Use of Feed Additives in Diets for Pigs

Overview

- Copper and Zinc
- Prebiotics and direct fed microbials
- Nucleotides and Plant Extracts
General Mode of Action

Modify Gut Microbiota

Improved Intestinal Health
Copper and Zinc, ADG, g/d

Hill et al., 2000
Effect of Tribasic Copper Chloride

Espinosa and Stein, 2016
Effect of Tribasic Copper Chloride

![Bar chart showing the effect of different concentrations of Tribasic Copper Chloride (TBCC) on Start BW and Final BW. The chart illustrates the comparison between Control, 100 ppm TBCC, and 200 ppm TBCC.](image)

Espinosa and Stein, 2016
Prebiotics and Probiotics
High microbial diversity

Low microbial diversity

Lumen

Pathogen
Inflamed enterocyte
Commensal bacteria

Adapted from: Fouché, et al., 2016
Carbohydrates, overview

- **Monosac.**
- **Oligosaccharides**
  - Disaccharides
    - Sucrose
    - Lactose
    - Maltose
    - Celliobiose
    - Gentiobiose
    - α-GOS
    - FOS
    - TOS
    - MOS
  - Polysaccharides
    - Starch, Glycogen
    - Non-starch polysaccharides
Mode of action

1. **Growth of bacteria**
   - **Lactic + acetic acid**
   - **pH in intestine**

2. **Fermentation**
   - **SCFA**
   - **Pathogens**
Direct-fed Microbials

- Live naturally occurring microorganisms

- *Bacillus*-based DFM
  - Spore-forming
Effect of 3-strain DFM

Low or high fiber diets – d 1 to 42 PW

Jaworski et al., 2016
Body Weight, kg

- Low fiber
- Low fiber + DFM
- High fiber
- High fiber + DFM

Fiber

P < 0.05

Jaworski et al., 2016
Average Daily Feed Intake, g/d

- Low fiber
- Low fiber + DFM
- High fiber
- High fiber + DFM

- Fiber
  - $P = 0.05$

- d 0 - 14
  - Low fiber: 240
  - Low fiber + DFM: 219
  - High fiber: 206
  - High fiber + DFM: 172

- d 14 - 43
  - Low fiber: 922
  - Low fiber + DFM: 936
  - High fiber: 924
  - High fiber + DFM: 875

- d 0 - 43
  - Low fiber: 700
  - Low fiber + DFM: 702
  - High fiber: 691
  - High fiber + DFM: 646

Jaworski et al., 2016
Average Daily Gain, g/d

- Low fiber
- Low fiber + DFM
- High fiber
- High fiber + DFM

**Fiber**

- d 0 - 14: 189, 187, 178, 168
- d 14 - 43: 619, 629, 598, 599
- d 0 - 43: 479, 485, 461, 459

**P < 0.05**

*Jaworski et al., 2016*

university of illinois at urbana-champaign
Gain: Feed, g/g

- Low fiber
- Low fiber + DFM
- High fiber
- High fiber + DFM

DFM
P < 0.05

Jaworski et al., 2016
Gain: Feed, kg/Mcal NE

Low fiber  | Low fiber + DFM  | High fiber | High fiber + DFM

DFM $P < 0.05$

0.317 | 0.337 | 0.271 | 0.272 | 0.281

DFM $P < 0.05$

0.366 | 0.426 | 0.269 | 0.270 | 0.290

Jaworski et al., 2016

illinois.edu
SCFA, g/d DMB

- Fecal excretion, g/d:
  - Fiber: 94.7 (P < 0.05)
  - Fiber: 91.1

- Cecal SCFA, g/d:
  - Fiber: 1.46
  - Fiber: 1.41

- Fecal SCFA, g/d:
  - Fiber: 0.88
  - Fiber: 0.87

Jaworski et al., 2016
Liver Gene Expression

DFM, $P < 0.10$

MCT-1

DFM, $P < 0.05$

CD 147

DFM, $P < 0.01$

GLP-2R

Jaworski et al., 2016
Nucleotides

Chinese Studies Symposium

At Urbana-Champaign

University Of Illinois
Mode of action

- Immune system
- Intestinal health
- Microbiota
Nucleotide Structure

Pyrimidine

Purine
Nucleotide vs. Nucleoside

NUCLEOTIDE

NUCLEOSIDE
Digestion and Absorption

- Nucleoproteins
  - Nucleic acids
    - Nucleotides
      - Pi
      - Nucleosides
  - ENTEROCYTE
    - Nucleotides
    - Nucleosides
Pyrimidine Synthesis

