Nutritional strategies for enhancing gut function in broiler chickens challenged with coccidiosis

E. Kiarie, E. Kim, H. Leung, and J. Barta
Department of Animal Biosciences, University of Guelph, Guelph, ON, N1G 2W1
Monogastric Nutrition Laboratory
ekiarie@uoguelph.ca
Why would poultry nutritionist be concerned about gut function?

• Diet formulation is a precise science
• Driven by the need to precisely match nutrient supply with requirements at least cost
  – Improve efficiency of production
  – Assure environmental sustainability
  – Maximize net income
Gut: A living ecosystem

Over 400 species of bacteria
- Numbers and diversity increase from proximal to distal GIT
  » Bacterial cells > host cells
  » 10x more than host cells
- Many small ecological niches
  » Mucosal or luminal

Role in nutrition and health
- Intestinal development and functionality
- Pathogen resistance
- Digestion and absorption
- Mucus secretion
- Immune development

Realities of a living gut?
-Normal microbiota-

**PROXIMAL GUT**
Gram⁺ facultative anaerobes

+ Colonization resistance
- Compete for nutrients
- Growth-depressing bacterial catabolites

**DISTAL GUT**
Gram⁻ anaerobes

+ Colonization resistance
+ VFA energy
- Growth-depressing bacterial catabolites

Large intestine
10¹⁰ CFU/g
Less acidic
Reduced flow rate
Thick mucus layer
Fermentation
Anaerobic

Symbiosis or Détente?
Gut: A living ecosystem, >Half Century

Sub-therapeutic antimicrobials:
- Hatchery
- Production
Digestion and absorption is not at all PERFECT/COMPLETE

Undigested nutrients = Pathogens overgrowth

Corn-soybean diet fed to broilers

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Apparent ileal undigested, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>46.9</td>
</tr>
<tr>
<td>Protein</td>
<td>15.3</td>
</tr>
<tr>
<td>Fat</td>
<td>15.7</td>
</tr>
<tr>
<td>Starch</td>
<td>3.1</td>
</tr>
</tbody>
</table>

305 Kcal/kg!

Romero et al., 2014; Kiarie et al., 2015
Peculiar gut energy utilization

In chickens, gut metabolism: 20-36% of the whole body energy expenditure

Priorities for nutrients utilization in poultry

- Total energy in feed (GE)
- Energy digested (DE)
- Energy available for metabolism (ME)
- Energy in feces
- Energy in uric acid & gases

Net Energy

- Basal metabolism, immunity
- Activity, locomotion
- Cold thermogenesis
- Work for depositing tissues, egg

Energy retained as products of growth (meat) & reproduction (eggs)

Housing, Gut health

Lost as heat
**Beneficial populations**

**Desired situation**

**Undesired situation**

**Pathogens**

**Opportunistic populations**

**Beneficial populations**
Coccidial infection, resulting either from natural disease outbreak or from introduction at low levels through live coccidiosis vaccination, can damage the intestinal epithelium, allowing the leakage of plasma proteins into the intestinal lumen—a rich nutrient substrate that *C. perfringens* can exploit for proliferation and toxin production. This can reduce performance and predispose birds to necrotic enteritis.
Transitioning from chemotherapy to vaccination in coccidiosis control

Cocci-vaccine use in US broiler operations

Caloric cost of sub-clinical coccidiosis

Energy partitioning of 14-20 d old broilers challenged with oocysts of three Eimeria species

Jejunal cells proliferation in broilers challenged with oocysts of three Eimeria species

Increased absorptive cell turnover and mucus production

Teeter et al. 2008. XXIII World Poult. Cong. Brisbane, Australia

Kim et al., 2017 Poult. Sci. in press
Summary of gene expression changes in duodenum of Eimeria acervulina-challenged layers and broilers.

S. Su et al. Poultry Science 2014;93:1217-1226
Challenged with 1 mL of Eimeria culture (25,000 *E. acervulina* and 5,000 *E. maxima*) via oral gavage (Kim et al., 2017; Leung et al., 2017)
Challenged with 1 mL of Eimeria culture (25,000 *E. acervulina* and 5,000 *E. maxima*) via oral gavage (Kim et al., 2017; Leung et al., 2017)
Epidermal Growth Factor

- Potent stimulant for neonate gastrointestinal development; present in milk, saliva, and blood
- Porcine EGF gene has been isolated, inserted in *Lactococcus Lactus* & modified to increase expression
- EGF developed by Dr. Julang Li, University of Guelph
  - Demonstrated to have positive effects on gastrointestinal growth in both mice and pigs


