for n-3 FA enrichment, LR isolated and membrane localization of TLR4 determined. Compared with the CON, pigs fed GRO had increased ileum and colon EPA, DHA and total n-3 FA content (*P* < 0.05; 200, 250, 300%, respectively). Overall, ileum LT did not differ due to FA or CH treatments. However, GRO-SAL treated pigs tended to have decreased LT by 37% compared with the CON-SAL pigs (*P* = 0.06). Pigs injected with CH had attenuated colon LT (*P* = 0.02). Pigs fed GRO also had reduced colon LT compared with the CON (*P* = 0.03; 2.0 vs. 7.4 Papp, respectively). Compared with CON-SAL treated pigs, ileum and colon TLR4 recruitment into LR micro domains was decreased in the GRO-SAL pigs. However, CH reduced ileum LR TLR4 protein in CON, but not GRO fed pigs. Localization of TLR4 into LR didn't differ in the colon of CON-CH and GRO-CH treatment groups. These data indicate that n-3 FA decrease TLR4 recruitment into intestinal LR. This may explain how DHA and EPA attenuate receptor mediated LT and LPS induced febrile response. Furthermore, reduced LR localization of TLR4 post CH, may describe an LPS tolerance mechanism.

**Key Words:** lipid raft, intestinal endotoxin transport, fatty acids

**2018 Effect of milk fractions on functional properties and inflammatory response in human and porcine intestinal epithelial cells.** M. Blais<sup>1</sup>, M. Fortier<sup>1</sup>, Y. Pouliot<sup>3</sup>, S. Gauthier<sup>3</sup>, Y. Boutin<sup>3</sup>, G. Robitaille<sup>2</sup>, and M. Lessard\*<sup>1</sup>, <sup>1</sup>*Dairy and Swine Research and Development Centre, Sherbrooke, Qc, Canada, <sup>2</sup>Food Research and Development Centre, Saint-Hyacinthe, Qc, Canada, <sup>3</sup>Institute of Nutraceuticals and Functional Foods, U. Laval, Quebec, Qc, Canada.*

Milk industry produces several by-products that may have beneficial effects on intestinal epithelium health and



function. In this study, we treated human colon carcinoma cells Caco-2/15 and porcine intestinal epithelial cells IPEC J2 with bovine serocolostrum, milk whey, lactoferrin or macropeptide, and verified their effect on cell proliferation, migration and inflammatory response. Caco-2/15 and IPEC J2 cells were treated with different concentrations of milk fractions. Cell proliferation was determined using the XTT assay, while migration was assessed by wound assay and adhesion was observed following cell trypsinization. Transient transfection and luciferase assay were done to verify the impact of milk fractions on cell inflammatory response using NF-kBluc, IL-8luc and IL-6luc as reporter genes. After the transfection, Caco-2/15 and IPEC J2 cells were stimulated with heat-killed *Escherichia coli* and *Salmonella typhimurium* (HK bacteria), in combination with different concentrations of milk fractions. Cell proliferation was increased by 20% in Caco-2/15 cells and up to 50% in IPEC J2 cells after 24h treatment with serocolostrum (10 mg/mL), lactoserum (10 mg/mL) and lactoferrin (1 mg/mL). Cell migration was increased ( $P < 0.05$ ) by serocolostrum in IPEC J2, while cell adhesion to the culture dish was significantly impaired by serocolostrum and lactoserum. In Caco-2/15 cells, lactoferrin decreased ( $P < 0.05$ ) the cell-cell adhesion, while macropeptide increased cell-matrix adhesion. Transient transfections and luciferase assay showed a decrease ( $P < 0.05$ ) in the induction of NF-kBluc, IL-8luc and IL-6luc transcriptional activity by HK bacteria in presence of serocolostrum. In conclusion, bovine milk fractions modulate differently functional properties of human and porcine intestinal epithelial cells by affecting cell proliferation, migration and adhesion in vitro, while inflammatory response is exclusively affected by bovine serocolostrum.

**Key Words:** milk fractions, intestinal epithelial cells

**2019 Serocolostrum modulates gene expression in porcine intestinal epithelial cells IPEC J2.** M. Blais<sup>1</sup>, Y. Pouliot<sup>2</sup>, S. Gauthier<sup>2</sup>, Y. Boutin<sup>2</sup>, and M. Lessard<sup>\*1</sup>, <sup>1</sup>Dairy and Swine Research and Development Centre, Sherbrooke, Qc, Canada, <sup>2</sup>Institute of Nutraceuticals and Functional Foods, U. Laval, Quebec, Qc, Canada.

Bovine serocolostrum contains nutrients and many bioactive molecules including growth factors, immunoglobulins and antimicrobial peptides. Previous studies have suggested the therapeutical use of serocolostrum to treat gastrointestinal disorders, but little is known about its specific impact on intestinal epithelium. The aim of this study is to verify effect of serocolostrum on gene expression, with or without stimulation of the inflammatory response, in porcine intestinal epithelial cells IPEC J2 by microarray analysis. The IPEC J2 cells were treated for 2 h or 24 h with serocolostrum (10mg/ml), in combination with heat-killed *Escherichia coli* and *Salmonella typhimurium* (HK bacteria), followed by RNA extraction. Gene expression was analyzed by microarray using Agilent porcine array. The statistical analysis of microarray data was done using the FlexArray 1.6.1 software package (Génome Québec, Canada) and list of genes that were significantly regulated by either HK bacteria or serocolostrum were classified according to their Gene Ontology (GO) Biological Processes. Serocolostrum

treatment significantly increased the expression of genes involved in cell proliferation, morphogenesis, development, locomotion and response to wounding. More than 50% of genes induced more than 2 times after HK bacteria stimulation were downregulated by addition of serocolostrum. These genes are mostly involved in immune response, defense response and inflammatory response, according to GO classifications. On the other hand, approximately 25% of genes induced more than 2 times after HK bacteria stimulation had increased levels of expression when serocolostrum was added, and these genes are rather involved in development. In conclusion, these results show that serocolostrum could have positive properties on intestinal epithelial integrity by stimulating basal levels of genes involved in proliferation, repair and development in intestinal epithelial cells in vitro. Also, serocolostrum acts as an anti-inflammatory agent by decreasing the level of induction of immune and inflammatory genes in presence of pathogens.

**Key Words:** microarray, porcine intestinal epithelial cells, serocolostrum

**2020 Influence of a phytogetic feed additive on digestive, microbiological and immunological measurements in weaned piglets.** J. Zentek<sup>\*1</sup>, S. Gaertner<sup>1</sup>, L. Scharek-Tedin<sup>1</sup>, A. Mader<sup>1</sup>, K. R. Wendler<sup>2</sup>, and W. Vahjen<sup>1</sup>, <sup>1</sup>Institut of Animal Nutrition, Freie Universitaet Berlin, Berlin, Germany, <sup>2</sup>DELACON Biotechnik, Steyregg, Austria.

To identify possible anti-enteroadhesive effects against an enteropathogenic *Escherichia coli* strain, flow cytometric measurements were performed with IPEC-J2 cells, using labeled *E. coli* (CFDA-SE). A feeding trial with 24 male castrated pigs was conducted using a complete feed without (control) or with 0.04% of a phytogetic feed additive (Fresta F, Delacon, Steyregg, Austria). The piglets were orally vaccinated with a live *Salmonella* Typhimurium vaccine to determine the specific antibodies. On d 28 and 29 of the trial, peripheral blood and digesta were sampled. Performance, intestinal pH, dry matter content of digesta and the intestinal microbiota (qPCR, Bifidobacteria, *Lactobacillus amylovorus*, *L. reuteri*, *L. johnsonii*; *Escherichia/Hafnia/Shigella* spp.; clostridial clusters I and XIV; streptococci) and bacterial metabolites (lactate, short chain fatty acids (SCFA)) were determined. Leukocytes from the blood and the lamina epithelialis of the proximal jejunum were isolated and phenotyped by flow cytometry. The phagocytic activity of isolated peripheral monocytes and granulocytes was measured (Phagotest®, Orpegen, Heidelberg, Germany). Proliferation of peripheral lymphocytes was analyzed with 3 mitogens (PWM, CON A, PHA-M). The adhesion of the *E. coli* to IPEC-J2 cells was reduced by the plant extract by 52.7% ( $P < 0.05$ ). In piglets fed the diet with the additive ileal pH ( $P < 0.05$ ) and digesta dry matter was not affected. Numbers of *Escherichia* spp. decreased in the jejunum and clostridial cluster I increased ( $P < 0.05$ ). Numbers of clostridial cluster XIV decreased in the cecum. Lactate and SCFA concentrations were similar in both groups. The immunological measurements were unaffected, including the concentrations of antibodies against *S. Typhimurium*, the lymphocyte proliferation and the phagocytic activity

of neutrophils and monocytes. It can be concluded that the additive had an effect on the adhesion of the tested pathogenic *E. coli* strain to enterocytes, which might be relevant for the prevention post-weaning diarrhea.

**Key Words:** phytogenic feed additive, adhesion, microbiota

**2021 Deoxynivalenol and lipopolysaccharides affect porcine small intestinal integrity along the proximo-distal axis.** J. Kluess\*<sup>1</sup>, L. R. Klunker<sup>1</sup>, N. Walk<sup>1</sup>, C. Nosol<sup>1</sup>, S. Kahlert<sup>1</sup>, B. Brosig<sup>2</sup>, S. Döll<sup>2</sup>, S. Dänicke<sup>2</sup>, and H. J. Rothkötter<sup>1</sup>, <sup>1</sup>*Institute of Anatomy, Medical Faculty, Otto-von-Guericke University, Magdeburg, Saxony-Anhalt, Germany*, <sup>2</sup>*Institute of Animal Nutrition, Federal Research Institute for Animal Health, Braunschweig, Lower Saxony, Germany*.

Deoxynivalenol (DON) is one of the most prevalent mycotoxins in temperate climates and occurs predominantly on cereal crops. Lipopolysaccharides (LPS) are part of the outer membrane of gram-negative bacteria. Both are thought to impair porcine intestinal morphology and epithelial barrier integrity. We investigated the effect of DON and LPS on crypt depth, cell proliferation and expression of tight junction protein (ZO 1) in the pig's small intestine. 48 barrows (26 ± 4 kg BW) were fed a barley-based control or a diet containing 3.1 mg/kg DON for 4 wk. Subsequently, control group was infused for 1 h either with 100 µg/kg BW DON (CON-DON) or 7.5 µg/kg BW LPS (CON-LPS) or both treatments (CON-DON+LPS) or 0.9% NaCl (CON-CON) and the DON group with LPS (DON-LPS) or NaCl (DON-CON). Pigs were killed 3.25 h after start of infusion. One hour prior to killing, all pigs received an infusion of bromodeoxyuridine (BrdU) a nucleotide analogue (10 mg BrdU /kg BW) as a proliferation marker. Tissue was taken from duodenum, proximal jejunum, mid-jejunum, proximal ileum and terminal ileum. Crypt depth, BrdU positive cells and immunofluorescence of ZO 1 were analysed and data compared by ANOVA. Duodenal crypts were deeper compared to the other gut sections irrespective of treatment ( $P < 0.001$ ). Proliferation was not highest in duodenum, but showed a bell-shaped distribution along the proximo-distal gut axis with the highest number of proliferating cells in proximal and mid-jejunum ( $P < 0.001$ ). There was no effect of treatment. ZO 1 was localized apical as well as cytosolic in the three upper gut sections whereas ileal sections showed only an apical signal. The LPS markedly altered the spatial distribution of ZO 1: a strong apical ZO 1 signal was present whereas the cytosolic localization disappeared in all gut sections. This effect was irrespective of DON presence. In conclusion, we demonstrated that proliferation shows a distinct pattern along the small intestine and is not necessarily linked to crypt depth. Furthermore we showed that LPS modified ZO 1 distribution along the gut axis.

**Key Words:** deoxynivalenol, epithelial morphology, tight junction protein

**2022 Effects of supplementing dietary laminarin and fucoidan in the weaned pig on intestinal morphology and volatile fatty acid concentrations.** A. M. Walsh,\*

T. Sweeney, C. J. O'Shea, D. N. Doyle, B. Flynn, and J. V. O'Doherty, *University College Dublin, Lyons Research Farm, Newcastle, Co. Dublin, Ireland*.

A 2 × 2 factorial experiment was conducted to investigate the interactions between two different fucoidan (0 vs. 240 ppm) and laminarin (0 vs. 300 ppm) levels on gut morphology and volatile fatty acid concentrations in the weaned pig. Twenty-eight piglets (24 d of age, 6.9 kg live-weight) were assigned to one of four dietary treatments for 8 days post-weaning and then sacrificed. The dietary treatments were as follows (1) control diet, (2) control diet + 240 ppm fucoidan, (3) control diet + 300 ppm laminarin, (4) control diet + 300 ppm laminarin and 240 ppm fucoidan. Tissue samples were taken from the duodenum, jejunum and ileum for morphological measurements. Digesta samples were taken from the caecum and proximal colon for volatile fatty acid (VFA) analysis. In the duodenum, there was a significant interaction between laminarin and fucoidan supplementation on villous height ( $P < 0.01$ ) and the villous height to crypt depth ratio ( $P < 0.01$ ). Pigs offered the laminarin diet had an increased villous height and villous height to crypt depth ratio compared to pigs offered the control diet. However, there was no effect of laminarin when fucoidan was added. There was no effect of dietary treatment on villous height, crypt depth and villous height to crypt depth ratio in the jejunum and the ileum ( $P > 0.05$ ). There was a significant interaction between laminarin and fucoidan supplementation on the molar proportion of isobutyric acid ( $P < 0.05$ ) in the caecum. Pigs offered the fucoidan diet had a higher molar proportion of isobutyric acid compared with the control. However, there was no effect of fucoidan when laminarin was added. Pigs offered the fucoidan supplemented diets had a lower molar proportion of acetic acid (0.531 vs. 0.560, s.e. ± 0.0084,  $P < 0.05$ ) in the colon compared to pigs offered diets without fucoidan supplementation. Overall, the increase in villous height and villous height to crypt depth ratio obtained suggest that laminarin may provide a dietary means to improve gut health in weaned pigs.

**Key Words:** laminarin, fucoidan, intestinal morphology

**2023 Porcine-derived mixed bacterial culture induces an innate immune response in gnotobiotic piglets.** R. B. Harvey,\* K. J. Genovese, H. He, and D. J. Nisbet, *U.S. Department of Agriculture, Agricultural Research Service, Food and Feed Safety Research Unit, College Station, TX USA*.

Our laboratory has developed a porcine derived mixed bacterial culture (CF) isolated from the ceca of a healthy, pathogen free pig. The CF culture has been shown to protect neonatal and weaned pigs from infection and disease caused by *Salmonella* and *E. coli*. However, the mechanism of action of protection from pathogens observed with the CF culture remains unclear. Recent evidence suggests that the initial interactions between the host and its microflora soon after birth aid in the development of the immune system of neonates and in "tolerance" or acceptance of the host's microflora. To this end, in the present study, 40 piglets from 4 sows were delivered by caesarian section

and reared under gnotobiotic conditions. Piglets were either given CF within 1 h after birth or were given sterile media. At times 0, 8, 24, 48, and 72 h after birth, piglets were euthanized and samples of spleen taken. Splenic cells from individual piglets were isolated and cultured with or without concanavalin A (conA). Splenic cells from CF treated piglets had increased levels of IL1 $\beta$ , IFN $\gamma$ , IL18, and IL10 at 8 h after birth compared with control piglets as measured by porcine cytokine ELISA. The increased levels of cytokines produced by CF treated piglet splenocytes then declined over time, returning to levels observed in control pigs, or in some instances, below control levels. These results suggest that CF may act as a modulator for certain aspects of innate immune development.

**Key Words:** commensal bacteria, innate immunity, gnotobiotic piglets

**2024 The effects of immune stressors on porcine intestinal epithelial cell integrity and inflammation.** V. Mani<sup>1,5</sup>, S. C. Pearce<sup>2,5</sup>, A. J. Harris<sup>3,5</sup>, T. E. Weber<sup>4</sup>, and N. K. Gabler<sup>1,5</sup>, <sup>1</sup>Department of Animal Science, Interdepartmental Toxicology Program, <sup>2</sup>Interdepartmental Nutritional Sciences Program, <sup>3</sup>Department of Animal Science, <sup>4</sup>USDA-ARS, Ames, Iowa, USA, <sup>5</sup>Iowa State University, Ames, Iowa, USA.

Intestinal epithelial cells continually encounter luminal pathogens, immunogens and toxins. However, data regarding the effects of these substances on intestinal integrity and function in pigs are limited. Our study objective was to examine the effect of immunogens on barrier integrity and inflammation in IPEC-J2 cells. Cells were plated on 0.4  $\mu$ m pore size collagen coated transwells, where they form a single confluent monolayer, polarize and form tight junctions (TJ). The transepithelial electrical resistance (TER) was measured to evaluate TJ formation and integrity along with FITC-Dextran (FD, 4 kDa) macromolecule permeability. When the cells attained peak TER, approximately 9 d post confluence, cells were treated with the immune agonists lipopolysaccharide (LPS, 10  $\mu$ g/ml, E.coli 055:05), PolyI:C (PIC, 20  $\mu$ g/ml), zymosan (ZYM, 100  $\mu$ g/ml) and deoxynivalenol (DON, 20  $\mu$ m) on the luminal side, or with tumor necrosis factor  $\alpha$  (TNF $\alpha$ ) and interleukin 1 $\beta$  (IL1 $\beta$ ) on the basolateral side for 48 h. The TER and FD permeability was assessed for membrane integrity. Interleukin 8 (IL-8) secreted into the media was measured as a marker of inflammation. After 48 h of DON or TNF $\alpha$  treatment, TER was significantly reduced compared to the non-challenged control ( $P < 0.05$ ; 53 and 63%, respectively). The TER was not different from the control when cells were exposed to ZYM, PIC or IL1 $\beta$ . Further, FD permeability did not differ between the treatments. Compared to the control, media IL-8 concentrations were increased by TNF $\alpha$  and LPS ( $P < 0.05$ ; 0.03, 2.68 and 0.96 ng/ml, respectively). Treatment with PIC and ZYM did not increase IL-8 secretion ( $P > 0.10$ ; 0.61 and 0.31 ng/ml respectively). These data indicate that IPEC-J2 cells are particularly responsive to inflammation and barrier integrity modifications induced by DON, TNF $\alpha$  and LPS. However, barrier integrity appears to be maintained under most challenge conditions.

**Key Words:** intestinal epithelial cells, inflammation, intestinal integrity

**2025 The effects of zinc on the adaptive T cell immune response in weaning piglets.** S. Kreuzer,<sup>\*</sup> J. Schulte, J. Assmus, and G. A. Brockmann, *Humboldt-Universität zu Berlin, Breeding Biology and Molecular Genetics, Berlin, Germany.*

Because mechanisms contributing to positive effects of zinc on health in pigs are unclear, we examined how the adaptive T cell immune response could be affected by zinc. After weaning at 26  $\pm$  1 d, Landrace piglets were fed a starter diet supplemented with a low (57 ppm, group A), moderate (164 ppm, group B), or high zinc concentration (2425 ppm, group C) over a period of 4 weeks. Immune cells of the blood as well as mesenteric lymph nodes (LN) and Peyer's Patches (PP) were analyzed by flow cytometry 1, 2, 3, and 4 wk after weaning ( $n = 6$  per group). Furthermore, expression of the master transcription factors FOXP3 and TBET were assessed by quantitative RT-PCR. Feeding of a high zinc level was accompanied with high growth rates during the first week after weaning in group C (9.47 kg vs. 8.43 and 8.33 in the groups A and B, respectively), while longer feeding led to growth impairment until 4 wk after weaning when piglets of group C were the lightest ( $P < 0.001$ ). Higher frequencies of CD4<sup>+</sup>CD25<sup>high</sup> regulatory T cells were found in blood ( $P < 0.06$ ), and in ileal LN ( $P < 0.03$ ) and PP ( $P < 0.05$ ) of group C compared with B 1 wk and in particular 2 wk after weaning. These findings are consistent with higher transcript amounts of the FOXP3 in ileal and jejunal LN in group C 1 wk after weaning. The high frequency of CD4<sup>+</sup>CD25<sup>high</sup> regulatory T cells in ileal PP was associated with significantly lower CD8a<sup>high</sup> cytotoxic T cells and CD4<sup>+</sup> T helper cells ( $P < 0.005$ ) with most CD4<sup>+</sup> T helper cells activated (CD4<sup>+</sup>CD8<sup>dim</sup>). Four weeks after weaning, the positive effects of zinc were no longer detectable neither on the cell nor the transcript level. But, at the same age, TBET, the master transcription factor of Th1 cells, was higher expressed in jejunal LN of the groups A and C compared with B ( $P < 0.05$ ) suggesting a high proliferation rate of naive T helper cells toward proinflammatory Th1 cells. In conclusion, short-term feeding of a high level of zinc around the critical time of weaning may have beneficial effects on growth and activation of the immune system, while continued low or high zinc supply can lead to impaired growth and loss of the positive effects on the T cell immune response.

**Key Words:** piglets, zinc, T cells

**2026 The effects of dam parity on microbial diversity in milk, and the in vitro effects of digested milk on immunoglobulin transport and neonatal Fc receptor expression in IPEC-J2 cells.** S. E. Tangeman, E. E. Hinkle,<sup>\*</sup> H. Tran, and T. E. Burkey, *University of Nebraska-Lincoln, Lincoln, NE, USA.*

Gastrointestinal (GI) health is impacted by interactions between microbes, epithelial cells, and the mucosal immune system. Bacteria in milk can affect the GI microbial profile of progeny and recent studies suggest that progeny



immune parameters and GI bacteria may be affected by dam parity. The objectives of this study were to evaluate microbial populations in colostrum (C) and milk (M) derived from parity (P) 1 and P3 sows (n=10), and to evaluate the in vitro effects of dam parity on immunoglobulin transport and neonatal Fc receptor (FcRn) gene expression in porcine jejunal epithelial cells (IPEC-J2). Samples of C and M were collected on d 0, 7, and 14 of lactation. Bacterial DNA was isolated from C and M samples and analyzed for bacterial diversity using denaturing gradient gel electrophoresis (DGGE). IPEC-J2 cells were grown to confluency, and treated apically with 1) media alone (CTL) 2) C pooled by P 3) diluted (1:10) C and 4) undiluted C. All C treatments were in vitro digested and gastric mucosa added to treatment wells 30 min before treatments were applied. After the addition of treatment media, cells were incubated at 37°C for 30 min. Treatment media was removed and CTL media was added to all wells and incubated for an additional 30 min. Apical and basolateral media were collected and IgA and IgG quantified via swine specific ELISA. Total RNA was extracted from all cells for FcRn expression. Samples of M/C had greater ( $P < 0.05$ ) bacterial species diversity (Shannon's and Simpson's) in P3 compared to P1 samples on d 0, 7, 14. Apical and basolateral IgG concentrations were greater ( $P = 0.03$ ) in media treated with C from P3 compared to P1 dams. No P differences were observed in IgA and IgG ( $P = 0.36$  and  $0.24$ , respectively) in the digested and undigested C. No differences ( $P = 0.60$ ) were observed in FcRn expression between cells treated with digested P1 and P3 C. The results from this study show that parity does affect the microbial diversity in colostrum and M; however, parity does not affect FcRn expression or IgA and IgG transport in IPEC-J2 cells.

**Key Words:** colostrum, parity, Ig transport

**2027 Consumption of guar gum and retrograded resistant cornstarch increases interleukin-10 abundance without affecting pro-inflammatory cytokines in the colon of pigs fed a high-fat diet.** M. Fan<sup>\*1</sup>, T. Archbold<sup>1</sup>, D. Lackeyram<sup>1</sup>, Q. Liu<sup>2</sup>, Y. Mine<sup>1</sup>, and G. Paliyath<sup>1</sup>, <sup>1</sup>University of Guelph, Guelph, Ontario, Canada, <sup>2</sup>Food Research Program, Agriculture and Agri-Food Canada, Guelph, Ontario, Canada.

Increases in dietary intake of viscous and non-viscous soluble fiber are reported to improve bowel health. However, related biological mechanisms are not very clear. This study was conducted to examine response in colonic abundances of anti-inflammatory cytokine interleukin 10 (IL-10) and 2 pro-inflammatory cytokines tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ) and interleukin-6 (IL-6) in pigs fed a high-fat basal diet supplemented with 15% viscous soluble fiber guar gum and non-viscous soluble fiber resistant starch. A total of 24 Yorkshire grower barrows were assigned into a standard corn and SBM grower diet as a positive control, an animal protein based high-fat basal diet as the negative control and 2 basal diets supplemented with 15% guar gum and retrograded high-amylose cornstarch, i.e., resistant starch, according to a completely randomized block design for 4 weeks. Cytokine abundances in homogenized extractable colonic tissue supernatant samples were measured by ELISA. Compared

with the 2 control groups, consumption of guar gum and resistant starch at 15% increased ( $P < 0.05$ ) colonic IL-10 abundance. Colonic IL-10 abundance was lower ( $P < 0.05$ ) in the corn and SBM positive control diet than that in the high-fat basal negative control diet. However, there was no difference ( $P > 0.05$ ) in colonic IL-10 abundance between the 15%-guar gum and the 15%-resistant starch groups. Furthermore, there were no differences ( $P > 0.05$ ) in colonic abundances of TNF- $\alpha$  and IL-6 among the control and high fiber diets. We conclude that consumption of 15% guar gum and resistant starch supplemented in a high-fat basal diet may protect the colon from developing inflammation by enhancing IL-10 abundance.

**Key Words:** cytokines, bowel inflammation, soluble fiber

**2028 The small intestinal apical hydrolase activities are decreased in the piglet with bowel inflammation induced by dextran sodium sulfate.** D. Lackeyram,<sup>\*</sup> Y. Mine, T. Archbold, and M. Fan, University of Guelph, Guelph, Ontario, Canada.

Inflammatory bowel disease (IBD) is characterized most commonly by cramping, abdominal pain, bloating, constipation, and diarrhea. We hypothesize that compromised activities of various gut apical hydrolases may contribute to the symptoms of IBD. Objectives of this study were to investigate changes in the small intestinal hydrolytic activities, protein abundances and mRNA expression of alkaline phosphatase (IAP), lactase, maltase, sucrase and aminopeptidase N (APN) in piglets with bowel inflammation chemically induced by dextran sodium sulfate (DSS). Yorkshire piglets at 5 d of age, with an average initial BW of about 3 kg, were fitted with intra-gastric catheters and divided into control (CON, n = 6) and treatment groups (DSS, n = 5). Both groups were infused with equal volumes of either saline or 1.25 g of DSS/kg BW.d in saline, respectively, for 10 d. Activity kinetic experiments for IAP, lactase, maltase, sucrase and APN were carried out by using p-nitrophenol phosphate (0 to 8 mM), lactose (0–75mM), maltose (0 to 75 mM), sucrose (0–75mM) and L-alanine-P-nitroanilide (0 to 32 mM) at 37°C with the isolated apical membrane of the collected jejunal tissues. The target hydrolase protein abundances on the apical membrane were analyzed by Western blotting and their mRNA abundances were measured by quantitative real time RT-PCR.  $\beta$ -actin was used as the housekeeping. DSS treatment decreased ( $P < 0.05$ ) the maximal specific activity ( $\mu\text{mol/mg protein}\cdot\text{min}$ ) of IAP (53%), lactase (75%), maltase (37%), sucrase (117%) and APN (14%), and decreases ( $P < 0.05$ ) in these target hydrolase protein abundances on the apical membrane were observed in the DSS group as for IAP (39%), (35%), sucrase (36%) and APN (54%), respectively. Decreases in the mRNA abundance for lactase (25%), sucrase-isomaltase (52%), maltase-glucosamylase (75%), and APN (39%) were observed in the DSS group. However, the IAP mRNA abundance in the jejunum was increased ( $P < 0.05$ ) by 3.5 fold in the DSS group. We conclude that decreases in the gut apical activities of major hydrolases contribute to the pathogenesis of IBD.

**Key Words:** alkaline phosphatase, digestive capacity, inflammatory bowel disease



**2029 The effect of potential immunomodulating milk components on mucosal immune responses and metabolomic plasma profile of ETEC-infected weaned piglets.** S. Sugiharto, M. S. Hedemann, B. B. Jensen, and C. Lauridsen,\* *Department of Animal Science, Faculty of Science and Technology, Aarhus University AU-Foulum, Tjele, Denmark., AU-Foulum, Tjele, Denmark.*

For the identification of immunomodulating milk components that could potentially diminish diarrhea in infants caused by pathogenic *Escherichia coli* (ETEC), a study using newly weaned pigs (n = 24; 28 d of age) was performed. A 2\*2 factorial study was carried out to investigate the effect of inoculation with *E. coli* K88 (F4) or not, and the effect of an experimental diet containing potential immunomodulating milk components or a control. The experimental diet was characterized by a lower crude protein content (2.5%), and a higher proportion of SFA (approximately 2%) than the control diet. Besides daily clinical evaluation of the pigs, blood was sampled (before and after challenge, and at the time of killing). Each of 4 pigs (1 per treatment) was killed at 6, 7, 8 and 9 d after challenge (being 12–15 d of

age, respectively). The length of small intestine (SI) was measured and divided into 3 regions of equal length. From the middle of each region, a 10-cm section was removed for measurement of intestinal dimensions and mucosal immune responses. The challenge with *E. coli* reduced the wet weight ( $P < 0.001$ ) as well as the dry weight ( $P < 0.05$ ) of all measured segments of the intestinal tissue, and the ADG of the pigs tended to be decreased ( $P = 0.06$ ), whereas fecal score and fecal DM were not affected. Piglets provided the experimental diet had a reduced nominal SI surface area ( $P < 0.05$ ), and the total wet weight of the SI tended to be reduced ( $P = 0.11$ ). Concentration of immunoglobulins in plasma and bile was not affected by the treatments. Metabolomic profile of the blood plasma showed impact of *E. coli* challenge, but no influence of dietary treatments. Although the present study showed that the experimental diet had some impacts on intestinal dimensions, the overall conclusion of the present study is that *E. coli* challenge rather than diet influenced the measured responses of the pigs.

**Key Words:** immunomodulating, mucosa, metabolomic



**Session IV: Neonatal Development of Digestive  
and Absorptive Capacity**

**2030 The preterm pig as a model for studying gastrointestinal development after preterm birth.** R. Buddington\*<sup>1</sup>, K. Buddington<sup>1</sup>, D. Black<sup>2</sup>, B. Hance<sup>1</sup>, S. Grimes<sup>2</sup>, S. Chattopadhyay<sup>1</sup>, E. Huang<sup>2</sup>, and P. T. Sangild<sup>3</sup>, <sup>1</sup>*Department of Health and Sport Sciences, University of Memphis, Memphis, Tennessee, USA*, <sup>2</sup>*Department of Pediatrics, LeBonheur Children's Hospital, Memphis, Tennessee, USA*, <sup>3</sup>*Department of Human Nutrition, University of Copenhagen, DK-1958 Frederiksberg, Denmark*.

