Nutrition and Gut Health in Piglets

Dr. Martin Nyachoti
Professor
Department of Animal Science
University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada
Email: Martin.Nyachoti@ad.umanitoba.ca

Summary

Post-weaning diarrhea is a major cause of mortality and morbidity worldwide and has been estimated to be responsible for as much as 50% of the economic losses seen in the production of weaned pigs. In herds with this disease, up to 2% mortality in weaned pigs can be seen, but of greater economic significance is the morbidity and reduction in growth performance in pigs that survive these infections (Cutler et al., 2007). The swine industry has traditionally managed this disease by utilizing highly digestible diets often containing sub-therapeutic level of antibiotics as growth promoters. However, the current trend is to discontinue use of in-feed antibiotics in livestock diets for fear that this practice represent a risk to human health. Consequently, there is a need for effective and safe alternative therapies for managing post-weaning diarrhea disease in piglets raised under antibiotic-free feeding regimen. To date, several products including spray dried porcine plasma, acidifiers, high levels of zinc and copper salts, probiotics, prebiotics, nucleotides and nucleotide-rich products, essential oils, egg yolk antibodies, lysozyme, and herbs and spices have been suggested for use in this regard. In general, there is ample evidence that many of these additives may positively influence gut health and function in weaned piglets, although much needs to be learned especially about conditions under which they work best and which combinations might act synergistically to provide the greatest benefits.

Background

Piglets are highly susceptible to enteric disorders during the immediate period after weaning. This condition is precipitated by various factors including an immature digestive system, whose capacity for nutrient digestion is impaired by the transition from a high quality liquid milk-based diet to a solid diet. Furthermore, at this stage the piglet is subjected to a number of significant stressors that further compromise its ability to resist
disease infection. Consequently, diarrhea is common post-weaning and is characterised by reduced digestive capacity in young pigs leading to poor growth performance (Pluske et al., 1997). Also, because of an immature intestinal immune system proliferation of enteropathogenic bacteria which further predisposes piglets to enteric infections increases. To mitigate these effects, the swine industry has historically fed weaned pigs complex diets based on costly ingredients like processed blood proteins and milk by-products and routinely supplemented starter diets with sub-therapeutic levels of antibiotics as growth promoters (de Lange et al., 2010). However, the current trend is to eliminate the use of antibiotics from swine diets for fear of risking human health with possible transfer of antibiotic-resistant bacteria to humans. Identifying alternative nutritional strategies for managing newly-weaned pigs, especially those fed antibiotic-free diets is therefore of critical importance in maintaining piglet performance and satisfying the ever growing consumer demand for pork products originating from pigs raised under such production systems.

Therefore, this paper reviews the application of available feed additives (i.e. eubiotics) to optimize gut health and function and therefore growth performance of weaned piglets in general and those raised under antibiotic-free feeding regimens in particular.

**The role of the gastrointestinal tract**

The gastrointestinal tract provides an important interface between the “outside” and the “inside” body systems. Among its many functions, it plays important roles that include digesting food and absorbing nutrients, barrier function, maintenance of a balanced gut microbiome, and maintenance of an optimal immune system. Therefore, an important goal in managing piglets under antibiotic-free feeding regimen is to augment these functions through nutritional interventions. To this end, a number of products have been suggested as eubiotics to help achieve this goal (de Lange et al., 2010; Heo et al., 2013). These includes spray dried porcine plasma, acidifiers, high levels of zinc and copper salts, probiotics, prebiotics, nucleotides and nucleotide-rich products, essential oils, egg yolk antibodies, lysozyme, feed enzymes, and herbs and spices. Whereas there is evidence that some of these additives may positively influence weaning transition individually or in combinations, it is also clear that response to their application varies considerably thus making it critical
to better understand conditions under which their benefits are maximized. The following is a brief discussion of the use of selected additives.

**Zinc oxide**

It has been demonstrated in many studies and in practice that pharmacological levels (up to 3000 ppm) of Zn offer an effective dietary tool to ameliorate and (or) prevent post-weaning diarrhea thereby acting as a growth promoter in weaned pigs (Hill et al., 2000). Although not fully understood, these effects have been attributed to the ability of Zn to modulate the animal’s defense mechanisms (e.g. increased gene expression of antimicrobial peptides in the small intestine) (Wang et al., 2004), gut barrier function, and the intestinal microbial population (e.g. maintaining the stability and diversity of intestinal microbiota). Clearly, ZnO fed at pharmacological levels can be a cost-effective strategy for controlling diarrhea, although at such high levels concerns about environmental contamination must be considered.