Gut mucosa (stained for cell proliferation)

Slide courtesy of Kees De Lange
Epidermal Growth Factor
Histomorphology – Villus Height and Crypt Depth Ratio

\[ \frac{VH}{CD} (\mu m: \mu m) \]

- NC, 0
- NC, 80\( \mu \)g
- NC, 160\( \mu \)g
- C, 0
- C, 80\( \mu \)g
- C, 160\( \mu \)g

\textit{Eimeria}, \( P < 0.01; \) EGF, \( P = 0.92; \) \textit{Eimeria}*EGF, \( P = 0.66 \)

Kim et al., 2017. Poult. Sci. in press
Gene Expression of Nutrient Transporters and Digestive Enzymes

An EGF and *Eimeria* interaction (p<0.05) was seen on expression of maltase, sucrase, glutamate transporter (GLUT), cationic amino acid transporter (CAT1), sodium glucose transporter 1 (SGLT1), and sodium-independent Cys-Glu transporter (xCT1)

Kim et al., 2017. Poult. Sci. in press
Yeast nucleotides

- Increased nucleotide requirement during inflammation in the gut (Grimble, 1994)
- Insufficient de novo synthesis of nucleotides in young chicks for optimal gut development (LeLeiko et al., 1983)
- Nucleotide supplementation has been shown to increase gut growth (Grimble, 1994) and improve recovery time from inflammation (Ortega et al., 1994)
- Nucleotide with effects on improving immune response (Kulkarni et al., 1986)
Evaluation of Yeast nucleotides- *Eimeria* challenge

<table>
<thead>
<tr>
<th>Item</th>
<th>No-Challenge</th>
<th>Challenge¹</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yeast, g/mt</td>
<td>0</td>
<td>500</td>
<td>0</td>
<td>500</td>
</tr>
<tr>
<td>Pre-challenge, d 0-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial BW, g</td>
<td>40.6</td>
<td>40.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Final BW, g</td>
<td>242.6</td>
<td>243.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BWG, g</td>
<td>202.0</td>
<td>202.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Feed Intake, g</td>
<td>384.2</td>
<td>393.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FCR, g/g</td>
<td>1.905</td>
<td>1.943</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acute Phase, d11-15²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final BW, g</td>
<td>411.8</td>
<td>417.3</td>
<td>389.3</td>
<td>409.3</td>
</tr>
<tr>
<td>BWG, g</td>
<td>168.8</td>
<td>177.5</td>
<td>147.0</td>
<td>163.0</td>
</tr>
<tr>
<td>Feed Intake, g</td>
<td>193.8</td>
<td>189.2</td>
<td>202.0</td>
<td>182.3</td>
</tr>
<tr>
<td>FCR, g/g</td>
<td>1.154</td>
<td>1.064</td>
<td>1.417</td>
<td>1.119</td>
</tr>
</tbody>
</table>

¹Chicks orally gavaged with 1 mL admixture of *E. acervulina*, *E. maxima* and *E. tenella* on d 10

Evaluation of Yeast nucleotides- *Eimeria* challenge

Yeast, $P=0.45$; *Eimeria*, $P<0.01$; Yeast*$Eimeria$, $P<0.01$

### Comparative effects of Bacitracin, yeast products & Salinomycin in broilers challenged with clinical Coccidiosis and *C. Pefringens*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Livability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>51.7</td>
</tr>
<tr>
<td>Bacitracin</td>
<td>90</td>
</tr>
<tr>
<td>Yeast</td>
<td>81.7</td>
</tr>
<tr>
<td>Salinomycin</td>
<td>96.7</td>
</tr>
</tbody>
</table>

YCW may act by enhancing immunity and shifting the gut microflora to reduce the damaging effect of clostridia.

M’Sadeq et al., 2015. Poult. Sci. 94: 898-905
Conclusions, implications and further research

✓ Proper nutrition is unachievable without a healthy and functional gut

✓ Good gut health requires good nutrition, strong immunity, a balanced microbiota, and an intact microstructure.

✓ We have developed an *Eimeria* challenge model to investigate nutritional approaches for maintaining gut function under sub-clinical challenge
  ✓ Reduced growth performance and impaired gut function

✓ Feeding epidermal growth factor or Yeast nucleotides improved indices of gut function upon *Eimeria* challenge
  • Currently investigating impact on growth performance to slaughter weight, immune status and gut microbiome