The incidence of preterm birth in the US is 12%, is increasing, and the almost 600,000 infants born at less than 92% of term (<37 weeks) are at higher risk of non-communicable, development-related diseases. The higher morbidity and mortality after preterm birth is caused by the immature organ systems of preterm infants. Notably, because of underdeveloped gastrointestinal (GI) functions, many preterm infants are initially reliant on parenteral nutrition before starting enteral nutrition (EN). Despite clinical research and medical advances there has been only limited progress in reducing the acute and chronic diseases suffered by preterm infants. Of particular concern is the increased risk of necrotizing enterocolitis among preterm infants fed formula instead of breast milk. Additionally, preterm infants commonly develop steatorrhea, indicating reduced lipid absorption. Successful transition to EN is dependent on provision of nutrients that are matched with the state of GI maturation. Although neonatal laboratory rodents have provided insights into GI development and maturation, development of their gastrointestinal tract is very different from that of the human infant, limiting their utility as an experimental model. Preterm pigs delivered by caesarian section experience GI health challenges similar to those known for late preterm human infants, including increased risk of NEC and reduced lipid absorption. This review focuses on 1) carbohydrase activities of preterm pigs and the potential relevance to NEC, 2) potential mechanisms of reduced lipid absorption, and 3) establishes the preterm pig as a model for studying GI development and nutrition after preterm birth by comparing results with emerging findings for preterm human infants. We provide evidence for the clinical relevance of the preterm pig while recognizing differences as compared with preterm infants and contend that the preterm pig will be a valuable model for evidence-based medicine that will lead to improved nutritional care of preterm infants.

**2031 The preterm pig as a model for necrotizing enterocolitis and intestinal resection.** P. T. Sangild\*<sup>1</sup>, L. Aunsholt<sup>2</sup>, T. Thymann<sup>1</sup>, A. Vegge<sup>1</sup>, S. Bering<sup>1</sup>, M. Cileborg<sup>1</sup>, M. Ladegaard<sup>1</sup>, M. Lykke<sup>1</sup>, Y. Li<sup>1</sup>, N. Quist<sup>2</sup>, D. Burrin<sup>3</sup>, and R. Buddington<sup>4</sup>, <sup>1</sup>*Department of Human Nutrition, Faculty of Science, University of Copenhagen, DK-1956 Frederiksberg, Denmark*, <sup>2</sup>*Hans Christian Andersen Children's Hospital, University of Southern Denmark, DK-5000 Odense Medicine, Denmark*, <sup>3</sup>*USDA/Agricultural Research Service Children's Nutrition Research Center, Baylor College of Medicine, Houston, Texas, USA*, <sup>4</sup>*Department of Health and Sport Science, University of Memphis, Memphis, Tennessee, USA*.

During the perinatal period, all mammals must rapidly adapt from the sterile uterine environment with constant supply

of nutrients via the placenta before birth, to a microbe-rich environment with intermittent oral uptake of complex milk nutrients via the gastrointestinal tract (GIT). Around birth, the GIT therefore undergoes marked maturation, modulated by both host genetics and environmental factors such as hormones, microbes and diet. Preterm birth disrupts the normal prenatal GIT maturation and may lead to severe neonatal GIT complications, such as necrotizing enterocolitis (NEC). NEC is closely related to oral feeding, bacterial colonization and immature digestion, absorption and GIT immunology. Consequently, preterm neonates represent a hyper-sensitive model to study neonatal GIT maturation. In the most severe cases of infant NEC, resection of the necrotic parts of the intestine is required to secure survival. Spontaneous preterm birth is less common in pigs than in humans but caesarean-delivered preterm pigs show many organ immaturities that are similar to those in preterm infants. The preterm pig may be an ideal model to study NEC and GIT adaptation to resection in infants, but may also serve as hyper-sensitive models to identify factors of importance for normal newborn pigs and infants. We review here some basic characteristics of the preterm pig model, clinical care procedures, ethical considerations, and its possible relevance for NEC in infants. We show how delivery mode, feeding procedure, diet components and bacteria affect NEC outbreak. Finally, we present some novel results on intestinal resection and show that adaptation after GIT surgery depends on gestational age at birth. The preterm pig has proved to be an important addition to existing models of infant NEC and intestinal resection. Its size, developmental characteristics and clinical similarity to preterm infants offer some obvious experimental and translational advantages. On the other hand, a relatively high cost of studies, demand for highly skilled personnel, and advanced experimental facilities, may be a limitation for widespread use of the preterm pig model.

**Key Words:** nutrition, perinatal, NEC

**2032 Potential new approaches to stimulate GLP-2 secretion and intestinal adaptation in weanling piglets.** I. R. Ipharraguerre\*<sup>1</sup>, D. G. Burrin<sup>2</sup>, A. Mereu<sup>1</sup>, D. Menoyo<sup>3</sup>, J. J. Holst<sup>4</sup>, and G. Tedó<sup>1</sup>, <sup>1</sup>*Feed Additive Division, Lucta S.A., Montornés del Vallés, Spain*, <sup>2</sup>*USDA/ARS Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, Texas*, <sup>3</sup>*Departamento de Producción Animal, Universidad Politécnica de Madrid, ETS Ingenieros Agrónomos, Madrid, Spain*, <sup>4</sup>*Department of Biomedical Sciences, University of Copenhagen, Copenhagen, Denmark*.

Weaning is a stressful event characterized by a transient period of anorexia and intestinal atrophy. The weaning-induced intestinal atrophy may be partly mediated by reduced secretion of glucagon-like peptide 2 (GLP-2), a trophic gut peptide secreted in response to luminal nutrition. We conducted 2 trials to investigate the hypothesis that stimulating endogenous GLP-2 secretion immediately after weaning may improve intestinal integrity in piglets. Treatment solutions were chenodeoxycholic acid [60 mg/kg BW, (CDC)] and  $\beta$ -sitosterol [100 mg/kg BW, (BSE)] in trial 1, and CDC (120 mg/kg BW) and zein protein hydrolyzate



(1.4 g/kg BW) in trial 2. In each trial, 36 piglets were weaned on average at 22 d of age and 6.1 kg of BW, distributed among treatments (12 pigs/treatment) in individual pens, and fed *ad libitum* a prestarter diet. During the first 6 d after weaning, feed intake was recorded daily and all piglets were intragastrically infused once daily at 7 p.m. with 50 mL of either water (control) or treatment solutions. On d 5 plasma was obtained from 6 pigs/treatment at -15, 0, 30, 60, and 120 min relative to infusions and on d 6 the remaining 6 pigs/treatment were weighed, sacrificed, and their intestines were collected for later analyses. Data were analyzed as a mixed-effect model with pig treated as random variable. Compared with control, CDC at 60 mg/kg BW increased ( $P < 0.05$ ) mean plasma GLP-2 by 77%, small intestine length, intraepithelial lymphocytes and cleaved caspase in the ileum; tended to increase ileum weight and length ( $P < 0.08$ ) and mean plasma GLP-1 ( $P < 0.13$ ) without affecting ( $P > 0.8$ ) intake and final BW. At 120 mg/kg BW, CDC also increased ( $P < 0.05$ ) GLP-1 and GLP-2, but reduced intake by about 50% and reduced BW as well as ileal crypt depth. Other treatments did not affect measured parameters, except that BSE tended to depress GLP-1 (27%) and GLP-2 (42%) compared with control. In conclusion, oral CDC treatment potentially enhanced GLP-2 secretion in weanling piglets, but the mitigation of weaning-induced intestinal atrophy was apparently counterbalanced by increased inflammation and reduced feed intake.

**Key Words:** bile acids, gut growth, pigs

**2033 Effect of feeding immunoglobulin (IgG) on gastrointestinal structure in newborn pigs.** J. Wolinski<sup>\*1</sup>, M. Slupecka<sup>1</sup>, P. Ochniewicz<sup>1</sup>, O. Fedkiv<sup>2</sup>, O. Prykholdko<sup>2</sup>, G. Ushakova<sup>3</sup>, G. Skibo<sup>4</sup>, T. Kovalenko<sup>4</sup>, I. Osadchenko<sup>4</sup>, K. Goncharova<sup>4</sup>, K. Szwiec<sup>2</sup>, B. Weström<sup>2</sup>, and S. G. Pierzynowski<sup>2,5</sup>, <sup>1</sup>The Kielanowski Institute of Animal Physiology and Nutrition, Jablonna, Poland, <sup>2</sup>Dept of Biology, Lund University, Lund, Sweden, <sup>3</sup>Dept of Biochemistry and Biophysics, Dnepropetrovsk National University, Dnepropetrovsk, Ukraine, <sup>4</sup>Bogomoletz Institute of Physiology, Kiev, Ukraine, <sup>5</sup>Dept of Medical Biology, Institute of Rural Health, Lublin, Poland.

Colostrum ingestion leads to increased gut growth and maturation and is an indispensable source of antibodies (IgG) protecting the newborn pig against infection. Here we studied the effect of feeding purified IgG on the GI tract structure. Newborn littermate pigs were either fed colostrum (Col), an elemental diet (ED) without or supplemented with purified serum IgG (ED+IgG) via a stomach tube, 10 mL/kg, during 24 h or then only ED up to 72 h where after they were sacrificed. For morphometric studies slides were prepared from the GI tract and stained with hematoxylin and eosin. Feeding the ED supplemented with IgG (ED+IgG) compared with not resulted in an increase of thickness of stomach mucosa (from 404 to 443  $\mu\text{m}$ ;  $P < 0.0001$ ) and muscularis (from 1053 to 1187  $\mu\text{m}$ ;  $P < 0.05$ ) similar to the values observed in Col-fed piglets at 72h. The addition with IgG had no effect on the stomach mucosal thickness after 24h. The duodenal and jejunal morphology became affected due IgG supplementation (ED+IgG) compared with ED group. Interestingly, at 24h IgG addition had

increased ( $P < 0.0001$ ) the values of measured parameters in duodenum (mucosa thickness from 274 to 380  $\mu\text{m}$ , villi length from 200 to 288  $\mu\text{m}$ , crypt depth from 87 to 96  $\mu\text{m}$ ) into those observed in col-fed piglets. Similar results were also obtained in the jejunum with IgG treatment. However, the effects of IgG treatment became more incoherent in the distal direction along small intestine. In conclusion, our results show that feeding an ED supplemented with IgG improved the morphology of the GI tract toward that of colostrum-fed piglets and indicates a beneficial per se effect of IgG on the GI tract in neonatal pigs.

**Key Words:** immunoglobulin G, colostrum, gut morphology

**2034 Chenodeoxycholic acid improves intestinal permeability in piglets.** Y. van der Meer<sup>1</sup>, W. J. J. Gerrits<sup>\*1</sup>, M. van den Bosch<sup>2</sup>, J. J. Holst<sup>3</sup>, W. Kulik<sup>4</sup>, and T. A. T. G. van Kempen<sup>5</sup>, <sup>1</sup>Animal Nutrition Group, Wageningen University, Wageningen, The Netherlands, <sup>2</sup>Provimi Holding B.V., Velddriel, The Netherlands, <sup>3</sup>Department of Biomedical Sciences, University of Copenhagen, Copenhagen, Denmark, <sup>4</sup>Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands, <sup>5</sup>North Carolina State University, Raleigh, North Carolina, USA.

Piglets are highly susceptible to gut health-related problems. Intravenously administered chenodeoxycholic acid (CDCA) affects gut health mediated through GLP-2. To test if CDCA is a suitable feed additive for improving gut health, a trial was performed with newly weaned (21 d) piglets offered a diet with or without 60 mg CDCA/kg feed ( $n = 24/\text{trt}$ ). Upon weaning piglets were fasted for 16 h and then intragastrically dosed with 20 g test feed in 40 g water. Subsequently, a jugular blood sample was taken on either 45, 90, 135, or 180 min for analysis of GLP-2, PYY, and glucose. Afterward, piglets were fed *ad libitum*. On d 3.5, 7.5, and 10.5 post weaning, 8 piglets per treatment were sacrificed for determination of *in vivo* intestinal permeability using lactulose and Co-EDTA. Both markers were administered intragastrically and after 2h, a blood sample was obtained through venipuncture. Immediately thereafter, intestines were harvested, and *ex vivo* permeability was measured using the everted gut sac technique with 4 kDa FITC-dextran as marker at 25, 50, and 75% of the length of the small intestines. Average daily feed intake, daily gain, gain:feed, blood glucose, plasma GLP-2, and PYY were not affected by dietary CDCA ( $P > 0.10$ ). Serum Co-EDTA and lactulose concentrations at d 10.5 tended to be lower in CDCA pigs compared with the control pigs ( $P = 0.054$ ,  $P = 0.089$ ). The everted gut sac technique data did not show any treatment effects on permeability ( $P > 0.10$ ), possibly due to reaction of the FITC-marker with light despite covering with aluminum foil. In conclusion, CDCA tended to improve intestinal permeability at 10.5 d post weaning when fed to newly weaned piglets, implying that CDCA deserves further study as a means for improving intestinal health.

**Key Words:** chenodeoxycholic acid, gut health, piglet

**2035 Evaluation of immunoglobulin absorption from colostrum supplements gavaged to newborn piglets.** J. Campbell<sup>\*1</sup>, S. Jacobi<sup>2</sup>, Y. Liu<sup>2</sup>, K. Hard Robertson<sup>3</sup>, J.

Drayton<sup>2</sup>, I. Medina<sup>2</sup>, J. Polo<sup>1</sup>, J. Crenshaw<sup>1</sup>, and J. Odle<sup>2</sup>, <sup>1</sup>APC, Inc., Ankeny, IA, US, <sup>2</sup>North Carolina State University, Raleigh, NC, US, <sup>3</sup>Virginia Tech, Blacksburg, VA, US.

Absorption of energy and immunoglobulin (IgG) at birth from colostrum may improve survival and immune-competency of newborn piglets. Adequate intake of colostrum may be difficult for piglets due to low birth weight, birth order, or viability. This study was designed to evaluate orally fed colostrum supplements with different energy sources and IgG from porcine plasma on piglet serum IgG content and absorption of IgG compared with pooled sow colostrum. Ninety-six newborn piglets from 12 sows with an average birth weight of 1288 g were used in the experiment. Eight piglets were removed from each sow immediately at birth, before suckling, and randomly allotted to receive either pooled sow colostrum or one of 3 colostrum supplements (A, B, and C) fed at 2 dosing schemes. Piglets received their allotted treatment as either 1–30 mL dose at 0 h or 3–10 mL doses at 0, 2, and 4 h. Pigs received ad libitum water at 2 h intervals after they had received their last treatment dose. Twelve hours after first dose, piglets were weighed and 4 mL of blood were collected. Plasma IgG content, apparent efficiency of absorption, hematocrit, protein, and glucose were determined. Birth weight and ending body weight did not differ between treatments; however, pigs fed sow colostrum lost more weight (–72 g) than pigs fed colostrum supplements (–40 g;  $P < 0.001$ ). No differences in hematocrit or serum glucose were detected. Serum protein was higher ( $P < 0.05$ ) in piglets fed colostrum supplements than in pigs fed sow colostrum. Serum IgG content was not different between treatments. Apparent efficiency of IgG absorption was greatest for sow colostrum followed by colostrum supplements B, A, and C (28.5, 27.6, 25.5, and 24.7%, respectively). The single and multiple dose regimens delivered comparable serum IgG, while the single dose yielded better piglet hydration as noted by less weight loss. Collectively, all colostrum supplements were comparable in delivering absorbable IgG to the neonatal piglet.

**Key Words:** colostrum, piglet, immunoglobulin G

**2036 Small intestinal development of very early-weaned piglets fed milk replacer.** M. De Vos,\* V. Huygelen, S. Willems, B. Tambuyzer, C. Casteleyn, S. Van Cruchten, and C. Van Ginneken, *University of Antwerp, Antwerp, Belgium.*

Within-litter birth weight variation usually has adverse effects on profitability. Indeed, the lightest piglets are confronted with a high mortality and impaired growth rate. Therefore, artificially rearing might help saving these piglets and assist catch up growth. However, the paucity in scientific literature makes it difficult to assess the effect of motherless rearing on crucial elements for optimal growth, such as the small intestinal morphology and digestion capacity. In this experiment, pairs ( $n = 28$ ) of low birth weight (LBW;  $< 1$  kg) and normal birth weight piglets were weaned at 3 d of age and allotted to one of 5 treatment groups: (1) group euthanized at d 3 of age (SOW3); (2) suckled piglets until d 10 of age (SOW10); (3) suckled piglets until 28 d of age

(SOW28); (4) formula-fed piglets from d 3 until d 10 (FOR10); (5) formula-fed piglets from d 3 until d 28 (FOR28). During the first post-weaning week, artificially fed piglets showed reduced average daily gain (ADG) compared with suckling piglets ( $P < 0.01$ ), being illustrative of a post-weaning growth-check. During that period, the effects of artificial rearing on small intestinal morphology were striking: FOR10 piglets had lower villi ( $386 \pm 3.4$  vs.  $489 \pm 6.5$   $\mu\text{m}$ ) ( $P < 0.01$ ), deeper crypts ( $119 \pm 1.4$  vs.  $76.0 \pm 0.69$   $\mu\text{m}$ ) ( $P < 0.01$ ) and reduced enzyme activities ( $P < 0.05$ ) compared with SOW10 piglets. In contrast, formula feeding until d 28 increased ADG compared with being sow fed ( $P = 0.03$ ). FOR28 piglets had higher villi ( $496 \pm 4.7$  vs.  $432 \pm 4.8$   $\mu\text{m}$ ) and deeper crypts ( $135 \pm 1.4$  vs.  $109 \pm 1.2$   $\mu\text{m}$ ) compared with SOW28 piglets ( $P < 0.01$ ). Besides that, FOR28 piglets expressed higher relative maltase and sucrase activities ( $P < 0.01$ ). Despite the differences created in the first post-weaning week, artificially feeding until 28 d of age improved piglets' growth and gut architecture. In conclusion, when the lightest piglets are reared on milk replacer, they catch up in growth more easily than LBW suckling piglets. This effect might be related to their elevated milk intake (measured at d 5,9,16) and increased capacity to absorb nutrients.

**Key Words:** sow milk, formula, birth weight

**2037 Half-life of porcine antibodies absorbed from a colostrum supplement containing porcine immunoglobulins.** J. Polo\*<sup>1</sup>, J. Campbell<sup>1</sup>, J. Crenshaw<sup>1</sup>, C. Rodríguez<sup>2</sup>, N. Pujol<sup>3</sup>, N. Navarro<sup>3</sup>, and J. Pujols<sup>3</sup>, <sup>1</sup>APC Inc., Ankeny, IA, US, <sup>2</sup>APC Europe, S.A., Granollers, Barcelona, Spain, <sup>3</sup>CRESA, Bellaterra, Barcelona, Spain.

Absorption of immunoglobulins (Ig) at birth from colostrum is necessary for piglet survival. The objective was to evaluate the half life of antibodies absorbed in the bloodstream of newborn piglets orally fed a colostrum supplement (CS) containing energy (fat and carbohydrates) and IgG from porcine plasma. Viable piglets ( $n = 23$ ; BW 900–1800 g) from 6 sows were colostrum deprived, blood sampled, and in 2 h of life randomly allocated to either group 1 ( $n = 9$ ) providing 30 mL of Ig-free milk replacer or group 2 ( $n = 14$ ) receiving 30 mL of CS by oral gavage. Piglets were transported to a BSL-3 facility at CRESA (Spain) and fed Ig-free milk replacer every 3–4 h for 15 d. Survival, weight, plasma IgG content by RID, and antibodies against porcine circovirus type 2 (PCV2), porcine parvovirus (PPV), porcine reproductive and respiratory syndrome (PRRS), mycoplasma hyopneumoniae (Mhy) and swine influenza virus (SIV) were determined by specific ELISA before treatment administration, 24 h and weekly for 56 d. No clinical symptoms were observed for either group. Mortality index was lower (17 vs 38%;  $P = 0.0214$ ) and BW higher (17.7 vs 15.3 kg;  $P = 0.035$ ) for pigs supplemented with CS. At 24 h post administration, the CS group had a plasma IgG mean of  $7.6 \pm 0.06$  vs  $0.14 \pm 0.03$  mg/mL for group 1. IgG levels in the CS group decayed until d 21 when de novo synthesis of IgG was detected in 25% of piglets. Half life of antibody concentration (HLAC) by RID was 6.2 d. In the CS group, high efficiency of PCV2 and PPV antibody transference was observed. For PCV-2 all animals remained positive by d 56 and the calculated HLAC was

17.7 d. For PPV 72.7% of piglets were ELISA positive by d 35 and HLAC was 12.0 d. Low transference of antibodies to PRRS, Mhy and SIV in reference to antibody levels in the CS product was observed. Calculated HLAC for PRRS, Mhy and SIV antibodies were 11.9, 8.4 and 3.0 d and by d 14 the percentage of animals with these antibodies were 25%, 33% and none respectively. The uptake and half-life of porcine supplemented antibodies varied by specific antibody showing greater absorption and duration for PCV2 and PPV vs PRRS, SIV or Mhy.

**Key Words:** colostrum, antibodies, half-life

**2038 Expression of mRNA for arginine succinate synthase and spermidine/spermine-N-acetyltransferase enzymes involved in the synthesis of polyamines by the enterocytes of recently weaned pigs.** N. Arce,\* A. Morales, M. Cervantes, D. Pérez, E. Yocupicio, and A. Araiza, *Universidad Autónoma de Baja California, Mexicali, Baja California, México.*

Polyamines are essential for the integrity and adequate functioning of the enterocyte in pigs. Early weaned pigs may experience damage of the enterocyte, which is partially associated with the impairment in the synthesis of polyamines. An experiment was conducted to evaluate the effect of weaning on the expression of mRNA for 2 enzymes involved in the synthesis of polyamines, arginine succinate synthase (ASS) and spermidine/spermine-N-acetyl transferase (SSAT) in enterocytes of pigs. Twenty 4 crossbred pigs (12 males, 12 females), weaned at 28 d of age with an average BW of  $7.43 \pm 0.52$  kg were used. All pigs received the same wheat-soybean meal diet. One group of 6 pigs was sacrificed on d 0, 3, 7, and 14 after weaning to collect mucosal samples from duodenum, jejunum, and ileum. Extraction of total RNA and the expression of mRNA coding for ASS and SSAT from mucosal samples were performed. Expression values at either, 3, 7 or 14 d vs. 0 d after weaning were compared. Relative expression (arbitrary units; mRNA for each enzyme: rRNA  $\times 10^{-3}$ ) of ASS at 0, 3, 7, and 14 d after weaning were: duodenum, 1.57, 3.28, 0.80, 0.81; jejunum, 1.04, 0.69, 1.09, 0.93; ileum, 9.47, 7.96, 8.48, 23.82. The relative expression of SSAT was: duodenum, 1.37, 4.77, 1.59, 1.21; jejunum, 0.94, 1.03, 1.01, 0.62; ileum, 1.80, 4.99, 2.19, 4.58. The expression of ASS in duodenum was 158% higher ( $P = 0.05$ ) at 3 d after weaning, but reduced at basal levels at d 7 and 14 ( $P > 0.10$ ); there was no effect of weaning date in jejunum ( $P = 0.88$ ) and ileum ( $P = 0.39$ ). The expression of SSAT was not affected by the day after weaning ( $P > 0.05$ ). The expression values of ASS and SSAT appear to be higher in ileum than duodenum and jejunum. In conclusion, the expression of ASS increased at d 3, but returns to basal levels at d 7, suggesting an additional arginine need for polyamine synthesis during the first week after weaning.

**Key Words:** polyamines, enterocytes, weaned pigs

**2039 Low birth weight is not related to higher intestinal distribution or increased serum levels of 5-hydroxytryptamine.** S. Willemen<sup>1</sup>, L. Che<sup>2</sup>, M. De Vos<sup>1</sup>, V. Huygelen<sup>1</sup>, C. Casteleyn<sup>1</sup>, S. Van Cruchten<sup>1</sup>, and C. Van

Ginneken<sup>\*1</sup>, <sup>1</sup>*University of Antwerp, Wilrijk, Belgium*, <sup>2</sup>*Sichuan Agricultural University, Yaan, Sichuan, China.*

Mortality and morbidity of piglets continues to be an economic burden and threat to animal welfare. Perinatal mortality is especially high among small for gestational age (SGA) piglets. In addition to their high perinatal morbidity and mortality, SGA piglets have difficulties catching up their growth resulting in poor carcass and meat quality. Retarded fetal growth can be attributed to placental insufficiency and impaired fetal gut functioning. Thorough understanding of the mode of gut failure and the extent to which this failing persists after birth is essential to evaluate nutritional strategies. Increased brain serotonin (5-hydroxytryptamin, 5HT) in SGA infants suggests that 5HT metabolism goes astray in case of fetal growth retardation, possibly resulting in impaired gut functioning. Thus, the aim of this study was to assess 5HT expression in enteroendocrine cells and 5HT serum levels in piglets. Fetal (day (d) 70–80 and d 90–105 of gestation) and healthy (not suffering from diarrhea) postnatal pigs (d 0 and d 3 of age) were assigned SGA (mean body weight – 1.5 SD) or NBW (normal birth weight) (mean body weight  $\pm 0.5$  SD). Each of the groups contained 5 pairs of gender-matched pigs. Proximal and distal parts of the small intestine were processed for immunohistochemistry against 5HT. 5HT serum levels were measured in d 0 and d 3 pigs by ELISA. The density of 5HT enteroendocrine cells, showed no regional ( $P = 0.12$ ) or body weight ( $P = 0.23$ ) related differences. Only the NBW fetuses had a significantly higher density of 5HT cells compared with d 3 NBW ( $P = 0.03$ ). The serum levels of 5HT revealed no age- ( $P = 0.40$ ) and body weight ( $P = 0.38$ ) related differences. These results contrast with serum and brain 5HT levels in human, guinea pig and mouse SGA and suggest that differences regarding serum and gastrointestinal 5HT cannot explain differences in gastrointestinal functioning often observed between SGA and NBW. But, since data regarding the level of 5HT in nervous tissues, and regarding the presence of the serotonin transporter are missing, an excess of 5HT and role for 5HT in gut impairment in SGA pigs cannot be excluded.

**Key Words:** serotonin, birth weight, intestine

**2040 Permeability changes in the small intestine of neonatal piglets fed formula.** V. Huygelen,\* M. De Vos, S. Willemen, B. Tambuyzer, C. Casteleyn, D. Knapen, S. Van Cruchten, and C. Van Ginneken, *University of Antwerp, Wilrijk, Antwerp, Belgium.*

Within-litter birth weight variation is adversely correlated to piglet survival and postnatal growth. Interfering by feeding these less competitive piglets a milk replacer will reduce mortality rates and ensures adequate milk intake. A compromised epithelial barrier function possibly increases paracellular permeability enabling entrance of toxins, allergenic compounds or bacteria into systemic tissues, resulting in inflammation and immunologic responses. This experiment investigated the barrier function of the small intestine of normal birth weight piglets (NBW;  $1.46 \pm 0.10$  kg) and low birth weight piglets (LBW; less than 1 kg at birth). A total of 16 pairs of LBW and NBW piglets,



aged 3 d, were selected and randomized in 3 experimental groups: a control group euthanized at d 3 of age (SOW3), sow fed piglets until d 10 (SOW10) and formula fed piglets from d 3 until d 10 (FOR10). To measure gut permeability, piglets were dosed intragastrically with 0.75 g lactulose/kg body weight (bwt) and 0.3 g mannitol/kg bwt, 4h before euthanasia. After euthanasia, small intestinal samples were snap frozen for protein analysis. Urinary sugar excretion was measured using an enzymatic spectrophotometric method. Low lactulose levels in urine of FOR10 ( $4.43 \pm 2.29$  mmol/l) versus SOW10 ( $26.40 \pm 10.22$  mmol/l) piglets are suggestive for a reduction in paracellular permeability of the intestinal mucosa of FOR10 piglets. This was further evidenced by the 6-fold elevated protein expression of occludin in FOR10 versus SOW10 ( $P < 0.01$ ). In addition, the expression of occludin, an important tight junction protein, correlated with the lactulose levels ( $R^2 = 0.32$ ;  $P < 0.01$ ). Mannitol levels in the FOR10 group ( $30.99 \pm 18.15$  mmol/l) were lower compared with SOW10 piglets ( $61.11 \pm 10.24$  mmol/l), indicating a reduced absorptive capacity. This effect could be related to the shorter villi ( $P < 0.01$ ). These results suggest a reduced absorptive capacity and a decrease in permeability of the small intestine of formula fed compared with sow fed piglets irrespective of their birth weight.

**Key Words:** small intestine, permeability, low birth weight

**2041 Insoluble nonstarch polysaccharides (iNSP) in diets for weaned piglets.** R. Gerritsen\* and P. van der Aar, *Schothorst Feed Research, Lelystad, The Netherlands.*

During the post-weaning period, diet composition can reduce intestinal damage or stimulate recovery. We examined effects of the inclusion of insoluble non-starch polysaccharides in weaner diets on post-weaning piglet performance and intestinal integrity in 2 experiments. In Exp. 1, 180 piglets were weaned at 28 d of age and divided over 3 treatments: positive control (PC; highly digestible protein), negative control (NC; standard diet) and an experimental diet (iNSP; standard+ 15% iNSP (wheat straw, oat hulls)). The experimental diets were fed during 14 d post-weaning. From d 14 onwards all piglets were fed the same phase 2 diet. Feed intake, average daily gain (ADG) and feed conversion ratio (FCR) were determined. In Exp. 2, the same diets were fed to 6 individually-housed piglets. On d 5 and 15 post-weaning, 18 piglets were euthanized to determine enzyme activity, intestinal morphology, microbiology and organ development. To determine intestinal permeability, a sugar absorption test was performed on d 1, 4 and 12 post-weaning. Data were analyzed as a randomized design by ANOVA (ANOVA). The inclusion of iNSP increased ( $P < 0.05$ ) feed intake during the first week post-weaning (173 g/d) compared with the PC (149 g/d) and NC (147 g/d) diets. The ADG of piglets fed the iNSP diet was higher ( $P < 0.05$ ) than of piglets fed the PC diet. The FCR did not differ during the first week post-weaning. Fecal consistency during the first 2 weeks was improved when piglets were fed the iNSP diet. Compared with the NC diet, the iNSP diet increased activity of the brush border enzymes, especially in the jejunum. Also the iNSP diet reduced the concentration of *E. coli* bacteria ( $3.96 \times 10^8$

log/g vs.  $5.63$ ;  $P < 0.01$ ). The iNSP diet stimulated physical adaptation of the GIT, because the stomach as percentage of the body weight was heavier than of pigs fed the negative control diet (0.89% vs. 0.76%;  $P < 0.01$ ). Liver, pancreas and intestinal weight were not affected. In conclusion, iNSP in weaner diets stimulates digestive adaptation in weaned piglets without reducing post-weaning performance.

