FEEDING THE PIG'S IMMUNE SYSTEM

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ABSTRACT

Diet formulation and feeding strategies may be used to boost the pigs' immune system and reduce the negative impact of weaning. Post-weaning diarrhea can be reduced or prevented by feeding diets that have low concentrations of crude protein. Such diets may supply fewer amino acids than recommended and pig growth rate may be reduced, but if pigs are provided a diet with a normal or elevated concentration of protein after the immediate post-weaning period, then the overall post-weaning performance will not be compromised. Diets that are based on barley, oats, or naked oats have been shown to improve pig performance compared with diets based on wheat or corn, and there is evidence that the fiber fraction in barley and oats help improve intestinal health of pigs. However, it has also been shown that diets based on cooked white rice may improve performance and the immune status of the pig. Diets fed in a liquid or in a fermented liquid form improve pig performance compared with diets fed in a dry form, and the liquid diets help maintain intestinal integrity during the post-weaning period. It is, therefore, recommended that weanling pigs should be fed liquid diets to maximize performance.

Introduction

Feeding pigs to help it's immune system requires that many different approaches be used but the one thing these approaches have in common is that they all aim at improving the pigs' ability to prevent pathogenic bacteria from colonizing in the intestinal system. This can be accomplished via an improved immunological response to pathogens or via mechanisms that prevent the pathogens from adhering to intestinal tissue, and thus, reduce the damaging effects of the pathogens. In this summary, some of the approaches that are available to improve the pigs' ability to reduce the impact of intestinal pathogens will be discussed. However, this is not a complete list of strategies or supplements that may be used and other strategies or products that are equally or more effective than the ones discussed here, may be available.

Low-Protein Diets

The single most important nutritional factor for reducing scouring in pigs fed diets without antibiotic growth promoters is to reduce the dietary crude protein concentration because undigested crude protein entering the large intestine will increase microbial fermentation in the hind gut and provide substrates for pathogens. It is also likely that the increased metabolic demand for deaminating excess amino acids and excreting the extra nitrogen compromises the pigs' immune system. In addition, undigested feed protein may accelerate the production of toxic nitrogenous compounds including ammonia which is harmful to intestinal health (Bolduan et al, 1988; Pluske et al., 2002; Nyachoti et al., 2006). Therefore, formulating low-protein diets supplemented with crystalline amino acids results in less diarrhea and fewer intestinal problems than using diets with greater protein concentrations (Ball and Aherne, 1987; Bolduan et al., 1988; Goranson et al., 1995). For most groups of pigs, it is possible to reduce the dietary concentration of crude protein by 3-4% without

compromising the pig's requirement for amino acids (Cinq-Mars et al., 1988; Hansen et al., 1993; Han et al, 1995). In a recent experiment, it was demonstrated that by reducing the dietary crude protein concentration from 21.2 to 18.4, a linear reduction in diarrhea was observed, but growth performance was not affected (Reynoso et al., 2004). The low protein diets that were used in this experiment were fortified with crystalline amino acids, which is likely the reason performance could be maintained. Likewise, le Bellego and Noblet (2002) reduced dietary crude protein concentration from 22.4% to 16.9% with the addition of crystalline amino acids without reducing pig performance.

It is usually possible to reduce the dietary concentration of crude protein in diets fed to weanling pigs to approximately 18% by including crystalline amino acids in the diets without under-supplying any indispensable amino acids. However, sometimes it may be necessary to formulate diets containing less than 18% crude protein during the immediate post-weaning period to avoid scouring and intestinal malfunctions. In such diets, it may not be possible to include the indispensable amino acids at recommended concentrations. Therefore, growth performance will be compromised. However, if the pigs suffer from diarrhea, they will also have reduced performance (Goranson, 1997). Because the period of time that amino acid concentrations are sub-optimal is usually relatively short (i.e., 2-4 weeks), it is of little or no practical consequence that growth performance is slightly reduced during this period. Recent data indicate that pigs fed diets containing approximately 20% less amino acids than recommended (NRC, 1998) will have a reduced daily gain of 40 – 60 g per day (Table 1). If such diets are fed during the initial two weeks post weaning, then a total of 560 - 840 g of gain is sacrificed. However, if the protein concentration in the diet is returned to normal levels from day 15 post-weaning, then the pigs on the low-protein diets will compensate and by day 35 post-weaning, there is no difference in the body weight of pigs regardless of the protein concentration they received during the initial 2 weeks post weaning (Stein and Kil, 2006; Table 1). These observations are consistent with data demonstrating that pigs will compensate for protein restriction during one period of growth by utilizing proteins more efficiently when dietary protein levels are restored to normal values (Kyriazakis et al., 1991; Reynolds and O'Doherty, 2006). It is, therefore, concluded that the incidence of diarrhea during the post-weaning period may be reduced by feeding low-protein diets without compromising overall nursery pig performance.