**Organic acids**

During the weaning transition piglets are unable to maintain the proper gastric pH due to such factors as dietary changes and inability to produce sufficient acid in the stomach. Thus, piglets often have high gastric pH values (up to 5.0), during weaning transition compared with a mature pig whose pH ranges between 2.0 and 3.0. To optimize nutrient digestion and prevent pathogen overgrowth, it is critical that a low gastric pH is maintained. Dietary addition of organic acids such as citric, fumaric, lactic and formic acids to weaned pig diets is used as a strategy to maintain low gastric pH and control proliferation of pathogenic bacteria and therefore improve growth performance and health of piglets (Heo et al., 2013). Available organic acid products contain either a single acid or a combination of acids but in general there are inconsistencies reported as to the effectiveness of these products regardless of the formulation. Table 1 summarizes the percentage improvement in performance of piglets fed organic acid supplemented diets.
Pre- and Probiotics

Probiotics are live microorganisms which when administered in adequate amounts confers a health benefit on the host. The beneficial effects of these additives are mediated through one or more of the following mechanisms in the gut: stimulation of a healthy microbiota, prevention of enteric colonization by pathogens, improving digestive capacity and lowering the pH, improving mucosal immunity, or enhancing gut tissue maturation and integrity (de Lange et al., 2010). Microorganisms used as probiotics should be able to survive in the gastric acid and bile salts. The three categories of organisms that are commonly used as probiotics are bacillus, yeast and lactic acid-producing bacteria such as *Lactobacillus, Bifidobacterium*, and *Enterococcus* (de Lange et al., 2010). As recently reviewed by de Lange et al. (2010) and Heo et al. (2013), there are many studies that have demonstrated positive effects of probiotic supplementation on performance and controlling post-weaning diarrhea in newly-weaned piglets. However, it is important to note that there are other studies that have failed to demonstrate such positive effects (see

<table>
<thead>
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<th>Organic acid</th>
<th>With</th>
<th>Without</th>
<th>% improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blend</td>
<td>308</td>
<td>323</td>
<td>+4.6%</td>
</tr>
<tr>
<td>Blend</td>
<td>308</td>
<td>330</td>
<td>+6.8%</td>
</tr>
<tr>
<td>Benzoic</td>
<td>475</td>
<td>530</td>
<td>+10.4%</td>
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<tr>
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<td>475</td>
<td>532</td>
<td>+10.7%</td>
</tr>
<tr>
<td>Fumaric</td>
<td>206</td>
<td>241</td>
<td>+14.5%</td>
</tr>
<tr>
<td>Benzoic</td>
<td>190</td>
<td>235</td>
<td>+19.1%</td>
</tr>
<tr>
<td>Fumaric</td>
<td>206</td>
<td>257</td>
<td>+19.8%</td>
</tr>
</tbody>
</table>

Table 1. Summary of research results demonstrating ability of dietary organic acid supplementation to boost growth performance in piglets.
review by Heo et al., 2013). In general, such inconsistencies can be explained by differences in dosage, and type of strain of probiotic, sanitation conditions, and diet type.

A prebiotic is "a selectively fermented ingredient that allows specific changes, both in the composition and (or) activity of microbiota, that confer benefits upon host well-being and health" (Gibson et al., 2004). In general, the addition of prebiotics is targeted at stimulating the proliferation and activities of bacteria associated with a healthy gut, such as bifidobacteria and lactobacilli. In this context, fructooligosaccharides and transoligosaccharides offer the best example. However, other fibre types (e.g. inulin, sugar beet pulp, and coarsely ground wheat bran) have been reported to alter the composition of bacterial microbiota and prevent intestinal colonization with pathogenic E. coli in weaned piglets (Molist et al., 2012).