**Key Words:** iNSP, intestinal integrity, microflora

**2042 The juvenile pig as a model for exocrine pancreatic insufficiency (EPI) in children: How to achieve sufficient vitamin A and vitamin E supply in EPI-patients ?** A. Moessler\*<sup>1</sup>, T. Schwarzmaier<sup>1</sup>, J. Grunemann<sup>2</sup>, PC Gregory<sup>2</sup>, and J. Kamphues<sup>1</sup>, <sup>1</sup>*Institute of Animal Nutrition, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany,* <sup>2</sup>*Abbott Products GmbH Germany, Hannover, Germany.*

Patients suffering from EPI are susceptible to deficiencies in fat soluble vitamins. EPI is common in children with cystic fibrosis (CF) and the aspect of achieving sufficient vitamin supply in the young is of special interest. The aim of this study was to test, which application form is best to maintain normal vit A and E levels in growing pigs with EPI - used as a model for children. In 12 pigs aged 8 weeks the pancreatic duct was ligated (PL), 4 sham operated pigs served as controls (C). The pigs ( $n = 16$ ) were individually housed and pair fed (13393 IU vit A, 122 mg vit E/kg dm of diet); from d 47 onwards, the diet was fed ad libitum. All PL ( $n = 12$ ) were supplemented with CREON (19.8g (1.048727 IU lipase)/kg feed and divided into 3 groups ( $n = 4$ ): PL-i.m.: 5250 IU vit A and 3.15 mg vit E/kg bw/week i.m. (aqueous) plus 700 mg vit E/animal/wk i.m. (oily); PL-oral: 90000 IU vit A and 600 mg vit E/kg dm added to the diet plus an emulsifier (E 484) beginning 2 weeks post OP; PL-0: no extra vitamin supply. Pigs were killed at the age of 16 weeks. Most vit A levels in serum were within the reference values (0.24–0.48 mg/L) and did not differ from C, but higher values (mean 0.52) were found at wk 8 post OP in PL-i.m. ( $P \leq 0.05$ ). In all PL-pigs serum tocopherol levels decreased within 2 weeks post OP. After 7 weeks, tocopherol levels were reduced in PL-i.m. and PL-0 but at C level in PL-oral. Tocopherol levels in liver were reduced ( $P \leq 0.05$ ) in PL-0 and PL-i.m. (6.91 resp. 8.61 mg/kgDM) while PL-oral did not differ from C (27.4 resp. 25.8 mg/kg DM;  $P \geq 0.05$ ). Liver vit A levels were lower ( $P \leq 0.05$ ) in PL-0 (136 mg/kgDM) but higher in PL-oral (375) compared with C (241). Extra oral supply of high doses of vit A and E with a high efficient emulsifier was adequate to maintain vit A and E in liver tissue within reference values. The fact that this non-invasive application form (tested in a very high dose) is highly effective is of great benefit, when thinking about the need to treat children with CF regularly (avoiding injections).

**Key Words:** vitamin A, vitamin E, EPI

**2043 Kidney bean lectin extract induces gut maturation resembling weaning.** R. Zabielski\*<sup>1</sup>, M. M. Godlewski<sup>1</sup>, P. Matyba<sup>2</sup>, J. L. Valverde Piedra<sup>3</sup>, B. Westrom<sup>4</sup>, and S. G. Pierzynowski<sup>4,5</sup>, <sup>1</sup>*Department of Physiological Sciences and Veterinary Research Center, Faculty of Veterinary*



Medicine, Warsaw University of Life Sciences, Warsaw, Poland, <sup>2</sup>Animal Clinic, Kleczew, Poland, <sup>3</sup>Department of Animal Biochemistry and Physiology, University of Life Sciences, Lublin, Poland, <sup>4</sup>Department of Biology, Lund Univ, Lund, Sweden, <sup>5</sup>Institute of Rural Health, Lublin, Poland.

We propose a novel, active strategy of pig weaning aimed at reduction of post-weaning gastrointestinal disorders. This idea originated from 20 studies with over 3000 piglets over last 10 years. Early weaning is a key to success in intensive pig production, because it increases number of pigs delivered per year. Conversely, it increases magnitude of digestive disorders caused by discrepancies between food composition and physiological capacity of suckling. Previous strategies focused on weaning diet modifications and variations in feeding mode. We propose inducing earlier maturation of the digestive system that predates actual weaning. Kidney bean lectin extract (640 U/piglet) was applied once orally (d 10–14), followed by weaning at d 28. Piglets were killed at different time points, from d 15 to 84. Lectin extract reduced ( $P < 0.05$ ) villous length and mucosa thickness, enhanced ( $P < 0.05$ ) intestinal epithelium mitosis, reduced ( $P < 0.05$ ) apoptosis and DNA damage and increased ( $P < 0.05$ ) gut immune status (CD19+ and CD3+ indexes). Furthermore, lectin extract increased ( $P < 0.05$ ) body weight gain and feed conversion ratio (both before and after weaning) and reduced ( $P < 0.05$ ) incidents of post-weaning diarrhea. Finally, onset of voluntary solid feed intake started earlier. In conclusion, lectin extract is a potent inducer of changes resembling weaning in gastrointestinal tract that may actively condition the digestive system for weaning.

**Key Words:** phytohemagglutinin, maturation, intestinal mucosa

**2044 Feed supplementation with pancreatic-like enzymes improve growth of exocrine pancreatic insufficient (EPI) pigs.** S. G. Pierzynowski<sup>1,2</sup>, K. Szwiec<sup>1</sup>, J. Valverde Piedra<sup>3</sup>, D. Gruijic<sup>1</sup>, O. Prykhodko<sup>1</sup>, O. Fedkiv<sup>1</sup>, G. Skibo<sup>4</sup>, G. Ushakova<sup>5</sup>, T. Kovalenko<sup>4</sup>, I. Osadchenko<sup>4</sup>, D. Kruszewska<sup>2,6</sup>, S. Szymanczyk<sup>3</sup>, P. Swieboda<sup>1</sup>, R. Filip<sup>2,7</sup>, and B. Westrom<sup>\*1</sup>, <sup>1</sup>Department of Biology, Lund Univ, Sweden, <sup>2</sup>Inst of Rural Health, Lublin, Poland, <sup>3</sup>Department of Biochemistry & Animal Physiology, Univ Life Sciences, Lublin, Poland, <sup>4</sup>Bogomoletz Inst of Physiology, Kiev, Ukraine, <sup>5</sup>Department of Biophysics & Biochemistry, Dnepropetrovsk National University, Ukraine, <sup>6</sup>The John Paul II Catholic Univ, Lublin, Poland, <sup>7</sup>Warsaw University of Life Sciences, Poland.

Pig growth correlates with the efficiency of pancreatic enzyme secretion. The question arises whether feed supplementation with microbial-derived enzymes that mimics the porcine pancreatic enzymes could improve growth in pigs. We investigated the effectiveness of feed supplementation with microbial enzyme on digestion and growth of young EPI pigs. To induce EPI 6 weeks old pigs underwent pancreatic duct-ligation surgery. In addition, to access the intestinal contents, ports were inserted in the stomach, duodenum and ileum to 6 EPI and 3 control pigs. After one month of recovery, pig fed diet supplemented

with enzymes for one week and digesta were collected for analyses. Body weight of EPI pigs did not change during the recovery period ( $11.7 \pm 0.9$  vs.  $11.6 \pm 0.6$  kg), while an increase was observed after a week of enzyme feeding ( $14.1 \pm 1.0$  kg,  $P < 0.01$ ). Lipase and protease activities in chyme samples from EPI pigs were very low compared with control pigs. After feeding with enzymes: lipase activity increased in duodenum from  $79 \pm 75$  to  $421 \pm 192$  U/ml ( $P < 0.01$ ), similar to that of the controls ( $507 \pm 70$  U/ml) and the total protease activity increased from  $8 \pm 9$  to  $70 \pm 87$  U/ml,  $P < 0.01$  (level in controls  $164 \pm 148$  U/ml). Fat and nitrogen digestibility increased with enzyme feeding from  $24 \pm 23\%$  to  $84 \pm 5\%$  and from  $36 \pm 28\%$  to  $57 \pm 15\%$ , respectively ( $P < 0.01$ ). Microbial enzyme feeding enhanced the fat and protein digestion similar to endogenous pancreatic enzymes in the gut lumen, thus mix of microbial enzymes can be used to stimulate growth of slow-growing pigs after the weaning period.

**Key Words:** growth, pancreas, enzymes

**2045 Feeding pancreatic-like enzymes increases gut barrier function in pre-weaned piglets.** O. Prykhodko<sup>1</sup>, J. Wolinski<sup>2</sup>, M. Slupecka<sup>2</sup>, P. Ochniewicz<sup>2</sup>, K. Szwiec<sup>1</sup>, O. Lozinski<sup>1</sup>, L. Lozinska<sup>1</sup>, O. Fedkiv<sup>1</sup>, D. Gruijic<sup>1</sup>, S. Pierzynowski<sup>1,3</sup>, and B. Westrom<sup>\*1</sup>, <sup>1</sup>Dept of Biology, Lund University, Lund, Sweden, <sup>2</sup>The Kielanowski Institute of Animal Physiology and Nutrition, Jablonna, Poland, <sup>3</sup>Dept of Medical Biology, Institute of Rural Health, Lublin, Poland.

In neonatal pigs the secretion of pancreatic enzymes is low and digesta has a high enzyme inhibition capacity due to the presence of inhibitors in the colostrum/milk and intestinal juice. In parallel to that, the gut has a relatively high permeability to macromolecules. However, with age as the pancreatic enzyme secretion increases and the level of inhibitors in the digesta decreases, the intestines become mature as manifested by a decreased macromolecular permeability. The study aimed to highlight the impact of pancreatic enzymes on gut maturation, specifically its barrier function. In 2 experimental sets, suckling 8d-old piglets were intragastrically fed with pancreatic enzymes for one week. In set I, piglets were fed twice a day with 2 enzyme preparations, both in a low and high dose: porcine Creon<sup>®</sup> or mixture of microbial-derived pancreatic-like enzymes (amylase, protease and lipase). In set II, piglets were fed a microbial protease once a day, every second day. Vehicle-fed littermate pigs were used as controls. The day after the treatment period (and 2 weeks later in set II), the gut permeability was tested by feeding the piglets a marker cocktail, containing Na-fluorescein (NaF, 376 Da) and bovine serum albumin (BSA, 69 000 Da), after which blood was sampled for either 4 (set I) or 24 h (set II). The intestinal in vivo permeability decreased in all enzyme-treated groups in a dose-dependent manner to both different-sized markers, 50% for BSA and 25% for NaF ( $P < 0.05$ ). Interestingly, also piglets fed only the microbial protease decreased their marker passage after the treatment (50% for BSA, 27% for NaF) and 2 weeks later (30% for BSA, 33% for NaF), as compared with their control littermates ( $P < 0.05$ ). Feeding pancreatic-like enzymes, including a single protease, induce maturational changes of the gut

enhancing the barrier properties. In practice, enzymes may be used to pretreat piglets before weaning to prevent post-weaning problems related to a leaky gut.

**Key Words:** gut permeability, pancreas, enzymes

**2046 Stimulating effect of pancreatic-like enzymes on the development of the gastrointestinal tract (GIT) in piglets.** M. Slupecka<sup>1</sup>, J. Wolinski<sup>\*1</sup>, O. Prykhodko<sup>2</sup>, P. Ochnewicz<sup>1</sup>, D. Gruijic<sup>2</sup>, O. Fedkiv<sup>2</sup>, B. Weström<sup>2</sup>, and S. G. Pierzynowski<sup>2,3</sup>, <sup>1</sup>The Kielanowski Institute of Animal Physiology and Nutrition, Jablonna, Poland, <sup>2</sup>Dept of Biology, Lund University, Lund, Sweden, <sup>3</sup>Dept of Medical Biology, Institute of Rural Health, Lublin, Poland.

Stimulation of GIT development to better utilize the nutritional components in milk, especially fat, is an important task for pig producers, since already from the 8–9th day of piglet life the energy value of milk is insufficient to obtain an optimal growth. The study investigated the effect of pancreatic-like enzymes on the development of the GIT in suckling 8d-old piglets. Two enzyme “cocktails,” porcine pancreatic enzymes (Creon) or microbial-derived pancreatic-like enzymes (amylase, protease and lipase), in both a low (n = 6) and high dose (n = 6), were fed via a stomach tube twice a day for 7 d and then the piglets were slaughtered for GIT dissection. Control littermates received milk alone. Administration of the enzyme cocktails, irrespective of their origin, increased triglyceride level in blood, but did not affect on the piglet body weight gain during and directly after treatment. In addition, enzyme feeding did not affect the weight (or length) of the GIT organs. However, feeding the low dose of pancreatic enzymes increased mucosa thickness ( $P < 0.001$ ; 35%), villi length ( $P < 0.001$ ; 40%), crypt depth ( $P < 0.001$ ; 35%) and mitotic division of enterocytes ( $P < 0.01$ ; 33%) in the distal small intestine. Crypt bifurcation and mature (non-vacuolated) villous enterocytes increased in the distal intestinal epithelium after both enzyme treatments. Although, pancreas weight did not change, and mitotic division of pancreatic cells increased ( $P < 0.05$ , 34%) in piglets receiving enzymes in low doses. The study revealed that pancreatic or pancreatic-like enzymes of microbial origin administered in the early post-perinatal period enhance GIT development and may be used to better prepare the piglets gut for milk utilization and weaning.

**Key Words:** pancreas, enzyme, gut maturation

**2047 Development of intestinal carbohydrates sensing, digestion and absorption mechanisms in piglets.** M. Al-Rammahi<sup>1</sup>, A. Moran<sup>1</sup>, D. Batchelor<sup>1</sup>, P. Sangild<sup>2</sup>, D. Bravo<sup>3</sup>, S. Shirazi-Beechey<sup>1</sup>, and C. Oguey<sup>\*3</sup>, <sup>1</sup>University of Liverpool, Liverpool, United Kingdom, <sup>2</sup>University of Copenhagen, Frederiksberg, Denmark, <sup>3</sup>Pancosma SA, Geneva, Switzerland.

Dietary carbohydrates are hydrolyzed by amylase, disaccharidases, sucrase, lactase and maltase into glucose, galactose and fructose. Glucose and galactose are absorbed across the apical membrane of enterocytes by Na<sup>+</sup>/glucose cotransporter 1 (SGLT1). The expression of

this transporter is regulated by dietary sugars present in the intestinal lumen. This regulation takes place via the activation of the intestinal sweet receptor, T1R2/T1R3 present in the enteroendocrine cells. Fructose is absorbed through the apical membrane of enterocytes by a passive transporter, GLUT5. The 3 monosaccharides exit the basolateral membrane of the enterocytes via Na<sup>+</sup>-independent transporter GLUT2. The objective of this work was to study the development profile of intestinal carbohydrates sensing, digestive and absorptive mechanisms in piglets. Intestinal tissues were removed from pre-term (fetal age 105 d, n = 4), full-term (115 d post-conception, n = 4), suckling (15 d old, n = 4) and weaned (28 d old, n = 8) piglets humanely euthanized. The presence of SGLT1, GLUT2, GLUT5 and the intestinal sweet receptor were measured by immunohistochemistry, quantitative PCR and functional assays, as relevant. Both before and after birth, SGLT1 was expressed on enterocytes luminal membrane, while GLUT2 was present on the enterocytes basolateral membrane and the sweet receptor in enteroendocrine cells. The GLUT5 was detected on the luminal membrane of enterocytes only in weaned animals. Levels of SGLT1 mRNA increased 11-folds between fetal age and full-term ( $P < 0.01$ ). The expression level of SGLT1 was weaned = suckling > term > pre-term. A similar expression pattern was observed for sucrase and maltase, while lactase expression was maximal in suckling animals. In conclusion, the piglet intestine is equipped early in life with majority of intestinal proteins involved in digestion and absorption of carbohydrates. Diet induces the expression and function of many of these proteins. This knowledge provides a platform for rationally designing feed and additives to ensure health and well-being of young pigs.

**Key Words:** carbohydrate sensing, digestion, absorption

**2048 Growth performance of early-weaned pigs is enhanced by feeding epidermal growth factor-expressing *Lactococcus lactis* fermentation product.** A. Bedford,<sup>\*</sup> E. Huynh, M. Fu, J. Zhu, D. Wey, C. F. M. De Lange, and J. Li, *Department of Animal and Poultry Science, University of Guelph, Guelph, Ontario, Canada.*

In early-weaned pigs digestive capacity limits expression of growth potentials, increasing the need for feeding high-quality animal proteins and antibiotics. Previously we have shown that feeding early-weaned pigs *Lactococcus lactis* engineered to express epidermal growth factor (EGF-LL) improves various measures of digestive function. To address the public concern over the use of genetically modified organisms, the aim of the current study was to investigate the effect of feeding the EGF-LL fermentation product, after separation from the genetically modified EGF-LL, on growth performance and indicators of digestive capacity of newly weaned pigs. A total of 124 newly weaned piglets (19–21 d of age; mean body weight 6.46 kg; 8 or 10 pigs/pen) were fed ad libitum in a 2-phase feeding program with moderate amounts of animal protein and without growth promoters. Four pens were assigned to each of 3 treatments: 1) blank bacterial growth medium (Control), 2) fermented EGF-LL (Ferm), and 3) supernatant

of the fermented EGF-LL (Supern). The amount of EGF was determined in the fermentation product and pigs were given 70–100 ug EGF/kg/day during the first 3 weeks post-weaning; growth performance was monitored for 4 weeks. Daily body weight gain (197 vs. 200 g/d; SEM 12) and Gain:Feed (0.450 vs 0.454; SEM 0.020) of pigs on the Ferm group was similar to that of the Control; these measures of performance were improved (254 g/d and 0.540;  $P < 0.01$ ) for pigs on Supern. Sucrase levels on d 9 of treatment were increased in Supern pigs (166.3 vs. 81.4 nmol glucose released/mg protein;  $P < 0.05$ ) compared with Control; sucrase levels of Ferm pigs were variable (202.2 nmol glucose released/mg protein). The lack of response to Ferm was likely due to an overload of bacteria (daily dose included  $9.13 \times 10^9$  EGF-LL). These results suggest that the EGF-LL fermentation product, after removal of EGF-LL, is effective in increasing growth performance of early-weaned piglets, can be used to reduce post-weaning growth lag, and may reduce reliance on feeding antibiotics and high quality animal proteins.

**Key Words:** epidermal growth factor, probiotics, growth performance

**2049 Early weaning decreases sodium-dependent acidic ileal excitatory amino acid carrier-1 (EAAC1) gene expression in pigs.** Q. J. Wang<sup>1</sup>, C. Yang<sup>2</sup>, X. Teng<sup>1</sup>, L. Xu<sup>1</sup>, D. Lackeyram<sup>3</sup>, K. Lien<sup>4</sup>, and M. Fan<sup>3</sup>, <sup>1</sup>North-east Agricultural University, Harbin, Heilongjiang Province, China, <sup>2</sup>Lucta-Guangzhou Flavors Co., Ltd., Guangzhou, Guangdong Province, China, <sup>3</sup>University of Guelph, Guelph, Ontario Canada, <sup>4</sup>University of Alberta, Edmonton, Alberta, Canada.

Enteral glutamate is preferentially used as metabolic fuel and for glutathione biosynthesis in the gut mucosa. Enterocyte apical excitatory amino acid carrier 1 (EAAC1) plays an essential role in uptake of luminal acidic AA glutamate. The glutamate transport-associated protein 3–18 (GTRAP3–18) is known to regulate post-translational trafficking and apical membrane anchoring of EAAC1. This study was conducted to examine the effect of early weaning on adaptive changes in glutamate concentration, status of oxidative stress, EAAC1 and GTRAP3–18 gene expression in ileum in weanling pigs ( $n = 6$ ) compared with the suckling counterpart ( $n = 6$ ) in Yorkshire pigs at ages of 10–22 d (initial BW  $3.23 \pm 0.13$  kg). Ileal tissue samples were partitioned into apical membrane and cytosolic fractions by differential centrifugation. Target gene protein abundances were analyzed by Western blotting while their gene mRNA relative abundances were measured by quantitative RT-PCR with the Quantitect SYBR Green kit by using  $\beta$ -actin as a housekeeping control. Weaning decreased ( $P < 0.05$ ) ileal free glutamate concentration (7.92 vs. 9.24, SEM = 0.29 mM) by 14% but did not significantly influence total antioxidant capacity and glutathione levels in the ileum compared with the suckling piglets. Weaning reduced ( $P < 0.05$ ) abundances of the 57-kDa pre-mature EAAC1 protein associated with ileal homogenate and the intracellular pool by 17 and 33%, respectively, and abundance of the 73-kDa mature EAAC1 protein associated with the apical membrane

by 22%. Weaning decreased ( $P < 0.05$ ) abundance of the 50-kDa GTRAP3–18 dimer protein associated with the ileal homogenate, the intracellular pool and the apical membrane by 8, 27, and 16%, respectively. Weaning also reduced ( $P < 0.05$ ) the ileal EAAC1 mRNA relative abundance by 73% without affecting the ileal GTRAP3–18 mRNA abundance. In conclusion, early weaning decreased the ileal free glutamate concentration and the apical acidic sodium-AA co-transporter EAAC1 abundance in association with GTRAP3–18 but did not affect status of oxidative stress in the ileum of early-weaned pigs.

**Key Words:** early-weaned pigs, gene expression, sodium-acidic amino acid co-transporter EAAC1

**2050 Early weaning up-regulates jejunal neutral amino acid exchanger (ASCT2) gene expression in pigs.** X. Teng<sup>1</sup>, Q. J. Wang<sup>1</sup>, C. Yang<sup>2</sup>, and M. Fan<sup>3</sup>, <sup>1</sup>North-east Agricultural University, Harbin, Heilongjiang Province, China, <sup>2</sup>Lucta-Guangzhou Flavors Co., Ltd., Guangzhou, Guangdong Province, China, <sup>3</sup>University of Guelph, Guelph, Ontario Canada.

Although the intestinal apical Na and Cl<sup>-</sup> dependent, broad-spectrum neutral AA exchanger ASCT2 (SLC1A5) activity does not lead to increased enterocyte net uptake of neutral AA, expression of the apical ASCT2 is known to sensing the luminal neutral AA availability as stimuli to enhance gut mucosal growth via the mammalian-target-of-rapamycin (mTOR) signaling. This study was conducted to examine the effect of early weaning on adaptive changes in ASCT2 gene expression in jejunum of weanling pigs ( $n = 6$ ) compared with the suckling counterpart ( $n = 6$ ) in Yorkshire pigs at ages of 10–22 d (initial BW  $4.48 \pm 0.26$  kg). The proximal jejunal tissue samples were partitioned into apical membrane and cytosolic fractions by differential centrifugation. Target gene protein abundances were analyzed by Western blotting while their gene mRNA relative abundances were measured by quantitative RT-PCR with the Quantitect SYBR Green kit by using  $\beta$ -actin as a housekeeping control. A 57-kDa ASCT2 protein was identified in the jejunum tissue homogenate, the intracellular fraction and on the apical membrane. Weaning increased ( $P < 0.05$ ) ASCT2 protein abundance in the jejunal homogenate and the intracellular soluble fraction by 25 and 26%, respectively, without significantly affecting ASCT2 protein abundance ( $P = 0.93$ ) on the apical membrane compared with the suckling piglets. Furthermore, weaning dramatically enhanced ( $P = 0.0095$ ) the relative abundance of the jejunal ASCT2 gene SLC1A5 mRNA by 109% in comparison with the suckling piglets. In conclusion, early weaning enhances the jejunal neutral AA exchanger ASCT2 gene SLC1A5 expression and preserves the apical ASCT2 protein abundance, which should biologically support potential practices of dietary supplementation of crystalline neutral AA for improving trophic gut growth and performance via the mTOR-signaling pathway in the early-weaned pigs fed corn and SBM-based low-cost weanling diets.

**Key Words:** Early-weaned pigs, Gene expression, Neutral AA exchanger ASCT2





**Session V: Long-Term Effects of Pre and Early  
Postnatal Nutrition/Environment**

**3000 Invited review: Long-term effects of pre and early postnatal nutrition and environment on the gut.** J. P. Lallès,\* INRA, INRA, UR1341 ADNC, F-35590 Saint-Gilles, France.

The Developmental Origins of Health and Disease (DOHAD) hypothesis formulated in the early eighties has stimulated research on long-term effects of early nutrition and environment over the last decades. Long-term is understood in this review as physiologically relevant periods such as after weaning, around sexual maturity and in adulthood, as opposed to early developmental periods. The small and large intestines as targets for long-term issues have received little attention until recent years while the stomach has been considered very rarely. Data have accumulated in laboratory animal models but they are still scarce in the swine species. Following the epidemics of metabolic diseases and obesity in Westernised countries, experimental evidence has been published showing that nutritional factors, including energy, fat and fatty acids, protein and micronutrients do impact various facets of gut function. These include alterations in intestinal digestive, absorptive, secretory, barrier and defense systems, often in a way potentially detrimental to the host. Environmental factors with long-term influence include stress (e.g., maternal deprivation; neonatal gut irritation), chemical pollutants (e.g., bisphenol A) and gut microbiota disturbances (e.g., by antibiotics). Examples of such long-term effects on the gut will be provided in both laboratory animals and pigs, together with underlying physiological mechanisms whenever available. Experimental evidence for the involvement of underlying epigenetic modifications (e.g., genomic DNA methylation) in long-term studies has just started to emerge with regard to the gastrointestinal tract. Also, interactions between the microbiota and the host are being considered as potential players in the early programming of gut functions. Finally suggestions for future research, especially in the swine species will be provided to better understand, and then control, early programming as an attempt to optimize vital functions of the gastrointestinal tract throughout adult life.

**Key Words:** nutrition, gut, long term

**3001 Long-term impact of piglet weaning age on intestinal epithelial barrier function and stress responsiveness.** A. J. Moeser,\* E. L. Overman, S. M. D'Costa, and J. Xu, North Carolina State University, College of Veterinary Medicine, Raleigh, NC, USA.

There is increasing evidence that the development and long-term function of the gastrointestinal system can be profoundly influenced by stressful experiences occurring in early life. Previous studies indicate that early weaning (weaning < 21 d of age) induces intestinal damage that is mediated by activation of intestinal stress signaling pathways (Moeser et al., 2006, 2007; Smith et al., 2010); however, the long-term effects of early weaning stress on intestinal function and stress responsiveness are unknown. In these studies, we investigated the impact of early weaning on intestinal epithelial barrier function and intestinal responsiveness to subsequent production stress.

Yorkshire-Hampshire-Large White-cross piglets were weaned either at 18 d of age (early weaned) or 28 d of age (late weaned) and housed under normal production conditions. At 12 weeks post-weaning, a subset of pigs ( $n = 6$ ) within each weaning age group were subjected to 3 h of mixing/commingling stress. Following the stress period, colon was harvested for assessment of intestinal epithelial barrier function by measuring transepithelial electrical resistance (TER) and mucosal-to-serosal flux of FITC dextran (4 kDa) in colonic tissues mounted on Ussing chambers. In addition, histological analysis of intestinal tissues were performed. Under baseline conditions (no mixing stress) colon from early weaned pigs exhibited impaired intestinal barrier function demonstrated by lower TER and greater FD4 flux rates compared with colon from late weaned pigs ( $P < 0.05$ ). Histological analysis revealed increased inflammatory cells (mast cells, neutrophils, and lymphocytes) in early weaned colonic tissues compared with late weaned pigs. Compared with unstressed controls, mixing stress in early weaned pigs caused reductions in colonic TER ( $P < 0.05$ ) and elevations in FD4 flux rates ( $P < 0.01$ ) whereas no changes were observed in late-weaned pigs subjected to the same stress. These data indicate that early life stress, such as early weaning, can have a long-lasting impact on intestinal barrier function and stress-responsiveness in the pig.

**Key Words:** intestinal barrier function, stress, early life

**3002 Butyrate supplementation to gestating sows and piglets induces muscle and adipose tissue oxidative genes and improves growth performance.** H. Lu and K. Ajuwon,\* Purdue University, West Lafayette, IN, USA.

The immediate post-weaning period often leads to post-weaning growth check in growing pigs due to changes in the diet, mixture of pigs from different litters, stress of moving and greater exposure to pathogen load. To alleviate this early growth and disease challenge, antibiotics have been used for decades to improve piglet survivability and performance. Antibiotics are now highly discouraged in pig diets due to increased risk of developing highly resistant pathogenic strains from continuous antibiotic use. We tested the effect of prenatal and postnatal butyrate supplementation on growth performance of piglets. In the first study, piglets were supplemented with 0.3% butyrate in a liquid feeding system from 4 d after birth to weaning (d21). Butyrate led to increased average daily gain of the supplemented piglets by 13% compared with saline treated control pigs. Gene expression analysis reveals significant induction of PGC-1 $\alpha$  in muscle, adipose tissue and ileum. PPAR $\alpha$  was also significantly induced in the subcutaneous adipose tissue and muscle (longissimus dorsi) of butyrate supplemented piglets. In vitro, butyrate increased ( $P < 0.05$ ) fatty acid oxidation in primary adipocytes and suppressed basal lipolysis by 62% compared with untreated cells. Butyrate significantly suppressed lipogenesis ( $^{14}\text{C}$ -glucose incorporation into lipids) in adipocytes. This was accompanied by an approximately 30% reduction in the mRNA expression of fatty acid synthase ( $P < 0.05$ ) in butyrate treated cells vs. controls. Additionally, piglets born to sows that were supplemented with 0.3% butyrate

during the last trimester of gestation had a 15% higher body weight at 12 weeks than controls. In summary, butyrate supplementation to gestating sows and piglets enhanced postweaning growth performance which may be mediated by increased substrate oxidation in butyrate treated animals

**Key Words:** butyrate, sows, piglets

**3003 Effects of early management on the long-term development of intestinal immunity in growing pigs.** M. A. Smits<sup>\*1,2</sup>, D. Schokker<sup>1</sup>, and A. J. M. Rebel<sup>2</sup>, <sup>1</sup>Wageningen UR Livestock Research, Lelystad, The Netherlands, <sup>2</sup>Central Veterinary Institute, Lelystad, The Netherlands.

Variations in early gut microbial colonization has been implicated in mucosal and systemic immune development. Early microbial colonization of the intestine in piglets may be influenced by conditions and management in the farrowing house. The objective of this study was to investigate the effect of the management on the long-term development of intestinal immunity in growing pigs. Three management systems were compared that only differed from each other in the use of antibiotics and stress factor at d 4 after birth. The used antibiotic is commonly applied in practice to prevent and/or reduce infections of the respiratory tract. The stress factors included the commonly applied practices of weighing, ear-tagging, and tail docking in pig husbandry. To investigate the effects on intestinal immunity, we performed genome-wide gene expression analyses at 2 different intestinal locations, jejunum and ileum, and at 3 different time points (8, 40, and 180 d) after birth. Differentially expressed genes were identified by pair-wise comparisons between treatment groups and tissues per time point. Functional analysis of the differentially expressed genes was used to identify intestinal processes that differed between the experimental groups. Luminal contents of the intestines were stored for analysis of microbiota composition. The results indicate that the antibiotic treatment and the applied stress factors at d 4 after birth greatly affect the expression of immune related genes in jejunum and ileum later in life. This suggests that both treatments have an effect on the development and/or activity of immune related processes in the gut of growing pigs. We hypothesize that these differences may be related to management-mediated variations in the early colonization of the gut by microbiota.

**Key Words:** early management, gene expression, immune development

**3004 The perinatal development of the gut is delayed in intrauterine growth retarded piglets.** M. Mickiewicz<sup>1,2</sup>, R. Zabielski<sup>\*2</sup>, B. Grenier<sup>3</sup>, L. Le Normand<sup>2</sup>, G. Savary<sup>2</sup>, J. J. Holst<sup>4</sup>, I. P. Oswald<sup>3</sup>, C. C. Metges<sup>5</sup>, and P. Guilloteau<sup>2</sup>, <sup>1</sup>UR 1341, Alimentation Adaptations Digestives, Nerveuses et Comportementales (ADNC), Institut National de la Recherche Agronomique (INRA), Saint Gilles, France, <sup>2</sup>Department of Physiological Sciences, Faculty of Veterinary Medicine, Warsaw University of Life Sciences, Warsaw, Poland, <sup>3</sup>INRA URPT, Unité de Recherche Pharmacologie-Toxicologie Toulouse 180 Chemin de Tournefeuille 31931, St-Martin-du-Touch, France, <sup>4</sup>Department of Medical Physiology, University of Copenhagen, Copenhagen,

Denmark, <sup>5</sup>Research Unit Nutritional Physiology, Leibniz Institute for Farm Animal Biology (FBN), Dummerstorf, Germany.