2 ATP, CO$_2$, GLN → Carbamoyl phosphate → Orotic Acid → UMP → CMP → dTMP

CPS II

GLN
Purine Synthesis

Ribose 5-P + ATP

PRPP

GLN, GLY, ASP

IMP

AMP

GMP
Tissue that cannot synthesize Nucleotides

1. Brain Cells
2. Erythrocytes
3. Bone marrow Cells
4. Intestinal Mucosal Cells
Immune compromised animals

During periods of stress

Rapidly dividing cells

If energy intake is low
Nucleotides in Porcine Milk

![Graph showing the content of GMP, AMP, CMP, and IMP over the days of lactation.](image)

Day of lactation

Content

GMP
AMP
CMP
IMP

Mateo et al., 2005a
5’ UMP in Porcine Milk

Quadratic ($P < 0.05$)

Mateo et al., 2005a
Nucleotides in Starter Diets and Milk (ppm, DM-basis)

<table>
<thead>
<tr>
<th>Item</th>
<th>AMP</th>
<th>CMP</th>
<th>GMP</th>
<th>IMP</th>
<th>UMP</th>
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<tbody>
<tr>
<td>Sow Milk</td>
<td>118</td>
<td>56</td>
<td>186</td>
<td>24</td>
<td>2,335</td>
</tr>
<tr>
<td>Starter diet</td>
<td>6.5</td>
<td>58.9</td>
<td>2.03</td>
<td>4.33</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Stein and Mateo, 2005
Nucleotides for pigs

- Control, no nucleotides added
- Low nucleotides, 30% of sow milk
- High nucleotides, 150% of sow milk
Serum IgG

Time effect ($P < 0.01$)

Mateo et al., 2005b

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Total Coliforms

Fixed effects ($P > 0.05$)

Concentration (log 10 cfu/g)

0 7 14

Treatment 1  Treatment 2  Treatment 3

Mateo et al., 2005
E. coli

Fixed effects ($P < 0.05$)

Concentration (log10 cfu/g)

0 7 14

Treatment 1  Treatment 2  Treatment 3

Mateo et al., 2005b
Cl. perfringens

Treatment, Time, and Treatment x Time effects ($P < 0.05$)

Concentration (log 10 cfu/g)

Treatment 1, Treatment 2, Treatment 3

a a a a ab b a b c

0 7 14

Mateo et al., 2005b
Bifidobacterium spp.

Treatment effect ($P < 0.07$)

Concentration (log10 cfu/g)

- Treatment 1
- Treatment 2
- Treatment 3

Mateo et al., 2005b
L. acidophilus

Treatment x time effect (P < 0.04)

Mateo et al., 2005b
Conclusions on Nucleotides

- Young pigs may have nucleotide deficiency
- Possible modulation of microbiota
- Challenge supplying and analyzing nucleotides
- Need for more research
Plant Extracts
Plant Extracts

1. Concentrated, hydrophobic, volatile aroma
2. Mixtures of secondary plant metabolites
3. Antimicrobial and Anti-inflammatory
4. Antiviral, Antifungal, Antiparasitic, Antitoxigenic
In vitro anti-inflammatory effects

![Graph showing TNF-α levels with different treatments.]

*P < 0.05

-Liu et al., 2012
In vivo Experiment, Diarrhea frequency

Liu et al., 2013
Improved Gut Health

Ileal villi height (d 5 PI)

MUC2 in ileal mucosa (d 5 PI)

 Possibly improved gut barrier function!

*P < 0.05 compared with control

Liu et al., 2013, 2014
Plant extracts reduced gut inflammation caused by *E. coli* infection

**E. coli** challenge group

- Control
- Capsicum
- Garlicin
- Turmeric

**The Prostaglandin Pathway**

- Arachidonic acid → Cyclooxygenase-2 (COX-2)
- PGG2 → PGH2
  - TXA2
  - PGF2α
  - PGE2
  - PGD2
  - PGI2

↑ Inflammation!

Liu et al., 2014
Reduced diarrhea and improved intestinal barrier function

Reduced TNF-α and white blood cells and intestinal inflammation

Need to have results verified in commercial experiments

Plant Extracts

Healthier Pig
Overall Conclusions

1. Many additives available
2. Documented effects in controlled studies
3. Need testing under commercial conditions
Evaluation

1. Copper and Zinc have consistent effects

2. Acidifiers and plant extracts have many positive data

3. Prebiotics, probiotics, yeast, and nucleotides may work
Use Additive

Economic value > cost?

Independent documentation?

Repeatable results on commercial farms?
Acknowledgement 致谢

http://nutrition.anisci.illinois.edu