**Feed Enzymes**

The use of feed enzymes to enhance nutrient utilization, allow inclusion a low quality feed ingredients (e.g. high fibre co-products) in non-ruminant diets and therefore mitigate high feed costs is well acknowledged. However, it has been suggested that he scope of feed enzymes may be expanded to include maintenance of gut health and function in young animals based on the hypothesized that carbohydrase enzymes targeting non-starch polysaccharides may generate hydrolysis products (e.g. oligosaccharides) within the gut which may in turn exert a prebiotic effect. Indeed, recent studies at the University of Manitoba have shown that hydrolysis products (HP) from soybean meal, canola meal, wheat and flaxseed generated following incubation with a multi-enzyme blend containing mainly pectinase, cellulase, mannanase, xylanase, glucanase, galactanase were able to maintain gut barrier function in small intestinal segments of piglets challenged with enterotoxigenic E. coli (ETEC) in an in situ perfusion model (Nabuurs et al., 1993; Kiarie et al., 2008a). As summarised in Figure 1, HP products significantly increased net fluid absorption which indicates an intact gut barrier and therefore potential to protect the piglet from losing intestinal fluid. In follow up studies, HP were shown to reduce fecal scores in ETEC-infected piglets (Figure 2) and support better growth performance.
Clearly, results of the studies described above demonstrate that carbohydrase enzymes targeting non-starch polysaccharides might offer a means of manipulating the GIT microbial activity to the benefit of the host (Kiarie, 2008). However, as enzymes are not antimicrobial agents, their greatest benefit in the context of nutrition and gut health in the piglet might be realized when used in concert with other additives whose mode of action is different.

Figure 2. Net fluid absorption in small intestinal segments of piglets challenged with enterotoxigenic *E. coli* and perfused with soybean meal and wheat enzyme hydrolysis products. *Higher values indicate an enhance gut barrier function.*

Figure 3. Fecal scores of piglets fed diets containing enzyme hydrolysis products upon challenge with enterotoxigenic *E. coli*. *Higher values show increased incidence of diarrhea.*
**Antibodies**

Products containing high contents of antibodies against specific pathogens have been shown to effectively control incidences of disease caused by such pathogens. Several studies have shown that supplementing nursery pig diets with products that contain antibodies against *E. coli* K88, the pathogen responsible for post-weaning diarrhea in piglets, maintains growth performance and minimizes incidences of post-weaning diarrhea (King et al., 2008). Because antibodies are very specific, such products will work best if used in situations where the target pathogen is responsible for piglet diarrhea.

**Nucleotides and nucleotide-rich products**

Nucleotides are low-molecular-weight intracellular compounds which are naturally present in all living cells and are involved in structural, metabolic, energetic and regulatory functions and are present in greater amounts in sow milk than in a high quality creep feed. The need for nucleotides during periods of stress such as weaning may exceed endogenous supply. Thus, it has been proposed that feeding a diet with supplemented exogenous nucleotides might help piglets to develop the gastrointestinal tract and immune functions to help with the weaning transition (Lee et al., 2007; Sauer et al., 2011). Although not fully elucidated, there is enough evidence to suggest that dietary nucleotides supplementation may positively impact piglet growth and intestinal integrity (Domeneghini et al., 2004). For example, feeding piglets a diet supplemented with nucleotides-rich yeast extracts at 1 g/kg for 28 days showed comparable growth performance compared with piglets received a diet with antibiotics after weaning (Patterson et al., unpublished data); however others failed to show such an effect (Domeneghini et al., 2004). The fact that most nucleotides-rich products are yeast fermentation extracts, they may contain other active compounds (e.g. β-glucans and peptides) that may influence the responses.

**Conclusions**

Reduced growth performance and the associated enteric diseases, including post-weaning diarrhea, are major concerns in the immediate post-weaning period that lead to considerable economic losses to the swine industry. The practice of using antibiotic-containing nursery diets to mitigate these challenges has come under increasing pressure
for fear of contribution to emergence of antibiotic-resistant bacteria, which in turn jeopardizes human health. To minimize production and economic losses associated with the removal of in-feed antibiotics, a large number of alternative feed additives and feeding strategies have been proposed. Whereas there is more work required to better understand how majority of the available additives can be effectively utilized, there is ample evidence to support the use of some of the additives in this regard. It is clearly evident from the current knowledge that for many of the additives and feeding strategies available, the most effective application will be achieved when used in combinations.

References
Available from the author upon request.