Protein level in maternal diet plays crucial role in fetal programming during pregnancy. Low or high protein level increases risk of intrauterine growth retardation (IUGR). Pigs with IUGR are weaker, smaller, and suffer from digestive disorders. This study was conducted to investigate small intestine (SI) development and function in piglets from sows fed control (C, 12.1%) high (HP, 30%) or low (LP, 6.5%) protein diet during pregnancy. Newborns were allocated in two groups: IUGR (birth weight < 1.18 kg) and non-IUGR (birth weight > 1.18 kg). Animals were slaughtered at postnatal day (PD) 1 and 28. LP-diet in non-IUGR decreased body weight at PD1, LP and HP-diet decreased ( $P < 0.05$ ) body weight and slowed down catch-up growth in IUGR until PD28. Concentration of GLP2 decreased ( $P < 0.01$ ) in HP-diet at PD28 in non-IUGR group. The HP and LP-diet increased ( $P < 0.05$ ) length of villi at PD1 in non-IUGRs but not in IUGRs. Vacuolated enterocytes were absent in mid-SI on PD28 in non-IUGRs, but still present in IUGRs. Mitosis-to-apoptosis ratio tended to increase in HP offspring as compared to C and was higher at PD1 in LP non-IUGR but not in IUGR piglets. Reverse effects in HP-diet were observed at PD28 in non-IUGR animals. Concluding, HP and LP diets led to retarded development of non-IUGR offspring. Several changes in SI enzymes activity profile were observed. Non-IUGR of LP and HP groups modified SI function, whereas IUGRs lost this ability. HP- and LP-diets slowed down catch-up growth, furthermore enzyme profile was not flexible which might result in reduced digestive function in IUGRs.

**Key Words:** IUGR, enterocyte, mucosa maturation

**3005 Effects of a simple or a complex starter microbiota on intestinal microbiota composition in caesarean derived piglets.** A. J. M. Jansman<sup>\*1</sup>, J. Zhang<sup>2</sup>, S. J. Koopmans<sup>1</sup>, R. A. Dekker<sup>1</sup>, and H. Smidt<sup>2</sup>, <sup>1</sup>Wageningen UR Livestock Research, Lelystad, The Netherlands, <sup>2</sup>Wageningen University, Laboratory of Microbiology, Wageningen, The Netherlands.

The present study was designed to develop a model in piglets that allows investigating the effects of the postnatal association with a simple or a complex microbiota on gut health and development. Thirty piglets from two sows were obtained by caesarean delivery (day 0) and were equally divided over two treatment groups housed in separate clean, non-sterile rooms. All piglets received orally a simple microbiota consisting of *Lactobacillus amylovorus*, *Clostridium glycolicum* and *Parabacteroides* sp. on days 1, 2 and 3 after birth. On days 3 and 4 the piglets received either a complex microbiota by providing them with a fecal inoculant of an adult sow (Complex Association, CA) or a placebo inoculant (Simple Association, SA). Piglets were fed a milk replacer diet during a period of five days and a commercial liquid diet during the remainder of the study. Piglets were studied during a period of 28 days with regard to health status, development of body weight, voluntary feed intake and microbiota composition of digesta and feces.

Fecal microbiota composition, as determined by DGGE and by Pig Intestinal Tract Chip analysis of 16S ribosomal RNA genes (days 3, 5, 7, 14 and 28) was less diverse in the SA group compared to the CA group. A difference in fecal microbiota composition between treatments persisted until the end of the study. In both experimental groups, microbiota composition changed over time during the study. In the CA group, further analysis of the faecal microbial patterns showed that clustering of microbial communities occurred among samples of piglets within this treatment group and with the profile of the feces from the donor sow. Less clustering of the microbiota profiles was observed in feces from piglets in the SA group.

It was concluded that the composition of microbiota in digesta and feces of CD-derived piglets is influenced by bacterial association in the first days after birth. Differences in intestinal microbiota composition between piglets exposed to simple or complex inocula at early age persisted for at least four weeks.

**Key Words:** starter microbiota, piglets, microbiota composition digestive tract

**3006 The influence of yeast extract in end gestation and lactation diets on piglets performance.** J. M. R. Pupa<sup>2</sup>, M. I. Hannas<sup>1</sup>, C. M. C. Pereira<sup>1</sup>, and F. Catunda<sup>3\*</sup>, <sup>1</sup>Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil, <sup>2</sup>AllNutri Consultoria e Planejamento em Nutrição Animal, Viçosa, Minas Gerais, Brazil, <sup>3</sup>Alltech do Brasil, Curitiba, Paraná, Brazil.

This study was conducted in a commercial farm to investigate the influence of yeast extract in end gestation and lactation diets for sows on piglet performance using a total of 62 sows PIC (primiparous = 10 and multiparous = 52) in a randomized block design with 2 treatments (0 or 2% of yeast extract, Nupro; Alltech, São Pedro do Ivaí, PR). Treatments were equalized by parity. Sows received diets that contained 0 or 2% yeast extract (control or yeast extract, respectively, n = 31/group). The yeast extract were included in diets to replace soybean meal. Females were fed the dietary treatments starting on 95 d of gestation. Daily feed allowance provided the same amount of diets during end gestation (3 kg/d). Throughout lactation, females were allowed to consume the lactation feed with same treatments ad libitum. Gestation and lactation diets were formulated to 0.72 and 1.10% of digestible lysine, respectively. All other nutrients met or exceeded Rostagno et al. (2005) requirements. Litters were standardized until 24 h after birth but piglets were maintain in the same room and treatments using individual earring. After 4 d, the piglets received creep feed ad libitum. All piglets were individually weight at birth, 7 d and 21 d after birth. We also recorded the total number of piglets alive, piglets that died and unviable during the first week after birth and at weaning. Piglets born from sows fed the yeast extract during end gestation have higher birth weight (1.59 kg vs. 1.45 kg;  $P < 0.001$ ). The piglets from sows fed yeast extract during the last trimester of gestation and lactation had greater body weight at 7 and at weaning,

respectively, (2.72 kg vs. 2.43 kg;  $P < 0.001$ ) and (5.37 kg vs. 4.78 kg;  $P < 0.001$ ) and grew faster (189 g/d vs. 167 g/d;  $P < 0.001$ ) than piglets from control sows. After first week the total number of piglets died or unviable were higher in the control group ( $P < 0.05$ ), but no differences ( $P < 0.05$ ) were observed at weaning. The use of yeast extract in sow diets during the last trimester of gestation and lactation promoted a better piglets performance until weaning.

**Key Words:** protein source, swine, weaning

**3007 Impact of *Pichia guilliermondii* (Pg) on weaned pig immune performance.** B. Bass<sup>\*1</sup>, V. Perez<sup>2</sup>, H. Yang<sup>2</sup>, T. Tsai<sup>1</sup>, D. Holzgraefe<sup>2</sup>, J. Chewning<sup>1</sup>, and C. Maxwell<sup>1</sup>, <sup>1</sup>University of Arkansas, Fayetteville, AR, USA, <sup>2</sup>ADM Alliance Nutrition, Quincy, IL, USA.

To determine whether a whole *Pichia guilliermondii* (Pg) yeast product (CitriStim; ADM Alliance Nutrition) fed to sows throughout gestation and lactation alters the immune system of the resulting progeny, an RCBP experiment was conducted. Treatments were in a 3 (sows fed 0, 0.1, or 0.2% Pg) x 2 (nursery pigs fed with or without Pg) factorial arrangement. The Pg was included in nursery diets at 0.2, 0.1, and 0.1% in phases 1 (7d), 2 (14 d), and 3 (14 d), respectively. Pigs (n = 336) were weaned at about 21 d of age; feed and water were offered to allow ad libitum intake. Blood samples were collected on d 5 and 28 post-weaning for analysis of leukocyte differential on whole blood as well as serum IgA, IgG, IgM, and haptoglobin. Within pigs from sows fed 0.2% Pg, those fed Pg had a larger percentage of total leukocytes that were eosinophils on d 5 than those fed without Pg (sow linear x nursery,  $P = 0.02$ ); on d 28, the same parameter increased in all pigs from sows fed 0.2% Pg (sow linear,  $P = 0.06$ ). On d 28, total leukocytes and eosinophils increased in pigs from sows fed 0.2% Pg (sow quadratic,  $P = 0.03$ ). Pigs from sows fed 0.1% Pg had an increased (sow quadratic,  $P = 0.03$ ) overall concentration of IgG (4.96, 5.96, and 5.38 mg/ml in those fed 0, 0.1, and 0.2% Pg, respectively), tended to have increased overall concentration of IgA (0.29, 0.41, and 0.31 mg/ml for those fed 0, 0.1, and 0.2% Pg, respectively; sow quadratic,  $P = 0.10$ ), and decreased concentration of haptoglobin (1.85, 1.49, and 1.94 mg/ml in those fed 0, 0.1, and 0.2% Pg, respectively; sow quadratic,  $P = 0.08$ ), than those from sows fed without Pg. It was previously reported that inclusion of Pg in sow diets increased ADG, ADFI, and BW of weaned pigs, and the improvement was additive if Pg was provided in nursery diets. In conclusion, feeding sows with Pg through gestation and lactation altered immune parameters in the resulting progeny.

**Key Words:** nursery pig, yeast product

**3008 Effect of age and of maternal antibiotic treatment on offspring gastric expression of the receptor for umami taste (TAS1R1) and of  $\alpha$ -transducin, a taste receptor signaling messenger.** P. Trevisi<sup>1</sup>, S. Messori<sup>1</sup>, D. Priori<sup>1</sup>, M. Mazzoni<sup>2</sup>, J.-P. Lalles<sup>3</sup>, and P. Bosi<sup>\*1</sup>, <sup>1</sup>DIPROVAL, University of Boogna, Bologna, Italy, <sup>2</sup>Dept. of Veterinary Sciences, University of Bologna, Ozzano nell'Emilia, Italy, <sup>3</sup>INRA, UR1341 ADNC, F-35590 Saint-Gilles, France.



Gut maturation during suckling and after weaning is influenced by maternal environment. Scarce is the knowledge on the presence and the regulation of taste receptors in the pig gastro-intestinal tract. The same is for the machinery that processes the taste signals, including  $\alpha$ -transducin. Our main goal was to assess if the age of offspring and maternal environment, as influenced by a maternal antibiotic treatment, could affect the expression of the receptors for umami and sweet taste in offspring stomach. Eighty 4 pigs reared from sows fed a diet with or without Amoxicillin (40 mg/kg BW/d, on -10 d to +21 d from farrowing, ATB) were sacrificed at 14 d, 21 d, 28 d (weaning) or 42 d, and sampled for oxyntic (OXY) and pyloric mucosa (PY). In PY, gene expression (RT Real-Time PCR, corrected for 2 housekeeping genes) for TAS1R3 (necessary for sweet and umami taste) was stable in time and not affected by ATB. TAS1R1 (complementary for umami) increased from suckling to post-weaning period ( $P = 0.001$ ), and was lower in ATB offspring ( $P = 0.013$ ). TAS1R2 (complementary for sweet) gene expression was not detected. TAS1R1 gene expression in OXY, increased with age in suckling period ( $P = 0.013$ ), but not later. Transducin gene expression in PY was higher in ATB offspring ( $P = 0.043$ ); the number of cells staining for transducin per gland in PY decreased during the suckling and post-weaning periods ( $P < 0.001$ ), while cell counts tended to be lower in ATB offspring ( $P = 0.092$ ). TAS1R1 and TAS1R3 gene expression in PY was also tested in littermate offspring that were reared up to the age of 5 mo, and then kept on the same diet (low fat, 2%) or switched to a high fat (11%) diet for 4 weeks ( $n = 10$  pigs per group). Neither perinatal ATB treatment nor later fat diet content affected the studied variables. Data show that sensing for umami taste has relevance for 2 different gastric mucosae. It can change with age and be potentially affected by maternal environment. For  $\alpha$ -transducin, divergent observations on gene expression and positive cell counts require further evaluation.

**Key Words:** umami, sow environment, taste

**3009 Effects of supplemental zinc amino acid complex on intestinal integrity in heat-stressed pigs.** M. V. Sanz-Fernandez<sup>\*1</sup>, S. C. Pearce<sup>1</sup>, V. Mani<sup>1</sup>, N. K. Gabler<sup>1</sup>, J. F. Patience<sup>1</sup>, M. E. Wilson<sup>2</sup>, M. T. Socha<sup>2</sup>, R. P. Rhoads<sup>3</sup>, and L. H. Baumgard<sup>1</sup>, <sup>1</sup>Iowa State University, Ames, IA, USA, <sup>2</sup>Zinpro Corporation, Eden Prairie, MN, USA, <sup>3</sup>Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Heat stress (HS) reduces livestock productivity and this may in part be mediated by reduced intestinal integrity or "leaky gut." Zinc improves intestinal integrity in a variety of human and small animal models. Consequently, we hypothesized that zinc amino acid complex (ZnAA) would mitigate HS-induced leaky gut in pigs. Crossbred gilts (43  $\pm$  6 kg BW) were ad libitum fed 1 of 3 diets: 1) control (120 ppm ZnSO<sub>4</sub>;  $n = 29$ ), 2) control + 100 ppm ZnAA from Availa Zn (Zn220; Zinpro Corporation;  $n = 14$ ), and 3) control + 200 ppm ZnAA from Availa Zn (Zn320;  $n = 16$ ). After 25d on experimental diets, half of the controls ( $n = 13$ ), and all Zn220 and Zn320-fed pigs were exposed to constant HS conditions (36°C,  $\approx$ 50% RH) and fed ad libitum. To

eliminate the confounding effects of dissimilar feed intake, 16 control pigs remained in thermo-neutral (TN) conditions (19°C,  $\approx$ 61% RH) and were pair-fed (PF) to the HS pigs. After either 1 or 7d of environmental exposure, pigs from each dietary treatment were euthanized and fresh ileum and colon sections were isolated and mounted into modified Ussing chambers. Intestinal permeability was assessed via measures of transepithelial electrical resistance (TER) and apparent permeability coefficients (APP) for fluorescein isothiocyanate-labeled (FITC) lipopolysaccharide (LPS) and the macromolecule FITC-dextran. As HS progressed, both ileal and colonic TER decreased ( $P \leq 0.01$ ; 31 and 17%, respectively). This was mirrored by an increase in ileal and colonic FITC-dextran APP with time ( $P \leq 0.01$ ; 15 and 6 fold, respectively). Colonic FITC-LPS APP tended to increase ( $P \leq 0.10$ ; 106%) from d1 to 7, but did not differ between treatments. There was a quadratic response ( $P = 0.02$ ) to increasing ZnAA on ileal TER, as it was improved ( $P \leq 0.05$ ; 57%) in Zn220-fed pigs compared with control HS pigs. This was paralleled with a weak ( $P = 0.13$ ) quadratic decrease in ileal FITC-dextran APP for Zn220-fed pigs compared with controls and Zn320-fed pigs. These data demonstrate that supplementing ZnAA at the Zn220 dose improves small intestinal integrity during severe HS.

**Key Words:** heat stress, zinc amino acid complex, intestine

**3010 The effect of feeding genetically modified Bt MON810 maize to sows during first gestation and lactation on maternal and offspring health.** M. C. Walsh<sup>1</sup>, S. G. Buzoianu<sup>1,2</sup>, G. E. Gardiner<sup>2</sup>, M. C. Rea<sup>3</sup>, O. O'Donovan<sup>2</sup>, R. P. Ross<sup>3</sup>, and P. G. Lawlor<sup>\*1</sup>, <sup>1</sup>Teagasc, Pig Development Department, Moorepark, Fermoy, Co. Cork Ireland, <sup>2</sup>Waterford Institute of Technology, Waterford, Ireland, <sup>3</sup>Teagasc, Food Research Centre, Moorepark, Fermoy, Co. Cork, Ireland.

The objective of this research was to examine the trans-generational effects of feeding Bt MON810 maize on maternal and offspring health in pigs. Sows ( $n = 24$ ) were fed Bt or isogenic maize diets from service to the end of lactation. Back-fat depth and BW were recorded at service, on d 56 and 110 of gestation and on d 28 of lactation and blood samples were taken for hematological and serum biochemical analyses. The number of piglets born alive, stillborn and weaned per litter was recorded. Individual piglet BW ( $n = 24$ ) was recorded at birth and weaning and ADG was calculated for the suckling period. The fourth piglet born alive was sacrificed, organs were weighed and blood samples were taken for serum biochemical and hematological analyses. Bt maize-fed sows were heavier on d 56 of gestation ( $P < 0.05$ ). Offspring from sows fed isogenic maize tended to be heavier at weaning ( $P = 0.08$ ) but not at birth and there was no difference in ADG. Sows fed Bt maize tended to have lower serum total protein ( $P = 0.10$ ) and gamma glutamyl transferase on d 28 of lactation ( $P = 0.06$ ) and higher serum creatinine ( $P < 0.05$ ). Serum urea tended to be lower in Bt maize-fed sows on d 110 of gestation ( $P = 0.10$ ) and in their offspring at birth ( $P = 0.08$ ). Sow hemoglobin ( $P = 0.06$ ) and hematocrit ( $P = 0.10$ ) tended to be decreased in response to feeding Bt maize and erythrocyte count was lower ( $P < 0.01$ ). Mean

cell hemoglobin concentration (MCHC,  $P = 0.05$ ) was lower and platelet count tended to be lower ( $P = 0.07$ ) on d 110 of gestation in Bt maize-fed sows; however, MCHC tended to be higher in their offspring at birth ( $P = 0.08$ ). Feeding Bt maize did not affect piglet organ weight at birth. The differences in sow serum biochemistry observed in response to feeding Bt maize were not indicative of organ dysfunction. Haematological differences are thought to be due to numerically higher litter size in Bt maize-fed sows and appear to be unrelated to Bt maize exposure. Although some differences in offspring serum biochemistry and hematology were observed at birth in response to maternal feeding of Bt maize, they are not believed to be of biological importance. Sows fed Bt maize were heavier on d 56 of gestation but their offspring tended to be lighter at weaning compared with the isogenic treatment.

**Key Words:** cry1Ab, safety, maize

**3011 Zinc oxide at low supplementation level improves productive performance and health status of piglets.** J. Morales<sup>1</sup>, G. Cordero<sup>1</sup>, C. Pineiro<sup>1</sup>, and S. Durosoy<sup>\*2</sup>, <sup>1</sup>PigCHAMP Pro Europa SL, Segovia, Spain, <sup>2</sup>ANIMINE, Sillingy, France.

Use of Zinc oxide (ZnO) at high doses (3000 ppm) for diarrhea prophylaxis in piglets is widely extended in post-weaning Spanish diets, in compliance with the national veterinary regulation. However, European feed legislation limits total dietary Zn to a maximum of 150 mg/kg of complete feed. The objective of this study was to compare a new potentiated form of zinc oxide (HiZox, Animine) at nutritional level (150 ppm) with pharmacological dosage (3000 ppm) of regular ZnO in starter diets on the productive performance and health status of piglets in a medium-low health status farm. A total of 144 pigs at weaning (28 d of age) were distributed in 6 piglets/pen and 12 pens/treatment. In the prestarter phase (28–42 d of age), all pigs received the same commercial feed, including 3000 ppm ZnO. In the starter phase (42–63 d of age) T1 included 3000 ppm of regular ZnO, and T2 was supplemented with 110 ppm Zn from potentiated zinc oxide (HiZox). Feed intake (FI), average daily weight gain (ADWG), feed conversion ratio (FCR) and PigMAP serum concentration, an acute phase-protein commonly used as unspecific biomarker of disease or other acute phase reactions, were measured at 42 and 63 d of life. Pen of 6 piglets was the experimental unit and data were analyzed using the GLM procedure of SAS v9.0. Piglets fed with T2-HiZox had improved ADWG and FCR ( $P < 0.001$ ) compared with piglets fed with T1-ZnO. In addition, at 63 d of age, T2 group has a lower PigMAP serum concentration than T1 group (1.71 vs 0.95  $\mu\text{g/ml}$ ;  $P < 0.05$ ), indicating higher health status in T2 group. In conclusion, in low-medium sanitary conditions and in compliance with European regulation, HiZox significantly increased piglet growth compared with pharmacological dosage of regular ZnO in the starter phase. This can be explained by a better health of pigs expressed by a lower level of inflammatory protein PigMAP.

**Key Words:** zinc oxide, PigMAP, piglets

**3012 Brain development is dependent on colostrum intake in newborn piglets.** G. Skibo<sup>\*1</sup>, T. Kovalenko<sup>1</sup>, I. Osadchenko<sup>1</sup>, K. Goncharova<sup>1</sup>, G. Ushakova<sup>2</sup>, J. Wolinski<sup>3</sup>, P. Ochniewicz<sup>3</sup>, M. Slupecka<sup>3</sup>, K. Szwiec<sup>4</sup>, O. Prykhodko<sup>4</sup>, O. Fedkiv<sup>4</sup>, D. Gruijc<sup>4</sup>, B. Westrom<sup>4</sup>, and S. G. Pierzynowski<sup>4,5</sup>, <sup>1</sup>Bogomoletz Inst of Physiology, Kiev, Ukraine, <sup>2</sup>Department of Biophysics & Biochemistry, Dnepropetrovsk National Univ, Ukraine, <sup>3</sup>The Kielanowski Inst of Animal Physiology & Nutrition, Jablonna, Poland, <sup>4</sup>Department of Biology, Lund Univ, Sweden, <sup>5</sup>Inst of Rural Health, Lublin, Poland.

Colostrum is an indispensable source of antibodies (IgG) protecting the newborn pig against infection. In addition, it has been observed that the behavior of colostrum-deprived piglets is different from ones that suckle. This study was designed to evaluate the role of colostrum in brain development in newborn pigs. Shortly after birth, piglets were divided into 5 groups: unsuckled (A), suckled (B), and fed: colostrum (C), elemental diet (ED), and ED + IgG (purified serum IgG) via a stomach tube, 10 mL/kg during first 24 h. From 24 to 72 h all pigs were fed with ED after which they were killed and the brain was dissected. The hippocampal neurons, astrocytes and microglial cells were identified by specific antibodies and analyzed with confocal microscope. Neuron-specific protein (NeuN), used as a marker of post-mitotic cells, labeled both mature and newly generated neurons in the hippocampal CA1 area. The number of newly generated neurons was diminished in C, ED and ED+IgG groups compared with group A (for ED+IgG group,  $P < 0.01$ ). Active migration of microglial cells and astrocytes from the proliferative areas and their significant increase was observed only in the hippocampus of suckling piglets (B). In the group ED we observed a 52% decrease in microglial cells by at 72h ( $P < 0.01$ ) as compared with group C. In group ED+IgG the microglial cell numbers was decreased only by 12% at 72h and was different from group ED ( $P < 0.01$ ). In conclusion, piglets deprived of colostrum in this study had a reduction in postnatal hippocampal neuro and gliogenesis. Feeding with ED, instead of colostrum, didn't help physiological postnatal brain development. Addition of IgG to ED improved the neurogenesis and supported immune status of the brain.

**Key Words:** colostrum, brain, development

**3013 Behavioral changes in response to feeding pancreatic-like enzymes to exocrine pancreatic insufficient (EPI) pigs.** S. G. Pierzynowski<sup>1,2</sup>, P. Swieboda<sup>1</sup>, K. Szwiec<sup>1</sup>, D. Gruijc<sup>1</sup>, J. Botermans<sup>3</sup>, J. Svendsen<sup>3</sup>, J. L. Valverde Piedra<sup>4</sup>, O. Prykhodko<sup>1</sup>, G. Skibo<sup>5</sup>, T. Kovalenko<sup>5</sup>, K. Goncharova<sup>5</sup>, G. Ushakova<sup>6</sup>, D. Kruszewska<sup>2,7</sup>, R. Filip<sup>2,8</sup>, and B. Westrom<sup>\*1</sup>, <sup>1</sup>Department of Biology, Lund Univ, Sweden, <sup>2</sup>Inst of Rural Health, Lublin, Poland, <sup>3</sup>Department of Rural Buildings, Swedish Univ Agricultural Sciences, Alnarp, Sweden, <sup>4</sup>Department Biochemistry & Animal Physiology, Univ Life Sciences, Lublin, Poland, <sup>5</sup>Bogomoletz Inst of Physiology, Kiev, Ukraine, <sup>6</sup>Department of Biophysics & Biochemistry, Dnepropetrovsk National University, Ukraine, <sup>7</sup>The John Paul II Catholic Univ, Lublin, Poland, <sup>8</sup>Warsaw University of Life Sciences, Poland.

It is well documented that the nutritional status of exocrine pancreatic insufficient (EPI) patients supplemented with porcine pancreatic enzymes is greatly improved. However, behavioral changes during the therapy have never been studied. The present study investigated behavioral changes in total EPI pigs where the feed was supplemented with pancreatic-like enzymes of microbial origin, in addition to the effect on growth. A 2 × 4 crossover-randomized study was used to test the effect of enzyme supplementation EPI pigs that underwent pancreatic duct-ligation. After 6 weeks of recovery, the study started including 2 control and 2 microbial pancreatic-like enzyme feeding periods of 10 d. At d 7 and 10 of each experimental period, behavior was monitored during 24 h and feed consumption and body weight were recorded. Behavioral observations focused on the pigs' position: lying down/passive, sitting or standing/active and were expressed as percent activity during 24 h. Body growth was totally inhibited during the recovery period, while during the study, the mean body weight of the pigs increased from 10.5 ± 1.1 to 14.0 ± 1.4 kg ( $P < 0.01$ ), despite enzyme feeding only every second week. Importantly, we found that EPI pigs were more active when fed microbial enzymes (19% /24h) than when fed control diet only (16% /24h,  $P < 0.01$ ). Microbial pancreatic-like enzyme supplementation improved the growth of the EPI pigs, but also increased their activity. This behavior contradicts the generally accepted norm according to which satiety reduces human or animal motility.

**Key Words:** behavior, pancreas, enzymes

**3014 Feed intake, rather than digestion is the growth-limiting factor in poor performing piglets.** S. P. Paredes\*<sup>1</sup>, A. Awati<sup>1</sup>, A. J. M. Jansman<sup>3</sup>, H. M. J. van Hees<sup>1</sup>, M. W. A. Verstegen<sup>2</sup>, and W. J. J. Gerrits<sup>2</sup>, <sup>1</sup>Nutreco Research and Development, Boxmeer, The Netherlands, <sup>2</sup>Animal Nutrition Group, Wageningen University, Wageningen, The Netherlands, <sup>3</sup>Wageningen UR Livestock Research, Lelystad, The Netherlands.

Variation in body weight gain during the nursery period has a large economic impact in pig production. Understanding the reasons for variation in animal performance and the factors that limit growth could result in management strategies to reduce this variation. To this aim, 2 distinct sub populations (Poor performers, P; High performers, H) of clinically healthy pigs were selected at 3 weeks post weaning (~6 weeks of age) based on an equation including BW at birth, weaning, 3 wk post weaning and sex. At 6 wk of age, P pigs (6.8 kg BW, SE 0.14) and H pigs (12.2 kg BW, SE 0.14), were housed individually in a high hygiene research facility and provided with high quality palatable diet (175 g/kg CP; 10.6 MJ NE; 13.5 g/kg AID Lys) until 10 wk of age. Pigs had ad libitum access to feed and water. Apparent ileal (slaughter) and total tract nutrient digestibility were measured. It was observed that fractional growth rate (i.e., ADG expressed as percentage of mean BW) was lower for H pigs than for P pigs (3.0 vs 3.3%;  $P < 0.01$ ). ADFI was higher for H pigs (275 g/d higher;  $P < 0.001$ ) than for P pigs throughout the 4 wk experimental period, while feed efficiency was not different. At the end of the experimental period, H pigs were heavier compared with

P pigs (30 vs. 19 kg BW), had greater body length (73 vs. 62 cm) and head circumference (49 vs. 43 cm), all  $P < 0.05$ . Apparent ileal digestibility (0.78, 0.80 and 0.81 for DM, GE and N, respectively) and total tract digestibility (0.87, 0.87 and 0.84 for DM, GE and N, respectively) were similar for P and H pigs. In conclusion, when compared with high performers, piglets identified as poor performers continued their poor performance during individual housing and optimized rearing conditions until 10 wk of age. The substantial difference in BW at 10 wk was related to differences in feed intake rather than to digestive utilization or feed conversion efficiency. We can deduct from these observations that the determinants for body weight at the end of the nursery period are already set during the first weeks of life.

**Key Words:** growth, limiting, digestion

**3015 Efficacy of prebiotics on lactose digestibility, whole body protein metabolic status and growth performance in replacing antibiotics in weanling pigs fed corn, soybean meal and dried-whey powder based diets.** M. Hayhoe,\* T. Archbold, Q. Wang, X. Yang, and M. Fan, *University of Guelph, Guelph, Ontario, Canada.*

This study was conducted to determine effects 4 prebiotic supplements on lactose digestibility, protein metabolic status and performance of weanling pigs in comparison with 2 control diets containing an antibiotic growth promoter or without antibiotics. Six experimental diets were corn (40%) and SBM (28%) based and supplemented with fish meal (9%) and dried whey powder (20%). Diet 1, being a negative control, was the basal diet, containing no antibiotics and supplemental prebiotics. Diet 2, being a positive control, was formulated by adding an antibiotic lincomix 44 at 0.10%. Diets 3 to 6 were formulated to contain 0.75% of 4 test prebiotics of inulin,  $\beta$ -glucan, resistant cornstarch and Fibersol-2, respectively. Titanium oxide (0.30%) was included as a digestibility marker. A total of 144 Yorkshire pigs, at the age of 21 d with an average initial BW of 9.7 kg, were allocated to the 6 diets for 21 d according to a randomized block design. Initial and final BW, PUN and ADFI were measured. Fecal samples were collected on d 11. Data were analyzed by using SAS procmixed model and Dunnett's test. There were no differences ( $P > 0.05$ ) in ADG, ADFI, feed to gain ratio, PUN and the lactose digestibility between each of the 4 prebiotic treatment groups and the antibiotic group or the negative control group, respectively. Furthermore, there were no differences ( $P > 0.05$ ) in these endpoints between the antibiotic and the negative control groups. Total tract lactose digestibility was measured to be at 100% in these diets, consistent with the previously estimated whole gut lactase digestive capacity in weanling pigs. The lack of antibiotic effects on total tract lactose digestibility would suggest that lactose (10.7%) in these diets was enzymatically digested by the host in the weanling pigs. These results suggest that supplemental prebiotics or feed antibiotics were not effective for further improving growth performance and body protein utilization in the weanling piglets under our experimental conditions.

**Key Words:** prebiotics, antibiotics, weanling pigs



**3016 Relationship between gut-derived endotoxin and postpartum dysgalaxia syndrome in sows.** D. Guillou<sup>\*1</sup>, V. Demey<sup>1</sup>, F. Chaucheyras-Durand<sup>1,2</sup>, and Y. Le Treut<sup>1</sup>, <sup>1</sup>LALLEMAND SAS, Blagnac, France, <sup>2</sup>INRA UR454, St-Genes Champanelle, France.

Endotoxin released by Gram-negative bacteria in the sow gastro-intestinal tract (GIT) has been suggested to play a role in the postpartum dysgalaxia syndrome (PDS). To study the fate of bacterial endotoxin from the GIT to bloodstream and their potential transfer to the milk, a trial was conducted in a farm with chronic PDS incidence. Sows were housed individually, blocked by parity and weight 3 weeks before expected parturition. A control group (C, n = 11) was compared with a group (n = 15) fed supplemental *Saccharomyces boulardii* (SB) at the rate of  $2 \times 10^9$  cfu/kg feed. Symptoms related to PDS were evaluated twice daily: constipation, behavior, udder aspect, vulvae fluid loss, rectal temperature (RT) and presence of neonatal diarrhea in the litter (ND). Fecal and blood samples were taken from each sow 10 and 2 d before expected parturition, then 3 and 21 d postpartum. Colostrum was sampled during the farrowing process and milk was sampled 1, 3 and 6 d postpartum. All samples were stored frozen in endotoxin-free tubes after adequate pre-treatment and transferred to the laboratory for endotoxin analysis using LAL chromogenic EndPoint Assays. Occurrence of PDS symptoms was related to treatment with Chi<sup>2</sup> statistics. Endotoxin content in feces, blood and milk were log-transformed to meet normality prior ANOVA. Frequency of sows exhibiting high rectal temperature tended to decrease in SB group ( $P = 0.09$ ), and combining high RT with presence of ND referred to sows from C group only. Treatment didn't significantly affect endotoxin content in sow feces, blood, colostrum, milk. However, sows with both high RT and ND had significantly higher endotoxin in the colostrum (133 vs. 26 ng/mL,  $P = 0.02$ ). Negative correlation ( $-0.48$ ,  $P = 0.042$ ) was observed between endotoxin level in feces and blood 2 d before farrowing and a positive correlation was found between content in colostrum and blood taken 2 d post-farrowing ( $+0.51$ ,  $P = 0.026$ ). These data support the relationship between endotoxin derived from intestinal bacteria and PDS.

**Key Words:** endotoxin, colostrum, live yeast

**3017 Short- and long-term effects of maternal antibiotic treatment around parturition on gut defence function.** M. E. Arnal<sup>\*1</sup>, J. Zhang<sup>2</sup>, S. Mroz<sup>1</sup>, S. Messori<sup>3</sup>, and O. Perez-Gutierrez<sup>2</sup>, <sup>1</sup>INRA, INRA, UR1341 ADNC, F-35590 Saint-Gilles, France, <sup>2</sup>Wageningen University, Laboratory of Microbiology, Wageningen University, The Netherlands, <sup>3</sup>Bologna University, DIPROVAL, Bologna University, Bologna, Italy.

The microbiota influences host gut function throughout life and is sensitive to diet. Evidence suggest that dysbiosis of the gut microbiota is related to various diseases, including gut inflammation and obesity. However, little is known on the effects of early disturbances in neonatal bacterial colonization on intestinal defense systems. We hypothesized that peripartum antibiotic treatment of

mothers alters their fecal microbiota composition, which in turn affects offspring gut function. This was tested in sows (11 antibiotic, ATBQ) treated with amoxicillin (40 mg/kg BW/d) orally around parturition (day -10 to +21) (12 controls, untreated). Offspring (1/sow/time) were slaughtered at d 14, 28 (weaning) and 42 (short-term). At 5 mo of age, pairs of offspring of similar BW within litters from each sows' group (10 pairs/treatment) were randomly offered a low (LF, 2%) or high (HF, 11%) fat diet for 4 weeks (long-term). Jejunal and ileal tissues were collected at slaughter and analyzed for HSPs, IAP, dipeptidyl-peptidase IV (DDP4) and sucrase (maturation index). Molecular analysis of sows' feces confirmed pronounced changes in the microbiota (decreased relative abundance of lactobacilli and increase of Bacteroidetes,  $P < 0.05$ ). Short-term effects were more marked in offspring ileum. IAP was transiently reduced at d14 ( $P < 0.01$ ) and DPP4 transiently increased at d28 ( $P < 0.05$ ). HSP70 was strongly reduced at d28 and d42 in ATBQ offspring ( $P < 0.01$ ). HSP27 was unaffected. Long-term effects were more pronounced in the jejunum. IAP was still depressed ( $P < 0.05$ ) and DPP4 was higher ( $P < 0.01$ ) in ATBQ offspring. Sucrase was lower in ATBQ offspring fed LF than in C-LF and higher in ATBQ-HF than in C-HF (interaction,  $P < 0.05$ ). Jejunal and ileal tissue levels of HSP27 and HSP70 were unaffected by early treatment or adult diet. To conclude, our data show that early disturbances in gut microbiota colonization affect specific components of gut function in the short and long-terms, sometimes in interaction with the diet in adulthood. Underlying genetic and epigenetic mechanisms of intestinal imprinting by the microbiota remain to be investigated.

**Key Words:** HSP, alkaline phosphatase, antibiotics

**3018 Body composition of piglets from sows fed the leucine metabolite  $\beta$ -hydroxy  $\beta$ -methyl butyrate (HMB) in late gestation.** C. Flummer<sup>\*1</sup>, N. B. Kristensen<sup>1,2</sup>, and P. K. Theil<sup>1</sup>, <sup>1</sup>Department of Animal Science, Aarhus University, Tjele, Denmark, <sup>2</sup>Syddansk Kvæg, Vojens, Denmark.

It has been shown that supplementation of the leucine metabolite  $\beta$ -hydroxy  $\beta$ -methyl butyrate (HMB) to sow diets during late gestation or lactation improved piglet health, survival, and growth. This study aimed to investigate the effect of HMB supplementation to late-gestating sows, on body characteristics of piglets. Control sows (CON) (n = 3) were fed a standard lactation diet from d 15 from parturition and throughout the experiment. Sows fed diets supplemented with HMB (n = 2) were fed the control diet, with 15 mg Ca(HMB)<sub>2</sub>/kg BW mixed in the morning meal from d 10 from farrowing until parturition. A total of 55 piglets were weaned at d 28, weighed and enriched with D<sub>2</sub>O to assess water mass. Blood samples were collected and piglets were euthanized. The weight of heart, stomach, liver, spleen, kidneys, cecum and small (SI) and large (LI) intestines as well as intestinal lengths, were recorded. Contents of dry matter, ash and protein (N  $\times$  6.25) of empty carcass were analyzed, and body fat content calculated. Two litters were treated for diarrhea, which was included in the statistical model. Weight at birth and d28 were not affected by maternal HMB supplementation ( $P > 0.4$ ). The total weight of SI of the HMB piglets was 15% lighter



( $P < 0.01$ ), suggesting a lower digestive and absorptive capacity. The cecum of HMB piglets were 15% longer and 17% heavier ( $P < 0.05$ ), whereas the LI was not affected by treatment. Diarrhea increased the length and weight of SI and LI ( $P < 0.05$ ), and weight of the kidneys ( $P < 0.01$ ). The liver was 9% heavier in the HMB piglets ( $P < 0.01$ ), indicating larger metabolic capacity and the spleen was 32% heavier in HMB piglets ( $P < 0.01$ ), indicating an improved immune status, which is in accordance with the suggested immunostimulatory effects of HMB. The weight of the kidneys was increased for the HMB piglets ( $P < 0.01$ ), whereas the weights of stomach and heart were not affected. HMB piglets had a lower DM content ( $P < 0.01$ ) suggesting more lean and less adipose tissue, which is in good agreement with the protein saving and lipolytic effects of HMB.

**Key Words:** prenatal programming, gastro-intestinal tract, body composition

**3019 Environmental control of early bacterial succession affects growth rate and postweaning gene expression in the pig.** D. Petri<sup>1,2</sup> and A. G. Van Kessel<sup>1</sup>, <sup>1</sup>University of Saskatchewan, Department of Animal & Poultry Science, Saskatoon, SK, Canada, <sup>2</sup>DuPont Nutrition & Health, Animal & Environmental Applications, Waukesha, WI, USA.

To investigate long-term effects of first colonizing bacteria on post weaning intestinal physiology, a gnotobiotic study was conducted using 24 germ-free piglets derived by caesarian section. Pigs were assigned to one of 4 isolators and were inoculated with either *S. infantarius* (S), *C. perfringens* (C), *L. mucosae* (L), or non-pathogenic *E. coli* (E). Piglets were conventionalized on d 7 with sow feces, merged and transferred to group pens. Piglets were weaned on d 20 and euthanized at 28 d of age to permit collection of jejunal contents and tissue. Using 16S rRNA gene-based molecular methods, analysis of rectal swabs taken on d 3 and 4 confirmed monoassociation of S, C, L and E pigs however, treatment L showed contamination with *E. coli* on d 4. Total RNA was extracted from snap frozen tissue and reverse transcription quantitative PCR used to measure expression of selected genes normalized to GAPDH. ADG from d 7–28 was higher ( $P < 0.01$ ) for pigs in treatments L and E and intermediate for C compared with S. Lowest ADG in treatment S was associated with lowest expression for PepT1 ( $P = 0.07$ ), SGLT3 ( $P < 0.05$ ) and Muc13 ( $P = 0.10$ ) whereas Muc2, TLR4 and NFkB1 gene expression was highest ( $P \leq 0.05$ ). Treatments C and L demonstrated highest ( $P \leq 0.07$ ) expression of nutrient carrier genes PepT1 and SGLT3. Treatment L showed highest ( $P < 0.05$ ) expression of digestion related genes aminopeptidase N (APN) and lactase-phlorizin hydrolase (LPH), and genes TLR2, TLR4, NFkB2, NFkBIA were also increased ( $P < 0.05$ ). Muc20 gene was expressed at lowest level ( $P < 0.05$ ). In contrast, treatment E showed lowest ( $P \leq 0.07$ ) expression of APN, PepT1, LPH and SGLT3, Muc2, TLR2, TLR4, NFkB1, and NFkBIA. Cytokine gene expression was not affected by treatment. Lower growth rate for pigs monoassociated early postnatal with *S. infantarius* was associated with reduced expression of nutrient assimilation genes and unbalanced barrier function

due to lowest attached mucus and highest secretory mucus gene expression. On the other hand, increased growth was not associated with a consistent pattern.

**Key Words:** jejunum, gnotobiotic, neonatal pig

**3020 Endotoxin transfer through colostrum from the dam to the piglet.** D. Guillou<sup>\*1</sup>, S. Isinger<sup>1</sup>, F. Chaucheyras-Durand<sup>1,2</sup>, and Y. Le Treut<sup>1</sup>, <sup>1</sup>Lallemand SAS, Blagnac, France, <sup>2</sup>INRA UR454, St-Genes Champanelle, France.

Neonatal diarrhea is a common feature in farms with high incidence of postpartum dysgalactia syndrome (PDS). It has been suggested that diarrhea could result from endotoxin transfer through colostrum from the dam to the piglet. To verify this hypothesis, a study was undertaken in a farm with chronic PDS incidence. Seven litters from sows in parity 1 or 2 were selected. After cleaning and disinfecting the teats, colostrum was sampled during the farrowing process. At 24h of life, piglets were weighed individually and blood was taken from 5 piglets randomly selected per litter. All samples were stored frozen in endotoxin-free tubes after adequate pre-treatment, and transferred to the laboratory for endotoxin analysis using commercial kits of LAL chromogenic EndPoint Assay. A linear regression was performed to relate endotoxin content in piglet's blood and sow colostrum. Expressing endotoxin in piglet's blood in ng/mL or scaled per body weight did not affect the observed relationships with endotoxin content in colostrum. Endotoxin levels in colostrum ranged between 12 and 27 ng/mL. Despite these rather low values, endotoxin in colostrum and piglet blood were positively correlated ( $+0.35$ ,  $P = 0.042$ ). Within litter variability in blood levels increased dramatically when endotoxin in colostrum increased. In case of the lowest endotoxin content in colostrum (12 ng/mL), endotoxin in the blood of piglet ranged between 0.19 and 0.29 ng/mL, whereas for levels in colostrum between 16 and 17 ng/mL the range in piglet's blood was 0.12 to 1.29 ng/mL, and in case of highest levels in colostrum (above 25 ng/mL) blood level ranged between 0.23 and 4.20 ng/mL. This huge variation might reflect individual differences in colostrum intake, or blood volume, or gut permeability. These data indicate a transfer of endotoxin from the dam to the piglet through colostrum. To verify the initial hypothesis, animal studies including a greater range of endotoxin concentration in colostrum would be necessary.

**Key Words:** endotoxin, colostrum, piglet

**3021 Impact of maternal dietary fat supplementation during gestation upon neonatal offspring liver and muscle development and fatty acid metabolism.** A. Mostyn<sup>1</sup>, H. P. Fainberg<sup>1</sup>, K. L. Almond<sup>1,3</sup>, D. Li<sup>2</sup>, C. Rauch<sup>1</sup>, M. E. Symonds<sup>3</sup>, and P. Bikker<sup>\*4,5</sup>, <sup>1</sup>School of Veterinary Medicine and Science, University of Nottingham, Sutton Bonington Campus, Leicestershire, UK, <sup>2</sup>School of Biosciences, University of Nottingham, Sutton Bonington Campus, Leicestershire, UK, <sup>3</sup>Early Life Nutrition Research Unit, Academic Division of Child Health, School of Clinical Sciences, University Hospital, Nottingham, UK, <sup>4</sup>Schothorst Feed Research, Lelystad, The Netherlands, <sup>5</sup>Wageningen UR, Livestock Research, Lelystad, The Netherlands.

Maternal nutrition during pregnancy may affect fetal development, neonatal growth and later life metabolic health in offspring. However, the relevance and role of macronutrient intake at constant energy intake has received little attention and the mechanism by which the maternal dietary fatty acid profile may influence the metabolic health of the offspring is still poorly understood. This study aims to determine the influence of the quality and quantity of maternal fatty acid consumption during pregnancy and clarify the potential role of alterations in early liver and muscular development. Two groups of sows were fed either a starch-rich control diet (C,  $n = 7$ ) or an isocaloric, palmoil based high fat diet (HF,  $n = 7$ ) during gestation. Histological and metabolic features of the liver and the biceps femoris muscle obtained from 7-d-old piglets were assessed. Basal plasma glucose levels of sows were not affected by gestation diet, but one week pre term the HF sows showed a lower glucose tolerance than C sows. Maternal diet did not influence liver glycogen or triglyceride content, nor glucocorticoid receptor (GR), 11 $\beta$ -HSD1, PPAR $\alpha$  and insulin receptor mRNA expression in offspring. Liver FAB1 mRNA expression was reduced in offspring of HF sows. Furthermore, HF offspring demonstrated enhanced muscular development, reflected by an increase in fractional growth rate, rise in myofiber cross-sectional area, increased storage of glycogen and reduction in lipid staining of myofibers. Although both groups had similar intramuscular protein and triglyceride concentrations, the fatty acid composition of muscular phospholipids was affected by maternal diet. The HF group had increased ratios of C20:3n6 to C20:4n6 and total n-6 to n-3 in conjunction with upregulation of genes associated with free fatty acid uptake and biogenesis. In conclusion, the increased fat in the maternal diet did not affect liver glucocorticoid metabolism but may accelerate the maturation of offspring biceps femoris muscle, reflected in increased glycolytic metabolism. Potential metabolic effects in later life now need to be established.

**Key Words:** sows, maternal diet, programming

**3022 Impact of *Pichia guilliermondii* (Pg) on lipopolysaccharide (LPS)-induced acute phase protein and cytokine response in the weaned pig.** B. Bass<sup>\*1</sup>, V. Perez<sup>2</sup>, H. Yang<sup>2</sup>, T. Tsai<sup>1</sup>, D. Holzgraefer<sup>2</sup>, J. Chewning<sup>1</sup>, and C. Maxwell<sup>1</sup>, <sup>1</sup>University of Arkansas, Fayetteville, AR, USA, <sup>2</sup>ADM Alliance Nutrition, Quincy, IL, USA.

To determine whether feeding CitriStim (a whole *Pichia guilliermondii* (Pg) yeast product; ADM Alliance Nutrition) throughout gestation and lactation affected the LPS-induced immune response of nursery pigs, at approximately 21 d of age, 36 weaned pigs were individually weighed and allotted to treatment in a 3 (sows fed 0 [SC], 0.1 [S1], or 0.2% [S2] Pg) x 2 (nursery pigs fed 0 [NC] or 0.2% [NPg] Pg) factorial arrangement in an RCBD. At approximately 35 d of age, pigs were individually penned in an isolated facility and allowed a 3 d acclimation period. Pigs were challenged with LPS (25  $\mu$ g/kg BW i.m.; 0 h) to induce an immune response. Individual BW, ADFI, and rectal temperature were recorded at -48, -24, 0, 24, and 48 h. Blood samples were collected at 0, 5, and 24 h for analysis of leukocyte differential and serum IL-1 $\beta$ , IL-6, SAA, CRP, haptoglobin, and BUN. Pigs

reared on S1 had increased ( $P = 0.07$ ) ADG at -48 to -24 h and -48 to 0 h compared to SC. Additionally, a linear increase ( $P < 0.04$ ) in ADFI was observed as the level of Pg increased in sow diets at -24 to 0 h, -48 to 0 h, and 24 to 48 h. Pigs in NPg had improved G:F at -48 to -24 h, but FI after LPS challenge was reduced compared to -48 to 0 h ( $P < 0.02$ ). There was a linear increase in rectal temperature with increasing Pg inclusion in sow diets at -48, -24, 0 and 5 h, and a quadratic response at 48 h with S1 being highest ( $P < 0.02$ ). However, temperature decreased more from 5 h to 24 h in pigs reared on sows receiving Pg. The number of monocytes and percent of leukocytes that were monocytes were higher in S2 compared to SC and S1 ( $P < 0.03$ ). Additionally, the number of neutrophils were reduced at 5 h in S1 ( $P < 0.05$ ), neutrophil:lymphocyte ratio was lower in S2 at 0 h and S1 at 5 h (time x sow treatment [T x ST],  $P < 0.01$ ), IL-1 $\beta$  concentration was greater in SC at 0 h and S1 at 5 h (T x ST,  $P < 0.02$ ), and IL-6 was higher in S2 at 0 h and S1 at 5 h (T x ST,  $P < 0.01$ ). Furthermore, BUN was higher in NC at 0 and 5 h than NPg ( $P = 0.05$ ). In conclusion, Pg, especially in gestation and lactation diets, appears to alter immune response to LPS stimulation in the weaned pig.

**Key Words:** pig, LPS, yeast product

**3023 Impact of *Pichia guilliermondii* (Pg) on sow and litter immune parameters.** B. Bass<sup>\*1</sup>, V. Perez<sup>2</sup>, H. Yang<sup>2</sup>, T. Tsai<sup>1</sup>, D. Holzgraefer<sup>2</sup>, J. Chewning<sup>1</sup>, and C. Maxwell<sup>1</sup>, <sup>1</sup>University of Arkansas, Fayetteville, AR, USA, <sup>2</sup>ADM Alliance Nutrition, Quincy, IL, USA.

A study was conducted using 3 groups of gestating gilts and sows ( $n = 98$ ) to determine the effects of a whole Pg yeast product (CitriStim; ADM Alliance Nutrition) on dam and litter immune parameters. Within 24 h of breeding, gilts and sows were allotted, based on BW and parity, to one of 3 dietary treatments consisting of a control (CON) diet or CON supplemented with either 0.1 or 0.2% Pg. On d 110 of gestation, sows were moved to a farrowing facility and provided a lactation diet, maintaining gestation treatment (CON, 0.1 or 0.2% Pg). Colostrum samples were collected following farrowing, and milk samples were collected approximately 14 d later. Blood samples were collected from sows on d 110 of gestation for group 3, and at weaning for all 3 groups. Blood samples were collected from piglets at 14 d of age. Leukocyte differentials were determined on whole blood samples. Colostrum, milk, and serum samples were analyzed for IgA, IgG, and IgM. No differences were observed in IgA, IgG, or IgM among treatments. However, serum concentrations of IgA were lower ( $P < 0.01$ ), and IgM was higher ( $P < 0.01$ ) at d 110 than weaning. Additionally, concentrations of IgA, IgG and IgM were greater ( $P < 0.01$ ) in colostrum than milk. On d 110 of gestation, total neutrophil count and neutrophil:lymphocyte ratio were greater ( $P < 0.02$ ) in sows that received 0.1% Pg than CON, with 0.2% Pg being intermediate. Additionally, lymphocytes comprised a greater ( $P = 0.03$ ) percentage of leukocytes in CON than 0.1% Pg sows. At weaning there was a linear increase ( $P < 0.03$ ) in number of neutrophils, neutrophil:lymphocyte ratio (1.66, 1.96, and 2.34 for 0, 0.1, and 0.2% Pg, respectively), and percentage of total leukocytes that were neutrophils

as level of Pg increased in sow diets. A linear increase in number born alive and weaned, without a change in average birth or weaning weight, as the level of Pg in the diet increased has previously been reported. In summary, inclusion of Pg had no effect on immune parameters measured in milk, colostrum, or d 14 serum. However, inclusion of Pg in gestation and lactation diets increased the inflammatory response of gilts and sows.

**Key Words:** immune function, yeast product, sow and litter

**3024 Ileal mucosa-associated, but not ileal digesta, bacterial profiles in grower pigs are influenced by nutrition and use of antibiotics for starter pigs.** C. L. Levesque<sup>\*1</sup>, H. Yu<sup>2</sup>, and C. F. M. de Lange<sup>1</sup>, <sup>1</sup>University of Guelph, Guelph, Ontario, Canada, <sup>2</sup>Guelph Food Research Centre, Guelph, Ontario, Canada.

A longitudinal study was conducted in pigs to evaluate the effect of nutrition and use of antibiotics for starter pigs on ileal bacterial microbiota. Fifty-six pigs were weaned at  $21 \pm 2$  d of age and fed a high (H) or low (L) complexity diet with (A+) or without (A-) chlortetracycline for 6 wk. All pigs received the same grower diet thereafter. Pigs were killed at wk 2, 4, and 8 and ileal digesta, as well as a 40 cm section of the distal ileum, were taken for extraction of digesta and mucosa-associated bacteria, respectively. Total DNA was extracted using a commercially available kit and PCR amplicons were generated using HDA1-GC

and HDA2 primers against the V3 region of the 16S rRNA gene. DGGE electrophoresis of PCR amplicons was used for separation of distinct bacteria communities. Similarities of PCR-DGGE profiles were analyzed with Bionumerics software and the degree of similarity represented by a similarity coefficient. At wk 2, compared with HA+, mucosal bacteria from pigs fed HA-, LA+, and LA- had a similarity coefficient of 85.7, 71.4 and 50.0%, respectively. At wk 4 pigs fed LA-, HA-, and LA+ had a similarity coefficient of 88.9, 57.1, and 35.5%, respectively compared with pigs fed HA+. Compared with HA-, pigs fed LA-, LA+, and HA+ had a similarity coefficient of 88.9, 84.2, and 73.7%, respectively, at wk 8. Ileal bacterial microbiota profiles were more similar within week than across weeks. Preliminary analysis showed effects of diet and antibiotic use on ileal digesta microbiota at wk 2 and 4 but not at wk 8. Detailed analysis of the PCR-DGGE bacterial profiles in ileal digesta is currently underway. Phylogenetic analyses of the mucosa-associated bacterial profiles at wk 2 and 8 are being conducted using 454 pyrosequencing. Diet quality in the starter phase had a greater influence on mucosa-associated microbiota profiles than antibiotics at wk 2; whereas, in-feed antibiotics appeared to have a greater long-term effect on ileal mucosa-associated microbiota (i.e., wk 8). Post-weaning nutrition permanently alters ileal mucosa-associated, but not ileal digesta, microbiota profiles.

**Key Words:** early nutrition, microbiota, pigs





## **Session VI: Methodologies and Their Application**

**3025 Gene expression profiles of peripheral blood mononuclear cell (PBMC) from young pigs fed high level of zinc oxide.** S. Y. Ji<sup>1,2</sup>, B. H. Choi<sup>1</sup>, B. G. Kim<sup>2</sup>, and C. H. Yun<sup>3</sup>, <sup>1</sup>National Institute of Animal Science, RDA, Suwon, Republic of Korea, <sup>2</sup>Department of Animal Science and Environment, Konkuk University, Seoul, Republic of Korea, <sup>3</sup>Protein Engineering & Comparative Immunology Laboratory, Seoul National University, Seoul, Republic of Korea.

This study was performed to investigate effects of high level of zinc oxide in diets on in vivo gene expressions of PBMC and growth performance in young pigs. Female Duroc pigs (n = 9, 36.4 ± 4.68 kg) were assigned into 2 dietary groups. One group (CON, n = 4) was fed the basal diet supplemented with no ZnO, and the other group (ZN2.5K, n = 5) was fed the basal diet supplemented with 2,500 mg ZnO/kg diet under ad libitum feeding condition for 14 d. In the post absorptive state on the 14th day, 8mL of blood were drawn from jugular vein into by BD-CPT tube with sodium citrate, and centrifuged (1,800 x g, 15 min) to obtain PBMCs from blood samples. All of these preparations were finished within 2 h, and then stored at -80°C until further analysis. After TRIzol extraction of total RNAs, their A260/280, A260/A230 ratio and RIN values were checked to be suitable for microarray analysis. Gene expression profiles were analyzed by using Affymetrix porcine expression array. Data were analyzed by using GeneSpring GX11.5.1 software (1.5 fold change,  $P < 0.05$ ). Average daily gain (ADG, kg/d) was measured for 2 weeks and did not differ ( $P > 0.10$ ) between ZN2.5K and CON (0.54 vs. 0.47 kg/d, respectively). Fifteen of differentially expressed genes (DEG) were significantly up (+)- or down (-)-regulated ( $P < 0.05$ , 1.5 fold change). Due to the lack of gene descriptions from pigs, only 3 genes of 9 (+)-DEGs were described as adrenergic  $\beta$  receptor kinase 2 (GenBank Accession # CK459913, CF175365), and tissue inhibitor of metalloproteinase-2 (#CK461818), which were significantly upregulated in ZN2.5K than CON ( $P < 0.05$ ). Three of 6 (-)-DEGs were described as dynein cytoplasmic intermediate chain 2 (#CK451466), Ca binding protein  $\beta$  (neural), Sus scrofa CD3g mRNA for TcR CD3 gamma-chain (#AB190229) which were downregulated in ZN2.5K than CON ( $P < 0.05$ ). In conclusion, pharmacological levels of dietary ZnO could affect in vivo immune responses by modulating gene expressions of PBMC in pigs.

**Key Words:** zinc oxide, Affymetrix, PBMC

**3026 Comparison of three intestinal permeability methods.** Y. van der Meer<sup>1</sup>, W. J. J. Gerrits<sup>1\*</sup>, M. van den Bosch<sup>2</sup>, M. Moret<sup>3</sup>, W. A. Buurman<sup>4</sup>, and T. A. T. G. van Kempen<sup>5</sup>, <sup>1</sup>Animal Nutrition Group, Wageningen University, Wageningen, The Netherlands, <sup>2</sup>Provimi Holding B.V., Velddriel, The Netherlands, <sup>3</sup>Faculty of Pharmacy, University of Barcelona, Barcelona, Spain, <sup>4</sup>Department of Surgery, Maastricht University Medical Centre, Maastricht, The Netherlands, <sup>5</sup>North Carolina State University, Raleigh, North Carolina, USA.

The determination of intestinal permeability remains a challenge. The Ussing chamber is an ex vivo technique which is generally well accepted. However, this technique

is tedious and requires a biopsy which can only be obtained through invasive surgery or post-mortem. It also represents a spot sample, sometimes less than 1 cm<sup>2</sup>. The everted gut sac technique uses a more relevant sample size, and in vivo permeability measurements using Co-EDTA or lactulose are much more practical. Our objective was to compare these 3 techniques. For this, 72 piglets were sampled either 3.5, 7.5, or 10.5 d post weaning. Both lactulose (1.3 g, 9.5 Å) and Co-EDTA (0.6 g, 10.0 Å) dissolved in 15 g demineralized water were administered intragastrically. Two hours later a blood sample was obtained through venipuncture. Subsequently, a 15 cm segment harvested at 25, 50, and 75% of the length of the small intestine was inverted, filled with phosphate buffered saline (PBS) containing 5 mM glucose, and sealed. Sacs were inserted for 60 min. in an aluminum foil covered bath with aerated PBS containing 125  $\mu$ M FITC-dextran (14.0 Å) and maintained at 39°C after which both the sac content and medium were analyzed for FITC. Statistical analysis was performed using the Pearson correlation test of SPSS 19 (2010). The FITC analysis of the buffer revealed that the FITC concentrations dropped quickly (half-life  $\pm$  3 h), even though it was kept from contact with light by aluminum foil. This is raising doubts about the validity of the test. Serum concentrations of Co-EDTA and lactulose were positively correlated ( $r = 0.67$ ,  $P < 0.01$ ). FITC dextran, corrected for a predicted change in half-life of stock solution, in contrast, did not correlate with either lactulose or Co-EDTA, for any of the segments compared. In conclusion, a correlation was found between Co-EDTA and lactulose suggesting that both marker molecules measure the same change in permeability, while ex vivo determinations using FITC-dextran in everted gut sacs requires additional work before it can be applied.

**Key Words:** intestinal permeability, piglet, everted gut sac

**3027 Flavor preferences conditioned by post-ingestive effect of sucrose and porcine digestive peptides (PDP) in post-weaning pigs.** J. Figueroa<sup>1</sup>, D. Solà-Oriol<sup>1\*</sup>, E. Borda<sup>2</sup>, S. A. Guzmán-Pino<sup>1</sup>, and J. F. Pérez<sup>1</sup>, <sup>1</sup>Universitat Autònoma de Barcelona, Bellaterra, Barcelona, Spain, <sup>2</sup>Bioibérica, Barcelona, Spain.

Pigs can learn to prefer a flavor if it has been previously associated to positive consequences. The aim of this experiment was study flavors preferences conditioned by the post-ingestive effect of nutrients in post-weaning pigs. A total of 240 weanling piglets were allocated in 24 pens (10 piglets/pen) and distributed to 2 experimental treatments. G1 pigs were trained during 8 d with one flavor (CS+) into a protein solution (4% Porcine Digestible Peptides, PDP) in odd days and another flavor (CS-) into 100mM of Monosodium Glutamate (MSG) solution on even days (5 lts-bottle for 24hr). In G2, CS+ was mixed into a 4% sucrose solution in odd days and CS- into 1% sucrose + 0.08% saccharine on even days. Hedonic attraction for PDP and MSG solutions and attraction for sucrose and saccharine + sucrose were previously matched, thus, in each group one flavor (CS+) was associated with a higher post-ingestive but the same hedonic value than the other flavor (CS-). Solution's amount offered during training

period were prepared to be totally consumed each day to equalize flavors intake. Flavors (anise or garlic, 0.0375%) were counterbalanced across replicates to act as CS+ or CS-. Double choice test between flavors dissolved in water (CS+ and CS-) were performed by selecting 2 pigs/pen on d 1, 6 and 8 after the training period. Solution intake was measured after 30 min. Data were analyzed by using the GLM procedure of SAS®. Piglets showed higher intakes for CS+ over CS- in G2 (212 vs. 76mL; 168 vs. 86mL;  $P < 0.05$  and 195 vs. 78mL;  $P = 0.15$ ) on d 1, 6 and 8, respectively. No differences between CS+ and CS-consumption was observed in G1. Present results indicate that weaning piglets can acquire strong flavor preferences resistant to extinction through associative learning between the flavor and the post-ingestive effects of sucrose. PDP failed in conditioning flavor preferences probably due to the negative 24 h exposure and possible post-ingestive effects of MSG. Learned flavor preferences may be used as a strategy to enhance voluntary intake in critical periods, such as weaning.

**Key Words:** learning, conditioning, post-ingestive

**3028 Evaluation of two external markers for measurement of ileal and fecal digestibility of humanized diets.** H. N. Lærke,\* M. M. Kasprzak, and K. E. Bach Knudsen, Aarhus University, Department of Animal Science, Tjele, Denmark.

Appropriateness of different external markers for determination of nutrient digestibility has often been evaluated in conventional dry feeds, but very little in less conventional feeds such as humanized diets used in model studies. In the current study, 5 ileum-cannulated pigs were fed 5 soft bread based diets for 1 wk in a Latin Square design. The diets consisted of white wheat bread, milled rye bread, whole kernel rye bread or wheat bread supplemented with concentrated oat  $\beta$ -glucan or arabinoxylan from wheat. The diets were supplemented with whey protein, vitamins and minerals, and chromic oxide and Celite® (AIA) as digestibility markers. The inclusion levels of the markers were 2–3 g chromic oxide/kg DM and 5–6 g AIA/kg DM. Estimates of digestibility based on the 2 markers were compared by linear regression. Ileal contents were collected twice weekly for 5 h and pooled before analysis, while a fecal grab sample was obtained once per week. Ileal and fecal digestibility of organic matter (OM) and non-starch polysaccharides (NSP) was calculated relative to the 2 digestibility markers. Across dietary treatments and site of collecting there was a high correlation with coefficients of determination of  $R^2 = 0.77$  for OM and 0.80 for NSP ( $P < 0.001$ ), and a linear model close to unity between values obtained using the 2 different markers. Evaluating ileal samples alone, the correlation was much poorer, particularly for NSP, which had a coefficient of determination of only 0.09 ( $P = 0.14$ ), while for OM it was 0.52 ( $P < 0.001$ ). On the other hand, fecal grab samples had a very strong correlation with coefficients of determination of 0.92 and 0.96 for OM and NSP, respectively ( $P < 0.001$ ). However, there was not unity between the estimates, as AIA gave higher values than chromic oxide in samples with lower digestibility, resulting in regression lines with intercepts

of 0.29 and 0.28 and slopes of 0.71 and 0.72 for OM and NSP, respectively. The discrepancy is presumably caused by analytical difficulties due to a very high fecal digestibility of OM and very high ash contents (14–44 g/kg DM) of feces from pigs fed the humanized diets.

**Key Words:** chromic oxide, acid insoluble ash, animal models

**3029 Use of medium without reducing agent for in vitro fermentation studies by bacteria isolated from pig intestine.** C. Poelaert\*<sup>1,2</sup>, C. Boudry<sup>1</sup>, D. Portetelle<sup>2</sup>, A. Théwis<sup>1</sup>, and J. Bindelle<sup>1</sup>, <sup>1</sup>Animal Science Unit, Gembloux Agro-Bio Tech, University of Liege, Gembloux, Belgium, <sup>2</sup>Animal and Microbial Biology Unit, Gembloux Agro-Bio Tech, University of Liege, Gembloux, Belgium.

Over the past decade, several in vitro methods have been developed to study intestinal fermentation in pigs and its influence on health. Samples are fermented by a bacterial inoculum diluted in a mineral buffer solution. A reducing agent, such as Na<sub>2</sub>S or cysteine-HCl, generates the required anaerobic environment by the release of H<sub>2</sub>S inducing an imbalance between bacterial species by the production of such toxic metabolites. H<sub>2</sub>S is also an end product of the fermentation of sulfur amino acids and its addition via the reduction agent impedes the use of in vitro methods to investigate intestinal protein fermentation. An experiment was conducted to study the impact of the reducing agent on fermentation patterns. Protein (soy proteins, casein) and carbohydrate (potato starch, cellulose) ingredients were fermented in vitro by pig intestinal bacteria from fresh feces of 3 sows fed an antibiotics-free commercial diet in 3 incubation media differing in reducing agent: Na<sub>2</sub>S, cysteine-HCl or without reducing agent. Gas fermentation kinetics were monitored over 72 h and short-chain fatty acid (SCFA) production after 8, 24 and 72 h were analyzed and compared according to ingredient and reducing agent by the MIXED procedure of SAS (n = 6). Results show that the gas production was higher when fermenting carbohydrate than protein ingredients ( $P < 0.05$ ). Whatever the ingredient, the fermentation patterns with Na<sub>2</sub>S and without reducing agent were quite similar and differed from those performed with cysteine-HCl. Except for soy proteins, SCFA production after 8, 24 and 72 h was similar for a same ingredient regardless the incubation medium ( $P > 0.05$ ). Comparison of SCFA molar ratios did not reveal differences when fermentation occurred with Na<sub>2</sub>S and without reducing agent ( $P > 0.05$ ). These results suggest that omitting the use of a reducing agent does not alter significantly the fermentation kinetics and the SCFA production. The saturation of the incubation medium with CO<sub>2</sub> seems sufficient to generate a suitable anaerobic environment. Further works on the samples involve the incidence on microbiota and on toxic metabolites production.

**Key Words:** in vitro fermentation, reducing agent, SCFA

**3030 Direct and regression methods do not give different estimates of digestible and metabolizable energy of wheat for pigs.** O. A. Bolarinwa and O. Adeola,\* Purdue University, West Lafayette, IN, USA.

Digestible and metabolizable energy contents of feed ingredients for pigs can be determined by either direct or indirect methods. There are situations when only the indirect approach is suitable and regression method presents a robust indirect technique. This study was conducted to compare the direct and regression methods for the determination of energy value of wheat for pigs. Twenty-four barrows with an average initial weight of 31 kg were assigned to 4 diets in a randomized complete block design. The 4 diets consisted of 969 g wheat/kg + minerals and vitamins (sole wheat diet) for the direct method and 3 corn-soybean meal diets. The 3 corn-soybean meal reference diets (RD) and RD + 300 or 600 g wheat/kg were used for the regression method. Energy-yielding ingredients in the RD were replaced by wheat in such a way that the same ratio of corn and soybean meal was maintained. The wheat used was analyzed to contain 883 g DM, 15.2 g N, and 3936 kcal gross energy/kg. Each diet was fed to 6 barrows in individual metabolism crates for a 5-d acclimation followed by a 5-d period of total but separate collection of feces and urine. The DE and ME for the sole wheat diet were 3830 and 3768 kcal/kg DM, respectively. Because the sole wheat diet contained 969 g wheat/kg, these translate to 3953 kcal DE/kg DM and 3889 kcal ME/kg DM. The RD used for the regression approach yielded 4001 kcal DE and 3913 kcal ME /kg DM diet. Increasing levels of wheat in the RD linearly reduced ( $P < 0.05$ ) DE and ME to 3878 and 3794 kcal/kg DM diet, respectively. The regressions of wheat contribution to DE and ME in kcal against the quantity of wheat DM intake in kg generated 3960 kcal DE and 3876 kcal ME /kg DM. The direct and regression methods data from each of 6 replicates were analyzed by GLM procedures using DE or ME as the dependent variable and method as independent variable. Values obtained for the DE and ME of wheat using the direct method (3953 and 3889 kcal/kg DM) were not different ( $0.78 < P < 0.89$ ) from those obtained using the regression method (3960 and 3876 kcal/kg DM).

**Key Words:** energy, pigs, wheat

**3031 Cell line IPEC-J2 develops properties of porcine jejunum if cultured under optimized conditions.** S. S. Zakrzewski<sup>\*1</sup>, J. F. Richter<sup>1,3</sup>, J. D. Schulzke<sup>2</sup>, M. Fromm<sup>1</sup>, and D. Günzel<sup>1</sup>, <sup>1</sup>*Institute of Clinical Physiology, Charité—Universitätsmedizin Berlin, Germany*, <sup>2</sup>*Dept. Gastroenterology, Div. Nutritional Medicine, Charité—Universitätsmedizin Berlin, Germany*, <sup>3</sup>*Institute of Anatomy II, University of Jena, Germany*.

Experiments on animal organs are irreplaceable if complex overall functions are studied, but for investigating subcellular and molecular mechanisms proper cell culture models are most suitable. For research on intestinal barrier function they allow studying effects of nutritional factors. For this, cell models should reflect epithelial architecture and display adequate transepithelial resistance (TER), express tight junction (TJ) proteins, and react to secretagogues. The TJ is of central interest as it forms a barrier against uptake of putatively immunogenic macromolecules and an excessive passage of water, small ions, and other solutes. The porcine jejunal cell line IPEC-J2 is established as an in vitro model for porcine infection studies, and was re-characterized here

regarding its barrier parameters. IPEC-J2 monolayers were cultured on permeable supports, either under conventional (fetal calf serum) or optimized (porcine serum) conditions. Electrophysiology ( $I_{SC}$ , TER,  $R^{trans}$ ,  $R^{para}$ ,  $C^{epi}$ ) was studied in Ussing chambers applying two-path impedance spectroscopy. Morphometry was assessed by confocal and transmission electron microscopy and the abundance and localization of typical small bowel TJ proteins were determined microscopically and by Western blotting. Porcine jejunal mucosa was analyzed for comparison. While under conventional treatment cells are abnormally flat and large and only few microvilli were observed, under optimized conditions cells became taller, resulting in a 60% decrease in cell diameter and a 5-fold increase in cell height, and exhibited a distinct brush border, much closer to typical enterocytes. Concomitantly, using porcine serum caused a drop in TER from  $3800 \pm 120$  to  $270 \pm 14 \Omega \cdot \text{cm}^2$  ( $n=20$ ) 14 days postseeding. This value fits well with stripped porcine jejunum if surface multiplication by villi and crypts was taken into account. Molecularly, the decline in TER is in accordance with the appearance of claudin-2 and altered expression levels of other TJ proteins. The IPEC-J2 cell line, when cultured under optimized conditions, forms a suitable model to investigate paracellular intestinal barrier function.

**Key Words:** IPEC-J2, pig jejunum, barrier function

**3032 An in vitro technique to model digestive behavior of feeds containing soluble fibers.** B. A. Williams,<sup>\*</sup> K. Shelat, J. Hanan, S. Dhital, and M. J. Gidley, *University of Queensland, Centre for Nutrition and Food Sciences, ARC Centre of Excellence in Plant Cell Walls, Queensland Alliance for Agriculture and Food Innovations, St. Lucia, Brisbane, Qld., Australia*.

In vitro technique can be useful to examine digestive behavior of soluble-fiber-containing-diets, under higher viscosity conditions. A study using dry matter(DM) contents more typical of the porcine GIT, with appropriate commercial enzymes, was carried out with gastric (25% DM), and small intestinal (SI; 10% DM) steps. We measured dynamic pH and DM losses for 3 and 4 h respectively. The SI step required use of a punctured plastic beaker surrounded by a dialysis membrane within a larger beaker, allowing end product and water movement between the 2 chambers. Two diets were compared,  $\pm 10\%$  wheat arabinoxylan (AX), on 3 occasions. pH values were unaffected by time or diets, for both gastric and SI steps, suggesting effective buffering. For the gastric step, %DM was measured at 0, 1.5 and 3 h, without differences for diet ( $P = 0.224$ ) or time ( $P = 0.4$ ). However, %DM in the SI step was affected by diets ( $P < 0.0001$ ) and time ( $P < 0.0001$ ). A regression was fitted to these SI profiles, and the AX diet showed a steeper downward slope ( $-0.794$ ), compared with the control diet ( $-0.470$ ), with  $R^2 > 0.96$  for both. Either the AX diet may be more rapidly digestible up to 4 h, or had more moisture retention, though more data are required to differentiate between these possibilities, including rheology and reducing sugars. Ultimately, computational modeling techniques will be used, to compare these in vitro results with in vivo values, to allow adjustment of this technique, for a range of soluble-fiber-containing-diets.



**Key Words:** in vitro, digestion, viscosity

**3033 Discrepancies in microbiota composition along the pig gastro-intestinal tract between in vivo observations and an in vitro batch fermentation model.** C. Boudry<sup>\*1</sup>, C. Poelaert<sup>1</sup>, D. Portetelle<sup>2</sup>, A. Thewis<sup>1</sup>, and J. Bindelle<sup>1</sup>, <sup>1</sup>*Animal Science Unit, Gembloux Agro-Bio Tech, University of Liege, Gembloux, Belgium*, <sup>2</sup>*Animal and Microbial Biology Unit, Gembloux Agro-Bio Tech, University of Liege, Gembloux, Belgium*.

In vitro fermentation models are increasingly used to assess prebiotic potential of novel indigestible carbohydrates (ICHO). A trial was performed to assess the validity of such approaches by comparing the influence of fermentation of inulin (INU) and cellulose (CEL) on microbiota in vivo and in vitro. Three INU and CEL based semi-purified diets (5% INU, 5% CEL and 2.5% of both) were fed to 3 groups of 4 pigs (~25 kg). After 3 weeks, the pigs were slaughtered and digesta was sampled from jejunum, ileum, cecum and 3 parts of the colon to measure pH, SCFA and microbiota population. One week before slaughter, an in vitro gas fermentation test was performed on INU and CEL with fresh feces of the experimental pigs as bacterial inoculum. The gas production kinetics were modeled and fermentation broth samples were taken after 5, 8, 12, 24 and 72 h. Total bacterial DNA was extracted from the samples and qPCR was performed to quantify total bacteria, *Lactobacilli*, *Bifidobacteria*, *Bacteroides*, *Clostridium Cl. I* and *E. coli*. Total bacteria quantification showed similarities between both systems. In vivo, total bacteria increased along the gut until the second part of the colon (from  $10^{5.7}$  to  $10^{10}$  cfu mg<sup>-1</sup>,  $P < 0.001$ ) and then decreased to  $10^9$  cfu ( $P < 0.05$ ), while in vitro, it increased until 12 to 24 h of fermentation ( $+5 \times 10^8$  cfu ml<sup>-1</sup>) and then decreased to initial level. This evolution was in relation with fermentation kinetics. In both models, INU increased *Bifidobacteria* and *E. coli* populations compared with CEL ( $P < 0.05$ ). However, in vivo this was observed only in the first parts of the gut while in vitro, the effect lasted during the 72 h fermentation. *Bacteroides* genus was not influenced by the ICHO source in the 2 systems ( $P > 0.05$ ). Finally, evolution of *Lactobacilli* and *Clostridium Cl. I* populations in both systems were not consistent. This can be ascribed to specific bacterial properties as e.g., adhesive properties or sensitivity to sulfur reducing agent used in the in vitro model. Further developments of the in vitro method are required to properly assess prebiotic potential of ICHO

**Key Words:** in vitro fermentation, microbiota, gut

**3034 Comparison of three internal markers in flow and recovery of feed enzymes in pigs.** H. Jørgensen<sup>\*1</sup>, L. Salmon<sup>2</sup>, H. N. Lærke<sup>1</sup>, and K. E. B. Knudsen<sup>1</sup>, <sup>1</sup>*Aarhus University, Department of Animal Science, Foulum, Denmark*, <sup>2</sup>*Danisco Animal Nutrition, Marlborough, United Kingdom*.

To quantify the flow and survivability of feed enzymes through the intestine a reliable marker is a prerequisite. The study investigated 3 internal markers used to test in vivo survivability of feed enzymes in cannulated pigs. The markers were: titanium dioxide (TiO<sub>2</sub>), chromium III oxide

(Cr<sub>2</sub>O<sub>3</sub>) and Celite analyzed as acid insoluble ash (AiA). Three male castrate crossbred growing pigs (initial weight 30 kg) were surgically fitted with 2 T-cannula (16 mm diameter) one at the duodenum and one anterior to the ileo-cecal junction. Pigs were kept in individual pens with half the floor area covered with raised plastic gratings throughout the whole experiment and the pens were equipped with toys and drinking nipples. The diet was based on barley-wheat-soybean meal fortified with vitamins and minerals and the diet was heat treated and pelleted to reduce the dietary phytase level. Pigs were fed according to scale 3 times daily (0800, 1600 and 2300h). In the morning meal (0800h) on Monday, Wednesday and Friday the marker and the enzyme preparation were added according to a 3 × 3 Latin Square design. Collection of digesta took place at 0800h and 0900h from the duodenum cannulas (300 g) and at 0900h and 1030h from the ileal cannulas (200 g). The digesta was immediately frozen (-20°C) until further analysis. The concentration of the markers in the bolus meal was as expected. The variation of the markers in both duodenum and ileal digesta was as expected higher than in the diet. The relative variation (CV, Std dev/Mean\*100) was in the duodenum digesta 13, 41 and 18% for Cr<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub> and AiA, respectively. For ileum collected at 1030h the variation was in the order of 25, 50 and 21%. The lowest concentration of markers and highest relative variations was found at ileum collected at 0900h, indicating that only a small portion of the bolus meal had arrived at this time. Furthermore in 2 cases the concentration of TiO<sub>2</sub> in ileal digesta collected at 0900 was close to the detection limit causing very high variation. For this kind of study chromic oxide and Celite was equal suitable.

**Key Words:** duodenum, bolus meal, ileum

**3035 Ex vivo model for investigating the bacterial association to the gut epithelium of pigs.** S. Sugiharto, B. Jensen, and C. Lauridsen, <sup>\*</sup>*Aarhus University, Foulum, Denmark*.

Diarrhea-like conditions are difficult to reproduce in pigs. To study Enterotoxigenic *E. coli* (ETEC) association, in vitro cellular models have been used, but these are less suitable for ETEC pathogenesis study in pigs. This experiment aimed to establish a model to study the association of ETEC to the gut epithelium of pig. Intestine cultures were prepared from 4 weaned pigs susceptible to both *E. coli* O149:F4 (homo- and heterozygotic, 2 pigs each) and O138:F18 (all homozygotic). Five segments (15 cm each) were taken from 50% of the intestinal length measured from duodenum (mid-small intestine [SI]), and a further 5 segments were taken from 90% (distal-SI), immersed in Dulbecco's Modified Eagle Medium (DMEM) and kept on ice. Polyethylene tubing was inserted into either end of the segment and tied. The tissue was washed with 50 mL of PBS. The other end of segment was tied, 10 mL of DMEM alone or DMEM containing either *E. coli* F4 or F18 was inoculated and the segment was sealed with Teflon plug. The culture was immersed in DMEM in a 300-mL infusion bottle in a shaking water bath (150 rpm) at 37°C. After 1 h the culture was removed, tissue was washed with 50 mL of PBS, weighed and homogenized in PBS. Final dilution of

10–6 was prepared from the content and homogenate. *E. coli* was counted on MacConkey agar. Data were analyzed by  $2 \times 3 \times 2$  factorial including the effects of culture (content or homogenate), *E. coli* strain and site of SI with GLM procedure. *t*-test was used to analyze the effect of genotype in F4-inoculated culture. The binding of *E. coli* on the tissue was 10 × higher ( $P < 0.001$ ) for F4 than F18. F18 was higher ( $P < 0.05$ ) in mid-SI, whereas no difference between sites of SI was seen for F4. Fewer ( $P < 0.001$ ) bacteria bound in the control and they associated more ( $P = 0.10$ ) at distal- than mid-SI. No effect of genotype in F4-inoculated culture was seen. The results suggest that ex vivo model might be feasible to investigate the ETEC association to the gut epithelium of pigs.

**Key Words:** *E. coli*, epithelium, adherence

**3036 Porcine gut microbial metagenomic library for mining novel cellulases established from grower pigs fed cellulose-supplemented high-fat diets.** W. Wang, T. Archbold, M. Kimber, J. Li, J. Lam, and M. Fan,\* *University of Guelph, Guelph, Ontario, Canada.*

Porcine gut microbiome is a novel genomic resource for screening novel cellulose-degrading enzymes. A plasmid metagenomic expression library was constructed from the hind-gut microbiota of grower Yorkshire pigs (25–40 kg) fed a high-fat basal diet supplemented with 10% Solka-Floc for 28 d. Fresh large intestinal digesta samples were collected and flash-frozen in liquid N<sub>2</sub> and stored under  $-80^{\circ}\text{C}$ . Metagenomic DNA was extracted, mechanically sheared and cleaned to remove smaller DNA fragments (<1.0 kb). The resulting DNA fragments were subjected to blunt-end polishing, fractionation and purification by using commercial kits. The end-modified DNA fragments were ligated to pCR4Blunt-TOPO vector and transformed into competent cells *E. coli* TOPO 10. Metagenomic plasmid libraries were screened for carboxymethyl cellulolytic activities by using LB agar plates. Positive colonies were picked, and the plasmids were recovered. The inserts were sequenced by the primer walking and assemble via commercial services. The open reading frames (ORFs) in the inserts were identified with the ORF finder at NCBI. The closest related protein sequences in the databases for the enzyme were searched for using BlastP at NCBI. Module structures and signal peptides of putative enzymes were predicted by using the Simple Modular Architecture Research Tool. Amino acids of the cloned cellulases and their highest matches from the Blast analyses and the glycosyl hydrolase families were aligned for phylogenetic analyses. The phylogenetic tree was generated with ClustalX1.83 and MEGA2.1 using the neighbor-joining method. Cellulase genes with amino acid coding sequences below 45% homology to the ones reported in the published databases are regarded as novel genes and used for enzyme protein overexpression and functional characterization. About 25 cellulose-degradation and metabolism related genes have been identified in our initial work and one novel cellulase protein has been overexpressed and characterized by using this metagenomic expression library.

**Key Words:** cellulases, metagenomic library, pigs

**3037 Effect of milk hydrolysates on inflammation markers and drug-induced transcriptional alterations in cell-based models.** D. S. G. Nielsen<sup>1</sup>, P. K. Theil<sup>1</sup>, L. B. Larsen<sup>2</sup>, and S. Purup\*<sup>1</sup>, <sup>1</sup>*Dept. of Animal Science, Aarhus University, Foulum, DK-8830 Tjele, Denmark,* <sup>2</sup>*Dept. of Food Science, Aarhus University, Foulum, DK-8830 Tjele, Denmark.*

Non-steroidal anti-inflammatory drugs (NSAIDs) are associated with gastrointestinal inflammation and subsequent damage to the intestinal tissue. Earlier studies in our laboratory have found that specific casein hydrolysates might be useful in the treatment of gastrointestinal wounds. The mechanisms by which inflammation and wound healing occur are not completely understood, but transcriptional alterations may be used as markers for inflammation and wound healing. The bioactivity of 3 casein hydrolysates prepared by treatment of commercial casein with pepsin (60 min) and corolase (0, 10 or 60 min) were investigated in intestinal epithelial cells treated with the NSAID indomethacin. The bioactivity was evaluated as transcriptional alterations of Transforming Growth Factor- $\beta$  (TGF- $\beta$ ), Cyclooxygenase-2 (COX-2), Peroxisome Proliferator-Activated Receptor- $\gamma$  (PPAR- $\gamma$ ) and Nuclear Factor  $\kappa$ B (NF $\kappa$ B) by real-time PCR. Furthermore, the effect of casein hydrolysates on lipopolysaccharide (LPS) induced inflammation was evaluated in macrophages by measuring PG E<sub>2</sub> (PGE<sub>2</sub>) levels. Casein hydrolysates treated with corolase for 10 and 60 min downregulated transcription of TGF- $\beta$  and NF $\kappa$ B ( $P < 0.05$ ) compared with hydrolysate only treated with pepsin. Hydrolysate treated with corolase for 60 min downregulated transcription of COX-2 ( $P < 0.05$ ) compared with hydrolysate treated with corolase for 10 min, while transcription of PPAR- $\gamma$  was not affected ( $P > 0.05$ ) by hydrolysates treated with corolase for either 10 or 60 min. Additionally, the hydrolysate not treated with corolase had a pro-inflammatory effect on macrophages via PGE<sub>2</sub> stimulation ( $P < 0.05$ ). In conclusion, casein hydrolysates produced by pepsin and corolase treatment downregulated the transcription levels of TGF- $\beta$ , COX-2 and NF $\kappa$ B.

**Key Words:** cell culture, gene expression, hydrolysates

**3038 Growth performance and preference studies to evaluate solvent-extracted *Brassica napus* or *Brassica juncea* canola meal fed to weaned pigs.** J. L. Landero\*<sup>1</sup>, E. Beltranena<sup>1,2</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>*University of Alberta, Edmonton, AB, Canada,* <sup>2</sup>*Alberta Agriculture and Rural Development, Edmonton, AB, Canada.*

Conventional dark-seeded (*B. napus*) canola meal (CM) and novel yellow-seeded (*B. juncea*) CM can potentially replace soybean meal (SBM) in pig diets. Napus and juncea CM contain 3.8 and 10.8  $\mu\text{mol}$  glucosinolates/g, respectively, and 3-fold more ADF than SBM (NRC, 1998) that may affect feed preference and feed intake. Previously in Exp. 1 and 2, growth performance was evaluated using 220 weaned pigs by replacing dietary SBM with 0, 5, 10, 15 and 20% napus CM (Exp. 1) or 0, 6, 12, 18 and 24% juncea CM (Exp. 2) for 28 d. In Exp. 3 and 4, preference for diets containing 20% of the 3 feedstuffs was evaluated using 216

pigs of 35-d of age housed in pens with 2 4-space feeders with diets offered in a paired choice as mash (Exp. 3) or pellets (Exp. 4) for 3 consecutive 7-d periods (3 d non test, 4 d preference). Diets were formulated to equal NE and SID AA using canola oil and synthetic AA. Feeding up to 20% napus CM to pigs did not affect growth performance. Increasing inclusion of juncea CM linearly reduced ( $P < 0.001$ ) ADFI, ADG and feed efficiency. In Exp. 3 and 4, pigs preferred SBM ( $P < 0.001$ ) over napus and juncea CM diets, and pigs preferred napus CM ( $P < 0.001$ ) over juncea CM diet. Glucosinolates likely reduced feed preference in juncea CM more than napus CM. The reduced growth performance of pigs fed juncea CM diets was associated to its higher glucosinolate content, most likely the bitter gluconapin-type dominant in juncea CM than the proigotrin-type dominant in napus CM. In conclusion, although pigs clearly preferred the SBM diet over napus or juncea CM diets, when given no choice, napus CM but not juncea CM can replace up to 20% SBM in diets for weaned pigs without affecting growth performance. Finally, the contrast of results between preference and performance studies feeding CM to pigs indicates that results of preference studies should be interpreted cautiously until validated by pig growth performance data.

**Key Words:** canola meal, preference, soybean meal

### 3039 Redox potential of cecum content of growing pigs and its relation with pH and VFA concentration.

R. Lizardo<sup>\*1</sup>, N. Tous<sup>1</sup>, M. A. Calvo<sup>2</sup>, C. Sampsonis<sup>3</sup>, R. D'Inca<sup>3</sup>, and J. Brufau<sup>1</sup>, <sup>1</sup>IRTA - Institut de Recerca i Tecnologia Agroalimentaries, Constantí, Tarragona, Spain, <sup>2</sup>UAB - Universidad Autónoma de Barcelona, Bellaterra, Barcelona, Spain, <sup>3</sup>LFA - Lesaffre Feed Additives, Marcq-en-Baroeul, Lille, France.

Digestive microflora is partly responsible for physiological gut conditions. Bacteria density in pig cecum exceeds  $10^9$  logCFU/g of digesta suggesting a high fermentation activity. The cecal milieu is anaerobic which suppose a redox potential (Eh) markedly negative, reflecting the absence of oxygen and a strong reducing power. Measurements of Eh and pH of digesta can give a basis for understanding microbial activity and dynamics of fermentation. However, few studies have assessed the Eh of the gastro-intestinal tract of pigs. Twenty-four pigs of around 30 kg liveweight were slaughtered to measure Eh and pH of cecum content in situ and, samples of ileum, cecum and colon contents for VFA determinations were taken. Pigs were previously fed with a non-medicated starter feed for 5 weeks. The cecum was reached through an incision on the abdomen then a second small incision (2–2.5 cm) was made to insert Eh and pH electrodes. Measurements were recorded first at 2 min and then each 5 min for 35 min to estimate kinetics and the delay to reach stabilization of Eh value. Cecum Eh dropped rapidly from  $-115$  to  $-180$  mV for 15th min after insertion of electrodes ( $P < 0.001$ ) and then slowly decreased until  $-185$  mV at 35 min. Cecal pH starts at 5.74 decreasing slowly afterward until 5.53 after 35 min ( $P < 0.01$ ). The Eh value after stabilization was negatively correlated with final pH ( $r = -0.64$ ;  $P < 0.001$ ). Acetic, propionic and butyric acids account for 58.7, 24.0 and 12.8% of

total VFA production of cecum content, respectively. VFA production of ileal content was lower when compared with cecum or colon (50.8, 142.1 and 130.8  $\mu\text{mol/g}$ ;  $P < 0.001$ ) and a higher proportion of formic and lactic acids was detected (32.3 and 27.0%, respectively). Proportions of acetic and propionic acids were correlated negatively ( $r = -0.53$ ;  $P < 0.01$ ) and positively ( $r = 0.66$ ;  $P < 0.001$ ) with Eh, respectively. In conclusion, cecal Eh was not easily measured, but predicted fermentative activity. So, it can be considered in future research relating feed additives and digestive physiology.

**Key Words:** piglet, redox potential, cecum

**3040 Blood sampling and hemolysis affect concentrations of plasma nutrients.** P. K. Theil<sup>\*1</sup>, L. J. Pedersen<sup>1</sup>, M. B. Jensen<sup>1</sup>, C. C. Yde<sup>2</sup>, and K. E. Bach Knudsen<sup>1</sup>, <sup>1</sup>Dept. of Animal Science, Aarhus University, Foulum, DK-8830 Tjele, Denmark, <sup>2</sup>Dept. of Food Science, Aarhus University, Kirstinebjergvej 10., DK-5792 Aarslev, Denmark.

Blood sampling of peripheral blood may be collected by vein puncture or from a catheter. The latter is preferred because stress of the animal and hemolysis of collected plasma is avoided, but most studies use vein puncture. This study aimed to reveal metabolites sensitive to stress and/or hemolysis and quantify the effect on metabolite concentrations. Blood was collected from early and mid pregnant sows fed one of 2 different diets. A total of 24 sows were blood sampled using vein puncture during nose snaring and another 30 sows were blood sampled via jugular vein catheters. Sows were fed twice daily (08 and 15 h) and blood sampled repeatedly 1, 4, 11 and 23 h after morning feeding. Plasma levels of isobutyrate ( $P < 0.001$ ), NEFA ( $P < 0.01$ ), and acetate ( $P < 0.05$ ) were lowered, and plasma levels of caproate ( $P < 0.001$ ), glucose ( $P < 0.01$ ), lactate, and isovalerate ( $P < 0.05$ ) were elevated in samples obtained via vein puncture. Plasma insulin, propionate and butyrate were not sensitive to the blood sampling procedure. These findings suggest that concentrations of many plasma metabolites are sensitive to the blood sampling procedure, likely due to stress imposed on the animal. Hemolysis is a common problem when blood is collected by vein puncture and the effect of hemolysis on plasma metabolite concentrations was studied in 48 sows fed 4 different diets (other conditions identical to that described above). Plasma was categorized according to no, minor or major hemolysis (clear ( $n = 218$ ), yellow ( $n = 97$ ) or red ( $n = 37$ )) upon centrifugation. Plasma NEFA ( $P < 0.001$ ) and plasma insulin ( $P < 0.10$ ) was lower in hemolyzed samples while plasma propionate, caproate, isovalerate ( $P < 0.001$ ), isobutyrate ( $P < 0.05$ ) and butyrate ( $P < 0.10$ ) was higher in hemolyzed samples compared with clear plasma samples. Plasma glucose and lactate were the only metabolites studied which were not affected by hemolysis. No dietary interactions were found ( $P > 0.05$ ). In conclusion, blood sampling procedure and hemolysis affect the measured metabolite concentrations and should be considered or accounted for when comparing results within and between experiments.

**Key Words:** analysis interference, blood metabolites, pigs



**3041 Development and validation of a spectroscopy method to predict protein digestibility.** L. F. Wang\*<sup>1</sup>, M. L. Swift<sup>1,2</sup>, and R. T. Zijlstra<sup>1</sup>, <sup>1</sup>University of Alberta, Edmonton, AB, Canada, <sup>2</sup>Alberta Agriculture and Rural Development, Lacombe, AB, Canada.

Protein digestibility is traditionally measured by chemical analyses of protein and marker concentration in digesta and diets. Potentially, protein digestibility can also be predicted by marker concentrations and spectral analyses of digesta and diets. Spectroscopy is a rapid, non-destructive method to ascertain qualitative and quantitative chemical information. Based on Beer's law, a spectroscopic method was developed to predict in vivo protein digestibility. Thus, 411 samples of digesta and diets from 7 feedstuffs with predetermined apparent ileal digestibility (AID) of protein were scanned on a Fourier transform mid-infrared instrument with a single-reflection attenuated total reflectance attachment. The AID of protein was calculated from peak intensities of spectra and measured marker concentrations in digesta and diets, and then compared with in vivo AID of protein. The AID of protein of wheat-based diets was predicted accurately with a deviation of  $0.68 \pm 0.86\%$  from in vivo AID ranging from 60.4 to 87.8% in an in vivo trial. The calculated AID of protein based on the amide I peak at  $1643 \text{ cm}^{-1}$  best predicted ( $R^2 = 0.99$ ) in vivo AID of protein. This peak is primarily induced by C = O stretching vibration (80%) plus C-N stretching. For feedstuffs mixed with N-free basal diet, accuracy was lower ( $R^2 = 0.72$  to 0.91). Fine corn starch particles may cover the surface of dietary feedstuff particles causing increased absorbance of corn starch and decreased absorbance of feedstuff protein, resulting in lower calculated AID of protein. The  $R^2$  between spectroscopy predictions and in vivo AID of protein was 0.91 for corn distillers dried grains with solubles (DDGS), 0.90 for wheat DDGS, 0.70 for blended DDGS, 0.90 for triticale DDGS, 0.72 for field pea and 0.83 for wheat millrun. In conclusion, instead of predictions based on calibration, protein digestibility can also be predicted directly from spectra.

**Key Words:** protein digestibility, pig, spectroscopy

**3042 The in vivo infusion of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) induces oxidative stress in piglets and differentially**

**affects the activities of small intestinal carbohydrate digesting enzymes in pigs.** D. Lackeyram,\* Y. Mine, T. Archbold, and M. Fan, University of Guelph, Guelph, Ontario, Canada.

Chronic fatigue syndrome (CFS) is characterized by persistent and relapsing fatigue that involves oxidative stress in its pathogenesis. We tested the hypothesis that decreases in key carbohydrate-digesting enzyme activities in the gut are one of the major biological mechanisms of developing CFS in liquid formula-fed piglets with in vivo infusion of  $\text{H}_2\text{O}_2$ . Piglets of 5 d of age were fitted with an intraperitoneal catheter and infused with either  $\text{H}_2\text{O}_2$  at 5 mmol/kg BW (PER,  $n = 8$ ) or the same volume of saline (CON,  $n = 8$ ) in 6 20-mL doses daily for a period of 10 d. During this time, animal behavior was monitored, blood samples taken and jejunal enzyme activity kinetic experiments for lactase, sucrase, maltase and maltase-glucoamylase were conducted. Plasma GSH levels remained similar ( $P > 0.05$ ) to the pre-infusion level over the study duration in the CON group, whereas this was 65% lower ( $P < 0.05$ ) than the pre-infusion level in the PER group. Piglets experiencing oxidative stress had lower ( $P < 0.05$ ) physical mobility and reduced maximal specific activities for lactase ( $V_{\text{max}}$ : PER,  $6.54 \pm 0.68$  vs. CON,  $12.65 \pm 0.69$ ) and maltase (PER,  $57.39 \pm 1.02$  vs. CON,  $75.6 \pm 1.04 \mu\text{mol/mg protein}\cdot\text{min}$ ), respectively. However, there were no differences ( $P > 0.05$ ) in the maximal specific activity of sucrase (PER,  $10.50 \pm 1.37$  vs. CON,  $12.40 \pm 1.55 \mu\text{mol/mg protein}\cdot\text{min}$ ) and maltase-glucoamylase ( $V_{\text{max}}$ : PER,  $0.71 \pm 0.08$  vs. CON,  $0.70 \pm 0.07$ ), respectively. We conclude that the infusion of a suitable dose of hydrogen peroxide induced chronic fatigue symptoms in piglets. In addition, oxidative stress in vivo differentially affected the maximal activities of key small intestinal carbohydrate-digesting enzymes. Dramatic decreases in gut mucosal lactase and maltase maximal activities in response to oxidative stress would lead to a reduced essential metabolic fuel availability to red blood cells and brain, contributing to the pathogenesis of CFS.

**Key Words:** chronic fatigue syndrome, digestive capacity, gut mucosal carbohydrate-digesting enzymes



## **Session VII: Manipulation of Digestion**

**3043 Effects of processing technologies and cell wall degrading enzymes on in vitro degradability of barley.** S. de Vries<sup>\*1</sup>, A. M. Pustjens<sup>2</sup>, H. A. Schols<sup>2</sup>, W. H. Hendriks<sup>1</sup>, and W. J. J. Gerrits<sup>1</sup>, <sup>1</sup>Animal Nutrition Group, Wageningen University, Wageningen, The Netherlands, <sup>2</sup>Laboratory of Food Chemistry, Wageningen, The Netherlands.

Effects of processing technologies and cell wall degrading enzymes on degradation of barley during in vitro digestion simulation were tested in a 5 × 2 factorial arrangement: 5 technologies (unprocessed, wet-milling, extrusion, autoclaving, and acid-autoclaving), with or without enzymes (xylanases and β-glucanases; 2.5 mL/g). Digestion in the upper gastrointestinal tract (adapted Boisen methodology) and subsequent, large intestinal fermentation (gas production) were simulated in duplicate. All technologies increased dry matter (DM) and starch disappearance of barley during Boisen incubation compared with the unprocessed control (Table 1). Wet-milling, extrusion, and acid-autoclaving increased protein disappearance, whereas autoclaving did not. Enzyme treatment increased DM, starch, and protein disappearance in unprocessed and autoclaved barley. Extent and maximum rate ( $R_{max}$ ) of fermentation of Boisen residues, and time at which  $R_{max}$  occurred ( $T_{max}$ ), were negatively correlated with starch disappearance during enzymatic digestion simulation ( $r = -0.93, -0.93, \text{ and } -0.81$ , respectively;  $P < 0.01$ ). Wet-milling, extrusion, and acid-autoclaving, which reduced starch content of Boisen residues compared with the untreated control, reduced extent of fermentation by 50%,  $R_{max}$  by 60–75%, and  $T_{max}$  by 45–70% ( $P < 0.01$ ). In conclusion, both processing and cell wall degrading enzymes might potentially untangle cell wall structure, thereby increasing accessibility of nutrients in barley. Processing technologies were generally more effective in improving nutrient digestion of barley compared with enzymes. The latter improved nutrient digestion only in barley that was unprocessed or little affected by processing.

**Table 1.** Effect of processing technology (T) and enzymes (E) on disappearance (%) of dry matter (DM), starch, and protein during Boisen incubation of barley

Enzyme:	DM		Starch		Protein	
	No	Yes	No	Yes	No	Yes
Processing method						
Unprocessed	40 <sup>d</sup>	59 <sup>c</sup>	49 <sup>e</sup>	73 <sup>d</sup>	58 <sup>c</sup>	71 <sup>b</sup>
Wet-milling	79 <sup>a</sup>	81 <sup>a</sup>	100 <sup>a</sup>	100 <sup>a</sup>	91 <sup>a</sup>	91 <sup>a</sup>
Extrusion	82 <sup>a</sup>	83 <sup>a</sup>	99 <sup>ab</sup>	100 <sup>a</sup>	87 <sup>a</sup>	89 <sup>a</sup>
Autoclaving	53 <sup>c</sup>	71 <sup>b</sup>	71 <sup>d</sup>	88 <sup>c</sup>	57 <sup>c</sup>	70 <sup>b</sup>
Acid-autoclaving	83 <sup>a</sup>	78 <sup>ab</sup>	97 <sup>b</sup>	97 <sup>b</sup>	88 <sup>a</sup>	85 <sup>a</sup>
SEM	2.3		1.8		2.3	
T	<0.01		<0.01		<0.01	
E	<0.01		<0.01		<0.01	
T × E	<0.01		<0.01		<0.01	

**Key Words:** barley, cell wall, digestion

**3044 Inhibitory action of analytical grade and of a new potentiated form of zinc oxide on the ex vivo growth of**

**porcine small intestine bacteria.** W. Vahjen<sup>1</sup>, J. Zentek<sup>1</sup>, and S. Durosoy<sup>\*2</sup>, <sup>1</sup>Free University of Berlin, Faculty of Veterinary Medicine, Institute of Animal Nutrition, Berlin, Germany, <sup>2</sup>Animine, Sillingy, France.

Pharmacological dosage of zinc oxide in piglet weaning diets is a common practice for growth performance and gut health. However, high zinc excretion in animal wastes poses environmental challenges. Alternatives to current practice are studied. Previous in vitro experiments showed a significantly higher growth repressing effect of a new and potentiated feed grade zinc oxide product (HiZox, Animine), compared with analytical grade zinc oxide, on 2 pathogenic bacterial *E. coli* strains. The inhibitory action of the 2 zinc oxide sources on the ex vivo growth of small intestinal bacteria from weaned piglets was studied. Piglets weaned at 28 d of age and fed a standard European diet were killed at 42 d. Chyme from the stomach and from jejunum was taken and diluted in Zn-containing media adjusted to different ZnO concentrations. All media were diluted with BHI for final concentrations of 80, 40, 20 and 10 μg ZnO/mL medium. Under anaerobic conditions, intestinal samples dilutions were inoculated into 180 μL medium in 96 well microtiter plates, with Zn concentrations ranging from 80 to 125 μg/mL medium, using LAB022 at pH 6.5. A microplate reader with anaerobic incubation capacity set to 690 nm detection was used to record turbidity as measure for bacterial growth. Measurements were taken every 5 min for 22 h. Growth data from the different Zn sources was compared at each Zn concentration using *t*-test ( $P < 0.05$ ). Data was exported and transformed into growth curves. A non linear regression analysis was employed to calculate coefficients for lag time (min) and maximum growth (OD). Lag time before bacterial growth was higher ( $P < 0.05$ ) in HiZox supplemented media from the stomach samples. No difference was measured in jejunum samples and in maximum growth data between sources. Bacterial growth depression was more drastic and more rapid in HiZox supplemented media when optical density was compared with the negative control. This new potentiated zinc oxide showed a higher inhibitory effect on bacterial growth in stomach and jejunum samples of piglets in comparison to analytical grade zinc oxide.

**Key Words:** zinc oxide, piglet, gut flora

**3045 Effects of oral supplementation with glutamate or combination of glutamate and N-carbamylglutamate on intestinal mucosa morphology and epithelium cell proliferation in weanling piglets.** X. Wu and Y. Yin,\* *Key Laboratory for Agro-ecological Processes in Subtropical Region, Institute of Subtropical Agriculture, Chinese Academy of Sciences, Hunan 410125, China.*

To evaluate the effects of glutamate (Glu) or combination of Glu and N-carbamylglutamate (NCG) on intestinal mucosa in weanling piglets, 18 piglets weaned at 28 d (BW 5.56 ± 0.51 kg) were grouped into 3 treatments, and fed one of the following diets for 30 d: a standard diet (SD), SD+Glu (1%), SD+Glu (1%)+NCG (0.05%). After the blood samples were collected all the piglets were killed for intestinal mucosa collection, and real-time PCR was used to detect mRNA

abundance of proliferating cell nuclear antigen (PCNA), vascular endothelial growth factor (VEGF), and  $\beta$ -catenin. The data from real-time PCR were analyzed with a  $\Delta\Delta C_t$  method and normalized to the amount of GAPDH cDNA as an endogenous control. The results showed that compared with the control group, Glu increased concentration of blood glucose and glucagon ( $P < 0.05$ ) and reduced plasma insulin ( $P < 0.05$ ) in weaned piglets. Both of Glu or combination of Glu and NCG decreased serum urea nitrogen and ammonia concentration ( $P < 0.05$ ), and Glu+NCG increased average intestine weight significantly ( $P < 0.05$ ). Compared with the control group, adding Glu to the diet resulted in a higher villus height ( $P < 0.05$ ) in both of duodenum and jejunum. However, there was no difference in crypt depth at the 2 different locations, and the villus height/crypt depth ratio was unaltered ( $P > 0.05$ ). The RT-PCR results showed that combination of Glu and NCG significantly increased PCNA mRNA abundance in both jejunum and ileum ( $P < 0.05$ ), while they also significantly increased  $\beta$ -catenin and decreased VEGF mRNA abundance in ileum ( $P < 0.05$ ). There were no differences in these genes expression between the Glu and Glu+NCG groups ( $P > 0.05$ ). Only Glu increased PCNA mRNA abundance in jejunum ( $P < 0.05$ ) and Glu+NCG decreased VEGF mRNA in jejunum ( $P < 0.05$ ). These results indicated that oral supply of Glu improved intestinal mucosa morphology, and combined Glu and NCG had more favorable effects on intestinal epithelium cell proliferation than glutamate alone.

**Key Words:** amino acids, nutrition, digestion

**3046 Dietary CLA modify gene expression in liver, muscles and fat tissues of fattening pigs.** N. Tous<sup>1</sup>, P. K. Theil<sup>2</sup>, C. Lauridsen<sup>2</sup>, R. Lizardo<sup>1</sup>, B. Vilá<sup>1</sup>, and E. Esteve-García<sup>1</sup>, <sup>1</sup>IRTA, *Monogastric Nutrition, 43120 Constantí, Tarragona, Spain*, <sup>2</sup>Aarhus University, *Department of Animal Science, Foulum, DK-8830 Tjele, Denmark*.

Conjugated linoleic acid (CLA) may be included in pig diets as a functional ingredient to reduce fat deposition and concomitantly increase intramuscular fat (IMF) retention. Yet, several studies with pigs have presented contradictory results, and the role of CLA in the organism seems to be quite complex. In a previous study a reduction of fat deposition without modification of IMF was observed. The aim of this study was to investigate underlying mechanisms of dietary CLA on lipid metabolism in various tissues. Sixteen gilts ( $73 \pm 3$  kg) were fed a control (without CLA) or an experimental diet (4% of sunflower oil in control diet replaced by CLA) and pigs were slaughtered at a live weight of  $115 \pm 5$  kg. Analysis of fatty acid (FA) composition in IMF of longissimus thoracis (LT) and semimembranosus (SM) muscles, LT subcutaneous fat and liver were conducted using gas chromatography. Expression of peroxisome proliferator-activated receptor  $\alpha$  (PPAR $\alpha$ ), peroxisome proliferator-activated receptor gamma (PPAR $\gamma$ ), fatty acid synthase (FAS), sterol regulatory element binding protein (SREBP1), acetyl-CoA carboxylase (ACC), lipoprotein lipase (LPL), delta-6-desaturase (D6D), and stearoyl CoA desaturase (SCD) were evaluated by real-time PCR in all tissues. While little impact was observed on animal fat deposition, CLA increased liver weight ( $P < 0.05$ ) and

modified ( $P < 0.05$ ) FA profile in all the tissues analyzed, i.e., increased the saturated fatty acids (SFA), and reduced the monounsaturated fatty acids (MUFA) in LT and LT subcutaneous fat, and polyunsaturated fatty acids (PUFA) in LT subcutaneous fat, liver and SM. The PPAR $\alpha$  was reduced in all the tissues studied ( $P < 0.05$ ) except in intermuscular fat. The PPAR $\gamma$  was increased in LT muscle ( $P < 0.05$ ). Gene expression related to FA synthesis was reduced in SM muscle and liver (ACC [ $P < 0.01$ ] in SM; FAS [ $P < 0.01$ ] in liver and SREBP in both tissues [ $P < 0.1$ ]). Expression of LPL and D6D were reduced in SM muscle ( $P < 0.05$ ) and SCD was increased in LT muscle and intermuscular fat but reduced in liver ( $P < 0.05$ ). It was concluded that dietary CLA affected nutrient metabolism in a tissue specific manner.

**Key Words:** fatty acid, oxidation, uptake

**3047 Does the dry matter content of the diet (fed dry or liquid) affects the intragastric milieu of pigs fed diets differing in grinding intensity and diets' physical form?**

A. Moessler\*, M. Wintermann, S. Sander, and J. Kamphues, *Institute of Animal Nutrition, University of Veterinary Medicine Hannover, Foundation, Germany, Hannover, Germany*.

Physical form of diets has an impact on development of gastric ulcers in pigs. An earlier study showed effects of fine grinding and pelleting on local intragastric milieu. Finely ground diets caused a more liquid gastric content and there was no physiological pH gradient in the stomach. This follow up study was conducted to prove effects of dry or liquid feeding on intragastric milieu (dry matter [DM], pH and buffering capacity [BC]) in pigs. Eighteen piglets were individually housed and fed for 6 wk with test diets and water ad lib. Both experimental diets used (coarsely ground diet fed as mash [CM] vs. finely ground pelleted diet [FP]) were identical in botanical (39.5% wheat, 34% barley, 20% SES) and chemical composition and were either offered dry or liquid (25% dry matter). At the end of the trial the animals were killed; stomach was withdrawn in toto and samples were taken from different localizations to determine intragastric milieu. There was no effect of feeding diets dry or liquid on pH ( $\geq 0.05$ ). The diet noticeably affected the stomach content. The FP resulted in a more liquid chyme ( $P \leq 0.05$ ) and intragastric pH did not differ between regions. Feeding CM caused marked effects of localization regarding pH (highest values: pars nonglandularis, lowest values: fundus). None of the pigs fed CM diet had gastric ulcers while score was sign. higher in pigs fed FP diet ( $P \leq 0.05$ ), but with no effect of feeding the diet dry or liquid. The BC at pars nonglandularis was lower ( $P \leq 0.05$ ) in gastric content of pigs fed FP. Performance parameters (weight gains and feed conversion rate) were not affected by grinding intensity of the diet (but higher daily weight gain in pigs fed liquid diets). Findings from earlier studies (homogenous pH values after feeding FP) were confirmed and there was no effect of the DM content of the diet on intragastric milieu. Predominant factor for milieu within the stomach content seems to be the structure (particle size) of the diet. Interestingly DM content of gastric ingesta was not affected by moisture of the diet.

**Key Words:** gastric ulcer, grinding intensity, intragastric milieu

**3048 The effects of supplementations with two potassium formate sources on performance of 8 to 22 kg pigs.** J. K. Htoo<sup>\*1</sup> and J. Morales<sup>2</sup>, <sup>1</sup>Evonik Industries AG, Hanau, Germany, <sup>2</sup>PigChampPro Europa, SL, Segovia, Spain.

Dietary inclusion of salts of organic acids may modulate intestinal microbiota and enhance pig performance. Published data on the effects of K-formate (46.5% K and 53.5% formate; pH 6.0–8.5) on pig performance are scarce compared with that of K-diformate (65% K-formate and 35% formic acid; pH 4.1–4.5). Therefore, the objective was to evaluate the effects of K-diformate or K-formate supplementation on performance of 8 to 22 kg pigs. A 35-d growth trial was conducted with 144 PIC pigs (initial BW of 7.9 ± 1.1 kg) with 6 pigs (3 gilts and 3 barrows) per pen and 8 pens per treatment. Pigs were blocked by BW and assigned to 3 diets based on corn, wheat and soybean meal for each of the pre-starter (d 1–21) and starter phases (d 22–35). The basal diets contained no antibiotics and met requirements for AA (1.25 and 1.12% standardized ileal digestible Lys for pre-starter and starter phase) and NE (2486 and 2414 kcal/kg for pre-starter and starter phase). The basal diet for each phase was supplemented with K-diformate at 1.20% or K-formate at 1.56% replacing corn starch to create diets 2 and 3, respectively. Room temperature was controlled at 26°C during wk 1 and gradually reduced by 1°C per week. The ADG during the pre-starter, starter and overall periods increased ( $P < 0.05$ ) by K-diformate or K-formate supplementation. The BW on d 35 of pigs fed diet supplemented with K-diformate or K-formate were higher ( $P < 0.05$ ) compared with pigs fed the basal diet. The ADFI was not affected by the treatments. The supplementation of K-diformate improved ( $P < 0.05$ ) FCR during the pre-starter and overall periods while K-formate addition improved ( $P < 0.05$ ) FCR during the pre-starter, starter and overall periods. Performance of pigs fed diets supplemented with K-formate and K-diformate were similar and no effects of K-formate source were observed. Diarrhea incidences were observed mainly during wk 1 but no differences were observed ( $P > 0.05$ ) among treatments with respect to the number of required antibiotic treatments and the fecal consistency scores. Overall, the supplementation of K-diformate or K-formate improved the performance of weaned pigs.

**Key Words:** K-diformate, K-formate, weaned pigs

**3049 Reduced small intestinal  $\alpha$ -amylase activity in the presence of soluble fibre arabinosyran.** A. M. Pluschke<sup>\*1,2</sup>, M. J. Gidley<sup>1,2</sup>, and B. A. Williams<sup>1,2</sup>, <sup>1</sup>The University of Queensland, Centre for Nutrition and Food Sciences, Brisbane, QLD, Australia, <sup>2</sup>ARC Centre of Excellence in Plant Cell Walls, Brisbane, QLD, Australia.

Soluble dietary fibers (SDFs) such as arabinosyran (AX), the major cell wall polysaccharide of wheat endosperm, are associated with reduced rates of starch digestion in the small intestine, though the causes of this are unclear. The aim of this work was to examine the hypothesis that dietary AX

reduces the activity of amylase available for starch digestion in the porcine small intestine, which would potentially have an effect on the glycaemic response of animals fed a starch-containing diet. Twelve Large White male pigs were housed individually and were fed a highly digestible diet based on wheat starch, egg powder, whey protein concentrate, palm oil and sunflower oil for 2 weeks before digesta collection, either with or without 10% wheat AX. Digesta was collected from the stomach and small intestine (SI-6 sub-sections) under anesthetic before euthanasia. SI1 and SI6 were measured as 1 m after the stomach and before the cecum respectively. SI2-SI5 consisted of the middle portion of the small intestine equally divided into 4 lengths. Analysis of  $\alpha$ -amylase activity was performed for the stomach and the first 4 sections of the SI, using an  $\alpha$ -amylase specific kit (Biovision # K711–100), modified for use with a micro-plate spectrophotometer at 415 nm. The presence of AX led to a significantly later half-time (to reach maximum absorbance for the assay;  $P = 0.0039$ ) throughout the SI. For the AX diet, the half-time values were also different between SI1 and SI2, compared with SI3 and SI4, whereby the values were later for SI3 and SI4. The data suggests 2 possible mechanisms. For the non-AX diet pigs, the increased amylase activity in SI1 and SI2 meant that there was no starch left to be degraded in SI3 and SI4, compared with the AX-diet pigs. Alternatively, the presence of AX may have resulted in a prolonged activity along the tract due to the viscous nature of the digesta. Both mechanisms will have consequences on the glycaemic response caused by SDFs such as AX.

**Key Words:** arabinosyran,  $\alpha$ -amylase, digestion

**3050 Comparison of four commercial feed proteases for improvement of nutritive value of poultry feather meal.** M. B. Pedersen<sup>\*1,4</sup>, S. Yu<sup>1,2</sup>, P. Plumstead<sup>3</sup>, and S. Dalsgaard<sup>1</sup>, <sup>1</sup>Enzyme R&D, Genencor, Danisco A/S, Edwin Rahrs Vej 38, DK 8220 Brabrand, Aarhus, Denmark, <sup>2</sup>Department of Biotechnology, Lund University, Lund, Sweden, <sup>3</sup>Danisco Animal Nutrition, Marlborough, United Kingdom, <sup>4</sup>Department of Molecular Biology and Genetics, Aarhus University, Aarhus, Denmark.

Feed industries are seeking new ways to cope with increased raw material costs. One of the approaches is to apply enzymatic treatment in the production of feed ingredients from animal by-products. It is known that feather is composed mainly of the highly rigid structural polypeptide, keratin, which is resistant to known digestive enzymes (e.g., pepsin and trypsin). Special proteases, keratinases, are capable of hydrolyzing keratin-rich material, and have been applied in the production of feather by-products for use as feed. A nutritional improvement of keratinase-pretreated feather meal has been reported compared to conventional hydrothermal processing, supporting possible benefits of using proteases in the feather meal processing industry. The use of enzymatic-pretreated feather meal as feed ingredient in pig diets is still to be investigated. However, studies using conventional feather meal show that feather meal can be incorporated at a level up to 6% into isolytic diets of growing-finishing pigs without adversely impacting animal performance, carcass composition, or pork quality. Furthermore, no difference in performance has been observed when up to 4% feather



meal was fed to pigs 0 to 4 wk of age and up to 8% for 4- to 8-wk-old pigs. The current study examined four commercial feed proteases used to hydrolyze chicken feather: These are from *Bacillus subtilis*, *B. licheniformis* PWD-1, *Aspergillus niger* and the symbiotic bacterium *Serratia proteamaculans* HY-3. The degree of keratinolysis by these four proteases was monitored by measuring released NH<sub>2</sub>-groups using  $\alpha$ -phthalaldehyde (OPA) and by Scanning Electron Microscopy. The results showed that all these four feed proteases were able to degrade feather when examined at pH 5.5 and 7.0. The degree of hydrolysis was stimulated by the addition of reducing reagents such as dithiothreitol (DTT) and sodium sulfite. In general, the protease from *Bacillus subtilis* was more efficient in degrading feather keratin compared to the other three feed proteases at both pH 5.5 and 7.0. For commercial production, the application of protease from *Bacillus subtilis* is even more advantageous if cost-in-use may be considered.

**Key Words:** feather keratin, feed proteases, enzymes

**3051 Use of COSITEC in vitro model of the pig colon to assess the effect of probiotic yeast on fermentation parameters and microbiota.** E. Pinloche<sup>1,2</sup>, M. Williams<sup>1</sup>, R. D'Inca<sup>2</sup>, E. Auclair<sup>2</sup>, and C. J. Newbold<sup>1</sup>, <sup>1</sup>*Institute of Biological, Environmental and Rural Sciences, Aberystwyth, United Kingdom*, <sup>2</sup>*Lesaffre Feed Additives, Marcq-en-Baroeul, France*.

This study evaluated 2 doses of a commercial live yeast probiotic (Actisaf Sc47) on fermentation parameters and microbiota using an in vitro model (COSITEC) to mimic digestion in the pig colon. Digesta content from colon and cecum of 8 growing pigs (circa 100 kg; fed a commercial diet with no probiotic) was collected and used as diet (freeze-dried digesta) and inoculum (fresh digesta). Live yeast (LY) was added to the freeze-dried digesta at a dose of 5 g/kg (L1), 50 g/kg (L2) or none (C) and fed at a rate of 2.2 g/d (n = 4). After 8 d of adaptation, samples were collected for 2 d to measure VFA, ammonia, gas and methane production together with LY counts, pH, redox potential (Eh), dry matter digestibility (DMD) and microbiota structure (T-RFLP). Statistical analyses were performed using randomized block design/repeated measures ANOVA and T-RFLP profiles were analyzed with MANOVA. Over a 24-h period, LY counts decreased by 2.5 log and it was estimated that 65 h (L1) and 100 h (L2) would be necessary for the LY to be totally washed-out of the fermentors. Treatments did not have an impact on pH (mean of 7.08), Eh (-253 mV), gas (550 mL/d) or methane production (0.6 mL/d). L2 (but not L1) significantly improved DMD (61%) compared with C (58%) and ammonia (+15%). VFA production increased with L2 compared with C: iso-butyrate (+14%), propionate (+8.5%), iso-valerate (+17%) and N-valerate (+25%) but only N-valerate was impacted by L1 (+13%). The analysis of the microbiota, performed on both the liquid (LAB) and solid associated bacteria (SAB), revealed that there was a significant difference in the structure of the microbiota between SAB and LAB ( $P < 0.01$ ), treatments ( $P < 0.001$ ) but that the interaction was also significant ( $P = 0.043$ ). Indeed, for the LAB only L2 had a significant impact on the microbiota ( $P < 0.01$ ) whereas L1 also tended to change the structure of the microbiota in

the SAB ( $P = 0.075$ ). Overall, this study showed that a LY probiotic could improve the fermentation pattern in a colonic simulation model but only at the higher dose used and this was probably due to a shift in the microbiota.

**Key Words:** yeast, dry matter digestibility, microbiota

**3052 Responses of dietary ileal amino acid digestibility to consumption of different cultivars of potatoes and conventional fibers in pigs fed a high-fat basal diet.** Q. Wang<sup>\*1</sup>, X. Yang<sup>1</sup>, S. Leonard<sup>1</sup>, T. Archbold<sup>1</sup>, A. Sullivan<sup>1</sup>, B. Bizimungu<sup>2</sup>, A. Murphy<sup>2</sup>, A. Duncan<sup>1</sup>, D. Ma<sup>1</sup>, J. Htoo<sup>3</sup>, and M. Fan<sup>1</sup>, <sup>1</sup>*University of Guelph, Guelph, ON, Canada*, <sup>2</sup>*Agriculture and Agri-Food Canada Potato Research Centre, Fredericton, NB, Canada*, <sup>3</sup>*Evonik Industries AG, Hanau-Wolfgang, Germany*.

While dietary fibers are well recognized for nutritional management of human health issues, fiber components are also known to be one of the anti-nutritional factors potentially affecting digestive utilization of dietary proteins. As a staple food, potato may be a significant dietary fiber source. The objective of this study was to examine effects of dietary supplementation of 6 potato cultivars that are different in soluble fiber contents and 2 conventional fiber components (cellulose and guar gum) on the apparent ileal amino acid (AA) digestibility in pigs fed a high-fat basal diet. The basal diet was formulated as a control to contain 41.5% poultry meal, 4% casein, 15% animal fat-oil blend, 2.8% sucrose, 31% cornstarch and the rest as trace mineral and vitamin supplements with fat contributing to 47% of dietary gross energy. The 2 fiber diets were formulated by diluting the basal diet with 10% guar gum and cellulose at the expense of cornstarch. Six other test diets were formulated by diluting the basal diet with 25.1% of 6 cultivars of dehydrated potato tuber powder to contain 10% total dietary fiber at the expense of cornstarch. Titanium oxide was included (0.30%) as a digestibility marker. A total of 81 barrows, with an average initial BW of 25 kg, were fitted with a simple T-cannula at the distal ileum and fed the 9 diets according to a completely randomized block design for 9 blocks with each block lasted 28 d. Total AA contents in samples were analyzed by gas chromatography-mass spectrometry. Compared with the control, apparent ileal digestibility of Leu, Phe, Pro and Gly were decreased ( $P < 0.05$ ) by 10% guar gum, while the digestibility of Leu, Phe and Gly were reduced ( $P < 0.05$ ) by 10% cellulose. However, potato supplementation did not significantly affect the ileal AA digestibility compared with the 2 fiber diets. Our results suggest that 10% guar gum and cellulose supplementation may adversely affect digestive utilization of dietary protein, however, consumption of high-soluble fiber potatoes unlikely influences protein nutrition.

**Key Words:** fiber, amino acids, pigs

**3053 Changes in the pig small intestinal mucosal glutathione system after weaning.** J. Degroote<sup>1,2</sup>, J. Michiels<sup>\*1,2</sup>, E. Claeys<sup>2</sup>, A. Ovyne<sup>2</sup>, and S. De Smet<sup>2</sup>, <sup>1</sup>*University College Ghent, Ghent, Belgium*, <sup>2</sup>*Ghent University, Melle, Belgium*.

Glutathione (GSH) serves as a major endogenous antioxidant in gut tissue and cells keep it predominantly in the reduced state, i.e., a low oxidized to reduced glutathione (GSSG/GSH) ratio. Glutathione peroxidase (GSH-Px) converts GSH to GSSG besides its direct action on other substrates. The aim of this study was to assess the effect of birth-weight, sex and days post-weaning on the small intestinal mucosal glutathione system. Newborns from 17 Danbred hybrid sows were weighed. At weaning ( $18.8 \pm 0.44$  d) pairs of intrauterine growth restricted (IUGR) and normal birth-weight sex-matched littermates were selected and fed a starter ad lib until 1 h before sampling at 0, 2, 5, 12 and 28 d post-weaning. Mucosa was collected from 2 small intestinal sites; at 5% (≈end of duodenum) and at 75% of total length, to determine GSH and GSSG by HPLC, GSH-Px spectrophotometrically and malondialdehyde (MDA), a marker of lipid peroxidation according to the TBARS method. GSH-Px and MDA were also determined in plasma. Data were analyzed by linear models. Birth-weight and sex showed no and minor significant effects, respectively. Both at 5 and 75% of total length, the GSH-Px activity and GSH concentrations increased gradually with days post-weaning to peak at d 12. The GSH-Px activity and GSH concentrations at 5% of total length were consistently higher as compared with 75% of total length (e.g., at d 12: 43.2 and 28.9 U/mg protein, and 21.5 and 15.4  $\mu\text{mol/g}$  protein, respectively). The GSSG/GSH ratio at 5% of total length was 2-fold higher at d5 compared with all other days ( $P < 0.05$ ), possibly indicating that the mucosal redox balance was disturbed in that time window. At 75% of length of the small intestine there was a tendency for GSSG/GSH to decrease with time. Malondialdehyde was only significantly affected at 75% of length; after weaning (2.44 nmol/mg protein) it decreased sharply until d5 (1.17 nmol/mg protein). The higher GSH-Px activity, GSH content and GSSG/GSH ratio in the proximal small intestine might illustrate the higher need for antioxidant action against dietary pro-oxidants at that site. Plasma MDA and GSH-Px activity followed a comparable pattern as in the small intestine.

**Key Words:** glutathione, peroxidase, weaning

**3054 Whole body protein deposition and plasma amino acid profiles in growing/finishing pigs fed different levels of sulfur amino acids with and without *E. coli*-lipopolysaccharide challenge.** J. C. Kim<sup>\*1</sup>, B. P. Mul-lan<sup>1</sup>, B. Frey<sup>2</sup>, H. G. Payne<sup>1</sup>, and J. R. Pluske<sup>3</sup>, <sup>1</sup>*Livestock Innovation, Department of Agriculture and Food, 3 Baron-Hay Court, South Perth, WA 6151, Australia*, <sup>2</sup>*Consistent Pork, East Perth, WA 6004, Australia*, <sup>3</sup>*School of Veterinary and Biomedical Sciences, Murdoch University, South Street, Murdoch, WA 6150, Australia*.

A split plot experiment with 72 male pigs weighing  $52.9 \pm 0.39$  kg (mean  $\pm$  SEM) was conducted to examine amino acid partitioning and body protein deposition rate in response to increasing dietary sulfur amino acids (SAA) with and without immune system (IS) activation. The main plot was with and without IS activation, and 4 diets containing different amounts of standardized ileal digestible (SID) SAA (SAA to lysine ratios of 0.45, 0.55,

0.65 and 0.75) were the subplots. Increased SAA was achieved by increasing the DL-methionine content in the diet. Pigs were intramuscularly injected with either saline or *E. coli* lipopolysaccharides (LPS, serotype 055:B5, Sigma, 30  $\mu\text{g/kg}$  BW) every Monday and Thursday to initiate IS activation. Blood samples were collected every 2 weeks and half carcasses were scanned through DXA at the end of the experiment. Split-plot ANOVA was used for statistical evaluation. Maximum body protein deposition and minimum plasma urea content were achieved at SID SAA:Lys ratio of 0.55 in saline-injected pigs, but were achieved at a SID SAA:Lys ratio of 0.65 and 0.75, respectively, in LPS-challenged pigs. The LPS challenge decreased red blood cell count ( $P < 0.001$ ) and hemoglobin content ( $P < 0.05$ ), and increased the proportion of neutrophils ( $P < 0.05$ ), compared with saline injection, while increasing dietary SAA had no effects on the measured variables. The LPS challenge decreased most plasma amino acids ( $P < 0.05 < P < 0.001$ ), while increasing dietary SAA linearly increased plasma methionine, cysteine and taurine contents ( $P < 0.001$ ) but linearly decreased plasma serine content ( $P < 0.001$ ). There was no interaction between LPS challenge and dietary SAA level for plasma amino acid contents. Results showed that increasing dietary SAA as DL-methionine in growing/finishing pigs altered plasma amino acid contents irrespective of LPS challenge, but utilization efficiency of the amino acids was improved when greater levels of SAA were supplemented in LPS challenged pigs.

**Key Words:** sulfur amino acids, immune system activation, protein utilization efficiency

**3055 Colostrum and milk production of sows is affected by dietary conjugated linoleic acid.** U. Krogh, C. Flummer, S. K. Jensen, and P. K. Theil,<sup>\*</sup> *Dept. of Animal Science, Aarhus University, Foulum, DK-8830 Tjele, Denmark*.

Adequate intake of colostrum and milk is a prerequisite for survival and growth of suckling piglets. Thus, yield of colostrum and milk is a major determinant for the weight and number of weaned piglets. Dietary conjugated linoleic acid (CLA) possesses various bioactive properties and the trans-10, cis-12 CLA is known to induce milk fat depression. In this experiment, 23 late pregnant sows were fed either a standard lactation diet (CON) or the CON diet supplemented with 1.3% CLA (trans-10, cis-12) from day 108 of gestation until weaning 4 weeks after parturition to evaluate whether dietary CLA affects the yield and composition of colostrum, time for initiation of milk production and the milk yield. Sows fed CLA tended to have a higher colostrum fat content (6.3 vs. 5.2 %, respectively;  $P = 0.10$ ) than CON sows, whereas the colostrum content of lactose, protein and dry matter was similar in the two groups. Sows fed CLA tended to have a lower colostrum production than CON sows (203 vs. 257 g/piglet, respectively;  $P = 0.07$ ) as predicted by the piglet rate of gain during the colostrum period (58 vs. 97 g/piglet, respectively;  $P < 0.07$ ). The piglet mortality during the first week of lactation tended to be higher for sows fed CLA than for CON sows (9.0 vs. 5.1%, respectively;  $P = 0.10$ ), and the number of piglets that died or was moved to others sows to ensure survival during the first week was more than

doubled in the CLA group (17.6 vs. 7.8%; respectively;  $P = 0.04$ ). Copious milk production was initiated 33 h [CLA] and 34 h [CON] after parturition and was not affected by dietary treatments ( $P = 0.41$ ). Sow milk yield was improved by the CLA treatment from d 3 to 14 of lactation ( $P = 0.03$ ). Weight at birth (1.39 kg for both groups;  $P = 0.98$ ) and at weaning (8.2 kg [CLA] and 8.0 kg [CON];  $P = 0.52$ ) was not statistically different. In conclusion, trans-10, cis-12 CLA inhibited colostrum production but improved the milk production in early lactation. These data suggest that feeding sows a transition diet and a lactation diet from early lactation to weaning with distinct fatty acid composition will improve the productivity of sows and piglets.

**Key Words:** lactating sows, piglet survival, sow productivity

**3056 Enteral formula feeding has limited effects on gut adaptation in newborn pigs just after intestinal resection.** L. B. Aunsholt<sup>2</sup>, B. Stoll<sup>3</sup>, A. Vegge<sup>1</sup>, N. Qvist<sup>2</sup>, T. Eriksen<sup>1</sup>, D. G. Burrin<sup>3</sup>, P. T. Sangild<sup>1</sup>, and T. Thymann<sup>\*1</sup>, <sup>1</sup>Department of Human Nutrition, University of Copenhagen, DK-1958 Frederiksberg C, Denmark, <sup>2</sup>Odense University Hospital, DK-5000, Odense, Denmark, <sup>3</sup>Childrens Nutrition Research Center, Baylor College of Medicine, Houston, TX 77030, USA.

Patients subjected to intestinal resection are generally supported with total parenteral nutrition (TPN) in the acute postoperative phase. However, little is known of whether addition of minimal enteral nutrition stimulates intestinal function in the acute postoperative phase in jejunostomy patients without a functional colon. We tested the hypothesis that enteral nutrition supplement improves gut adaptation relative to TPN alone. Three-day-old piglets were equipped with jugular catheters and subjected to resection of the distal 50% of the small intestine. The remnant intestine was exteriorized on the flank where a stoma was established. They were subsequently allocated to groups receiving 7 d of either TPN alone (TPN,  $n = 8$ ) or TPN and enteral nutrition with an artificial milk formula (TPN+FORM,  $n = 11$ ). Enteral nutrition was initiated at 2 mL/kg/3h and increased to 8 mL/kg/3h by d 3 after resection. On d 6 after resection, all pigs were fed formula at 10 mL/kg/2h for 24 h and stoma output was quantified in this period. Finally, as an indicator of gut permeability, an oral bolus of lactulose and mannitol was given on d 7, and their levels were determined in a urinary sample taken 3 h later. The enteral diet was well tolerated and the two groups showed similar body weight increase (166±71 vs. 204±72 g), similar weight of the remnant small intestine and similar weight of all other organs (heart, lungs, liver, kidney, spleen and colon) relative to body weight (all  $P > 0.05$ ). Likewise, similar values were found for stoma output during 24 h (mean 165±20 g) and specific activities of digestive enzymes (lactase, maltase, sucrase, aminopeptidase A and N and dipeptidylpeptidase) and urinary lactulose/mannitol ratios (all  $P > 0.05$ ). Adaptation of the remnant intestine in a neonatal jejunostomy model of short bowel syndrome, does not appear to be responsive to minimal enteral nutrition using an artificial milk formula. A functional colon, more long term feeding, or use of highly trophic diets, may be required to induce intestinal adaptation after distal intestinal resection in neonates.

**Key Words:** SBS, adaptation, resection

**3057 Effects of processing technologies combined with cell wall degrading enzymes on in vitro degradability of DDGS.** S. de Vries<sup>\*1</sup>, A. M. Pustjens<sup>2</sup>, H. A. Schols<sup>2</sup>, M. A. Kabel<sup>2</sup>, and W. J. J. Gerrits<sup>1</sup>, <sup>1</sup>Animal Nutrition Group, Wageningen University, Wageningen, The Netherlands, <sup>2</sup>Laboratory of Food Chemistry, Wageningen, The Netherlands.

Effects of processing technologies and cell wall degrading enzymes on degradation of Distillers Dried Grains with Solubles from maize (DDGS) during in vitro digestion simulation were tested in a 5\*2 factorial arrangement: 5 technologies (unprocessed, wet-milling, extrusion, autoclaving, and acid-autoclaving), with or without enzymes (xylanases and  $\beta$ -glucanases; 2.5mL/g). Digestion in the upper gastrointestinal tract (adapted Boisen methodology) and subsequent, large intestinal fermentation (gas production) were simulated in duplicate. Wet-milling and extrusion increased dry matter (DM) and protein disappearance during Boisen incubation compared with the unprocessed control, whereas acid-autoclaving was only effective in combination with enzymes (Table 1). Non-starch polysaccharide (NSP) disappearance was not affected by processing technology nor enzyme addition. Processing technologies and enzyme addition did not affect rate and extent of fermentation of Boisen residues. In conclusion, wet-milling and extrusion improved DM and protein digestion, but not NSP solubilisation of DDGS during Boisen incubation. Fermentability of Boisen residues was not affected by processing technologies nor addition of cell wall degrading enzymes. This illustrates that processing technologies may improve small intestinal digestion of DDGS rather than fermentation. The cell wall structure of DDGS was resistant to the processing technologies and cell wall degrading enzymes used in this study. Possibly more severe processing technologies are required to untangle the cell wall structure of DDGS.

**Table 1.** Effect of processing technology (T) and enzymes (E) on disappearance (%) of dry matter (DM), protein, and nonstarch polysaccharides (NSP) during Boisen incubation of distillers dried grains with solubles from maize.

Enzyme:	DM		Protein		NSP	
	No	Yes	No	Yes	No	Yes
Processing method						
Unprocessed	43 <sup>d</sup>	49 <sup>abcd</sup>	60 <sup>cd</sup>	66 <sup>bc</sup>	23	27
Wet-milling	51 <sup>ab</sup>	51 <sup>ab</sup>	72 <sup>ab</sup>	73 <sup>ab</sup>	34	26
Extrusion	52 <sup>ab</sup>	54 <sup>a</sup>	71 <sup>ab</sup>	75 <sup>a</sup>	28	27
Autoclaving	43 <sup>cd</sup>	47 <sup>bcd</sup>	53 <sup>d</sup>	58 <sup>d</sup>	29	30
Acid-autoclaving	45 <sup>cd</sup>	49 <sup>abc</sup>	66 <sup>bc</sup>	67 <sup>b</sup>	16	28
SEM	1.8		2.3		5.2	
T	<0.01		0.01		NS	
E	0.03		0.04		NS	
T × E	NS		NS		NS	

**Key Words:** DDGS, fiber, digestion



**3058 Wet distillers grains and liquid condensed solubles for growing pigs - digestibility and the impact of pre-fermentation.** N. Canibe,\* K. E. Bach Knudsen, B. B. Jensen, and H. Jørgensen, *Aarhus University, Blichers Allé 20, 8830 Tjele, Denmark.*

Two of the co-products obtained during bioethanol production are wet distillers grains (WDG) and liquid condensed solubles (LCS). Little is known on the digestibility of these separate liquid products and even less when they are obtained in a process including debranning of the grain before grinding. This type of products can be included in pig liquid feeding systems, and since fermentation has been reported to increase the digestibility of various nutrients, fermentation could be a strategy to improve their value. An in vivo study with ileal cannulated growers (37 kg BW) according to a double Latin square design with 8 pigs and 4 diets was carried out aiming at determining the apparent ileal and fecal digestibility of WDG and LCS, and the effect of fermentation on these values. The WDG and LCS were obtained from a plant using wheat and debranning before saccharification. Wet distillers grains or LCS were mixed with a basal diet based on casein, maize starch and sucrose. Backslopping was practiced every 24 h leaving 50% of the mixture in the tank (temperature 20°C). The results showed a higher ileal digestibility (75.0% vs. 63.4% for CP,  $P < 0.01$ , and 75.6% vs. 66.5%,  $P \leq 0.01$ , except lys and his,  $P > 0.05$ , for indispensable amino acids) of the WDG compared with that of LCS. The ileal digestibility of lysine was relatively high in both products (67.5 to 64.6%) compared with reported values for DDGS. Fermentation of the LCS-containing diet resulted in a lower ( $P < 0.01$ ) ileal CP digestibility of LCS (46.8%). The ileal non-starch polysaccharide digestibility was very low, whereas the fecal values reached 81.7 to 83.5% for both products. No effect of fermentation was measured at any site. These data showed that WDG contained a higher level of protein and amino acids and that their digestibility was significantly higher than that of LCS; and indicated that other factors than heat treatment (often claimed to affect amino acid digestibility of this type of products) contribute to the lower digestibility of LCS. The data also indicated that fermentation as carried out in the present study is not an advisable strategy to improve the value of WDG and LCS.

**Key Words:** distillers, fermentation

**3059 The effect of protease and non-starch polysaccharide enzymes on manure odor and ammonia emissions in finisher pigs.** P. O. Mc Alpine,\* C. J. O'Shea, P. F. Varley, P. Solan, T. Curran, and J. V. O'Doherty, *University College Dublin, Lyons Research Farm Newcastle, Co. Dublin, Ireland.*

Previous studies have suggested that dietary enzymes may improve nutrient digestibility in finisher pigs and thus reduce the excretion of compounds associated with manure odor and ammonia emissions. A 2x2 factorial experiment was conducted to investigate the effect of exogenous protease enzyme inclusion (0 vs. 200 g/kg) and carbohydrase enzyme inclusion (0 vs. 200 g/kg) in finisher pigs (64.2 ± 0.800 kg). The trial lasted

approximately 28 d. Sixteen pigs were assigned to one of 4 dietary treatments (T1) basal diet, (T2) basal diet + carbohydrase enzyme, (T3) basal diet + protease enzyme, (T4) basal diet + carbohydrase + protease enzyme. The basal diet contained wheat distillers (300 g/kg) rapeseed meal (210 g/kg) wheat (310 g/kg) barley (135 g/kg) soya oil (20 g/kg). The carbohydrase enzyme contained 1,000 fungal xylanase units/g of enzyme concentrate and was derived from *Thermomyces lanuginosus*. The protease enzyme was derived *Bacillus licheniformis*. The diets were formulated to contain similar concentrations of digestible energy (13.1 MJ/kg) and standardized ileal digestible lysine (8.8 g/kg). Manure samples from pigs offered diets containing protease showed increased molar proportions ( $P < 0.05$ ) of isobutyric acid (0.035 vs. 0.028 mmol; s.e.m ± 0.023), isovaleric acid (0.055 vs. 0.044 mmol; s.e.m ± 0.004), valeric acid (0.041 vs. 0.032 mmol; s.e.m ± 0.004) and branch chain fatty acids (0.134 vs. 0.106 mmol; s.e.m ± 0.008) in contrast to pigs offered diets without protease supplementation. Pigs fed diets with carbohydrase inclusion had reduced ( $P < 0.05$ ) manure odor emissions compared with pigs offered diets without carbohydrase supplementation (598 vs. 1306 OUE/m<sup>3</sup>; s.e.m ± 319). There was a carbohydrase x protease interaction on manure ammonia emissions from 0 to 96 h ( $P < 0.05$ ). There was no effect of carbohydrase on manure ammonia emissions when compared with the basal diet, however when added in combination with protease manure ammonia emissions increased. In conclusion, pigs offered carbohydrase included diets had suppressed manure odour emissions; however when carbohydrase was combined with protease, manure odour emissions increased.

**Key Words:** carbohydrase, protease, odor

**3060 Improving the nutritional value of rapeseed cake—Enzyme addition during liquid fermentation.** G. V. Jakobsen,\* B. B. Jensen, K. E. Bach Knudsen, and N. Canibe, *Aarhus University, Blichers Allé 20, 8830 Tjele, Denmark.*

The target set by the EU Commission for reduction of greenhouse gas emissions implies a higher use of biofuel, including biodiesel. In Europe, rapeseed is the main feedstock for biodiesel production. One of the co-products obtained from the biodiesel production from rapeseed is rapeseed cake, which contains protein of high nutritional quality. However, the content of anti-nutrients, e.g., glucosinolates, phytate and dietary fiber, puts a limit to its use in animal feed. Fermentation provides an opportunity to modify raw materials before feeding. An in vitro screening study was carried out with rapeseed cake with the aim of testing the impact of fermentation and addition of enzymes on the content of total-, soluble- and insoluble non-starch polysaccharides (NSP), and protein solubility. A total of 9 enzymes constituting carbohydrases, phytases and their combinations were tested at doses recommended by the manufacturers. Rapeseed cake and water were mixed (1:5.5 w/w) in bioreactors with a volume of 1 L and added one of the enzymes or enzyme combinations to be tested. The mixtures were incubated at 30°C and a sample taken at 0, 6, 24, and 48 h. After 48



h, 50% of the mixtures was removed and replaced with the same amount of fresh feed and water and enzyme. The same procedure was followed every 24 h until 168 h of incubation. A sample was taken at 168, 174, 180, and 192 h. Addition of some of the enzymes reduced the level of insoluble NSP ( $P \leq 0.01$ ). Specifically one enzyme combination (glucanase+xylanase) had the clearest effect on fiber degradation including a reduced recovery of total NSP (61% recovery after 48 h,  $P = 0.004$ , and 87% at 192 h relative to 168 h,  $P = 0.08$ ). Some enzymes increased protein solubility ( $P \leq 0.03$ ) during the initial 48 h. The data from this screening in vitro study indicated that addition of enzymes to rapeseed cake during liquid fermentation can be a strategy to improve the nutritional quality of rapeseed cake to pigs. These results need to be confirmed in vivo studies.

**Key Words:** fermentation, enzymes

**3061 Effect of HMB supplementation of sows in late gestation and lactation on sow production of colostrum and milk and piglet performance.** C. Flummer\* and P. K. Theil, *Department of Animal Science, Aarhus University, Tjele, Denmark.*

The leucine metabolite  $\beta$ -hydroxy  $\beta$ -methyl butyrate (HMB) has shown positive effects on colostrum fat content and piglet growth when supplemented to the sow in late gestation. This trial was conducted to investigate whether HMB supplementation would influence colostrum and milk yield of sows and early piglet survival (0–24 h). Control sows ( $n = 8$ ) were fed a standard lactation diet from d108 of gestation and throughout the experiment. Sows on HMB ( $n = 8$ ) were fed the same diet topdressed with 2.5 g Ca(HMB)<sub>2</sub>, supplied at equal amounts at 2 daily meals throughout the experiment. Litters were standardized to 12 piglets per sow, within experimental group on d1. Both groups had an average of 11.3 piglets per sow at weaning. Blood samples were taken from the sows by jugular vein puncture on d -7, -3, 1, 10, 17 and 28 (weaning) relative to parturition. Piglets were weighed at birth, after 24h, and repeatedly throughout lactation to estimate the colostrum and milk yield of the sows. Samples of colostrum and milk was collected and analyzed. Sows fed HMB produced more colostrum (309 vs. 233 g/piglet;  $P = 0.06$ ) estimated based on the piglet weight gain during the colostrum period (132 vs. 76 g/piglet;  $P = 0.05$ ) and more piglets survived during the colostrum period ( $P < 0.05$ ). The HMB sows tended to transfer more protein to the newborn piglets via colostrum ( $P = 0.06$ ), whereas transfer of other colostrum nutrients was numerically higher, but not statistically different from the control. The HMB sows produced milk with a higher content of fat and dry matter ( $P < 0.05$ ) than control sows, but the milk production of HMB sows was numerically lower (11.6 vs. 12.1 kg/d;  $P = 0.57$ ), and at weaning the HMB piglets weighed less than the control piglets (7.48 vs. 8.30 kg;  $P < 0.01$ ). These data indicate that HMB is beneficial for the colostrum production, but detrimental for the milk production of sows.

**Key Words:**  $\beta$ -hydroxy  $\beta$ -methyl butyrate, transition period, piglet survival

**3062 The effect of protease and carbohydrase enzymes on growth performance and nutrient digestibility in finisher pigs.** J. McAlpine, C. J. O'Shea, P. F. Varley, B. Flynn, and J. V. O'Doherty,\* *University College Dublin, Belfield, Dublin 4, Ireland.*

Two 2 × 2 factorial experiments were conducted to investigate the interaction between carbohydrase (0 vs. 200 g/kg) and protease (0 vs. 200 g/kg) enzyme supplementation on growth performance (experiment 1) and coefficient of ileal and total tract apparent digestibility in grower-finisher pigs (experiment 2). One hundred and twenty eight individual fed pigs (BW = 34.2,  $n=32$ ) were assigned to one of four dietary treatments (T1) basal diet, (T2) basal diet + carbohydrase enzyme, (T3) basal diet + protease enzyme, (T4) basal diet + carbohydrase + protease enzyme. The basal diet contained wheat distillers (300 g/kg), rapeseed meal (210 g/kg), wheat (310 g/kg), barley (135 g/kg) and soya oil (20 g/kg). The pigs offered diets containing carbohydrase enzymes had reduced daily gain (0.788 vs. 0.848 kg/day, s.e.m  $\hat{A} \pm 0.0170$ ,  $P < 0.05$ ), feed intake (1.87 vs. 2.00 kg/day, s.e.m  $\pm 0.039$ ,  $P < 0.05$ ) and final body weight (96.0 vs. 99.4 kg s.e.m  $\pm 1.15$ ,  $P < 0.05$ ) compared to pigs offered diets without carbohydrase enzymes. In Experiment 2, the nutrient digestibility experiment consisted of 24 intact male pigs ( $n=6$ , BW = 78 kg; SD $\pm 2.3$ kg), offered identical diets to that offered in Exp. 1. Following the fecal collections, the pigs were slaughtered and digesta samples were taken from the ileum in order to measure apparent ileal nitrogen (N) and gross energy (GE) digestibilities. Pigs offered diets supplemented with protease had increased coefficients of ileal digestibility of N compared to pigs offered diets without protease supplementation (0.583 vs. 0.449, s.e.m  $\pm 0.005$ ,  $P > 0.05$ ). There was a carbohydrase x protease interaction ( $P < 0.05$ ) on the apparent ileal digestibility of GE. Pigs offered diets containing protease only had increased apparent ileal digestibility of GE compared to basal fed pigs; however, the ileal digestibility of GE decreased when protease was combined with carbohydrase. Neither carbohydrase or protease enzymes had any effect on total tract digestibility of GE or N. In conclusion, carbohydrase and protease enzyme supplementation had no positive effects on grower-finisher pig performance.

**Key Words:** protease, carbohydrase, pigs

**3063 Addition of casein to a whey-based formula has limited effects on gut function in preterm pigs.** T. Thyman\*<sup>1</sup>, A. C. F. Støyt<sup>2</sup>, S. B. Bering<sup>1</sup>, L. Mølbak<sup>2</sup>, and P. T. Sangild<sup>1</sup>, <sup>1</sup>*Department of Human Nutrition, University of Copenhagen, DK-1958 Frederiksberg C, Denmark*, <sup>2</sup>*National Veterinary Institute, Technical University of Denmark, DK-2800 Lyngby, Denmark.*

Preterm infants are susceptible to gastrointestinal disorders like necrotizing enterocolitis (NEC). Risk factors for NEC include prematurity, formula feeding, and bacterial colonization. Whereas we have previously shown that the carbohydrate fraction in formula can influence NEC development, the role of the protein source is relatively unknown. Protein sources used in infant formula include hydrolysed protein and intact whey and casein protein. Using a preterm pig model the aim was to determine if a combined

whey/casein formula is superior to a formula based on whey and hydrolysed protein. Twenty-two cesarean-derived preterm pigs (92% gestation) were given total parenteral nutrition (TPN) for 48 h. They were then allocated to groups fed total enteral nutrition of either a whey-based formula (WHEY, n = 11) or a whey/casein-based formula (WHEY/CAS, n = 9). As an indicator of sugar absorptive function in vivo, each pig was given a bolus of galactose. The test was carried out at 6 h and 30 h after initiation of enteral nutrition. After 36 h of enteral nutrition all pigs were killed and evaluated for NEC-like lesions. A tissue sample from the jejunum was used for ex vivo measurement of hexose absorption using radiolabelled glucose. Finally, the concentration of SCFA in stomach and colon content was analyzed and small intestinal microbial profile was determined using a culture independent technique. The severity of NEC was similar between WHEY and WHEY/CAS in all gastrointestinal regions. Six hours after initiation of enteral nutrition, gut absorption of galactose was markedly higher in WHEY/CAS compared with WHEY ( $P < 0.01$ ), whereas this difference was not detected by the end of the enteral feeding period. In vitro rate of absorption of  $^{14}\text{C}$ -D-glucose was similar in between the 2 groups. Likewise, SCFA concentration in colon and stomach content and microbial profile of the small intestine were similar between the 2 groups. Adding casein to a whey-based formula has transient effect on sugar absorption, but does not influence clinical outcome and gut indices following 36h of enteral nutrition.

**Key Words:** casein, whey, NEC

**3064 Dietary inclusion of a microencapsulated blend of organic acids and pure botanicals impacts intestinal health in weaned pigs.** E. Grilli<sup>1</sup>, B. Tugnoli<sup>\*1</sup>, B. S. Seabold<sup>2</sup>, A. J. Moeser<sup>3</sup>, A. Piva<sup>1</sup>, and C. H. Stahl<sup>2</sup>, <sup>1</sup>DISMVET, University of Bologna, Ozzano Emilia, BO, Italy, <sup>2</sup>Lab of Developmental Nutrition, Department of Animal Science, NCSU, Raleigh, NC, USA, <sup>3</sup>Department of Population Health and Pathobiology, College of Veterinary Medicine, NCSU, Raleigh, NC, USA.

Aviplus-S (Vetagro SpA, Italy) is a microencapsulated blend of sorbic, citric acid, thymol and vanillin. Although dietary inclusion of organic acids and botanicals has been shown to improve pig performance, the mechanism behind their efficacy has yet to be elucidated. The objective of this study was to assess the impact of dietary inclusion of Aviplus-S on measures of intestinal health in weaned pigs. Twenty pigs weaned at 19 d of age and placed into one of two pens (n = 10) received either a basal diet or the basal diet supplemented with 5 g Aviplus-S/kg for 14 d. Individual body weights were recorded initially and every 7 d. At the completion of the study, 6 pigs closest to their group mean ADG were selected for tissue collection. Ileal and jejunal samples were collected for Ussing chamber analysis of intermittent short circuit current (Isc), and dextran flux. Ileal mucosal and blood samples were collected for analysis of cytokines (IL6, IL10, IL12, TNF $\alpha$ , IFN $\gamma$ , and TGF $\beta$ ) at mRNA level and circulating, respectively. Pigs fed the Aviplus-S had greater ( $P < 0.05$ ) ADG during both the second week of the study and overall. Pigs fed the Aviplus-S also had reduced jejunal dextran flux and Isc in the ileum ( $P < 0.12$  and  $P < 0.07$ , respectively); the gene expression of several cytokines were down regulated in Aviplus-S fed pigs and the corresponding proteins followed similar patterns. Overall, it appears that dietary inclusion of Aviplus-S improved intestinal health by allowing for tighter gap junctions in the jejunum (reduced dextran flux), and by possibly reducing the secretory activity of ileal mucosa (reduced Isc) via reduction in inflammation (reduced gene and protein expression of inflammatory cytokines). Whether the improved growth seen in this study with Aviplus-S is the result of reduced intestinal inflammation via modulation of intestinal microflora or by a direct effect on the intestinal mucosa requires further study, however this study does provide a biological mechanism to explain improved performance seen with dietary inclusion of microencapsulated organic acids and botanicals.

**Key Words:** sorbic acid, microencapsulation, intestinal health





XII INTERNATIONAL SYMPOSIUM ON  
**DIGESTIVE PHYSIOLOGY OF PIGS**

**THANK YOU TO OUR 2012 SPONSORS**

**Diamond**

BASF

**Platinum**

Lucta

Elanco

ChemGen

Pancosma

**Gold**

CHR Hansen

Jefo

Ajinomoto

Evonik

PIC

Archer Daniels Midland Company

National Pork Board

**Silver**

AB Vista

JBS United

Quality Technology International

American Society of Animal Science

Vetagro

DSM

DuPont

Novus International

**Bronze**

Diamond V

Micronutrients

Nutriad

Prinova

Ralco Nutrition Inc.

Huvepharma

International Ingredient Corporation

Animine

APC Inc.