Table 1. Effects of feeding low protein diets followed by either normal or high protein diets to weanling pigs [a,b]

Item Treatment:	High/low	High/high	Low/low	Low/high	SEM
Crude protein/lysine, day 0 - 14	20.8/1.35	20.8/1.35	15.7/1.15	15.7/1.15	-
Crude protein/lysine, day 14 - 35	17.5/1.15	19.3/1.34	17.5/1.15	19.3/1.34	-
Average daily gain, g, day 0 - 14	171 [xy]	180 [x]	148 [xy]	129 [y]	16
Average daily gain, g ,day 14 - 35	516	529	499	535	13
Average daily gain, g, day 0 - 35	377	389	359	373	11
Average daily feed intake, g, day 0 - 14	249	257	228	237	18
Average daily feed intake, g, day 14 - 35	790 [x]	756 [xy]	778 [xy]	735 [y]	17
Average daily feed intake, g, day 0 - 35	574	556	558	535	15
Average gain:feed ratio, g/g, day 0 - 14	0.68	0.70	0.65	0.55	0.029
Average gain:feed ratio, g/g, day 14 - 35	0.65 [x]	0.70 [y]	0.64 [x]	0.73 [z]	0.007

Average gain:feed ratio, g/g, day 0 - 35	0.66 [x]	0.70 [y]	0.65 [x]	0.70 [y]	0.007

[a] Data from Stein and Kil, 2006.
[b] Values are means of six pens per treatment with 5 pigs per pen.
[xyz] Values lacking a common superscript letter are different ($P < 0.05$).

Selected Cereal Grains

In most parts of the world, the major cereal grains used in diets fed to weanling pigs are corn, wheat, sorghum, or barley. These grains contain varying quantities of starch and non starch polysaccharides, which results in differences in the effects these grains have on intestinal physiology and on the concentration of the microorganisms in the intestinal tract (Bach Knudsen, 2001). Work in Australia has indicated that pigs fed diets based on cooked white rice and animal proteins are less susceptible to infections than are pigs fed diets based on other cereal grains with higher fiber contents (Pluske et al., 1996; 1998). Therefore, weanling pigs fed such diets have fewer incidences of diarrhea than pigs fed diets based on corn starch (Pluske et al., 2003), which often results in improved pig performance (Vicente et al., 2004, Mateos et al., 2006). The majority of the carbohydrates in diets based on cooked rice are digested in the small intestine with a subsequent absorption of monosaccharides. Therefore, only small quantities of non-starch polysaccharides will enter the large intestine, which in turn prevents pathogenic bacteria from getting nourishment in the GI-tract. Therefore, a change in the microbial population is observed, fewer pathogens are able to colonize in the intestinal tract, and fewer short chain fatty acids are produced (Siba et al., 1996; McDonald et al., 1999).
In contrast with the above results it also has been reported that the inclusion of barley and oats in diets fed to weanling pigs may reduce the incidence of diarrhea (Medel et al., 1999; Paulicks et al., 2000). Barley and oats contain both fermentable and non-fermentable fibers and they will, therefore, stimulate fermentation in the hind gut in contrast to diets based on cooked white rice. However, barley and oats may also contain unidentified nutrients that improve overall digestion of pigs and performance of newly weaned pigs fed diets based on barley or oats is elevated compared to pigs fed diets based on corn or wheat (Medel et al, 1999). Data from our laboratory indicate that this is also the case if diets are based on naked oats rather than corn, milo, or wheat (Stein and Kil, 2006; Table 2). The reason for these observations may be that the increased production of short chain fatty acids that results from the fermentation of the fibers in barley and oats may stimulate the expression of certain cytokines in the intestinal tract of the pigs (Pie et al., 2007). This in turn would improve the immune status of these pigs, which may explain the positive performance results from pigs fed diets based on barley or oats. Barley and oats also contain relatively high quantities of beta-glucans that may have prebiotic effects because they stimulate lactic acid production (Bach Knudsen and Canibe, 2000; O'Connell et al., 2005). The improved production of short chain fatty acids may also stimulate water and electrolytes absorption, improve gut morphology, and reduce colonic pH to levels that are unfavorable for pathogens, which in turn may reduce the incidence of diarrhea (Montagne et al., 2003).

These results indicate that two options for improving performance, health, and the immune status of weanling pigs are available. One option is to reduce the concentration of dietary fiber to reduce the nourishment for microbes in the hind gut, and therefore, reduce colonization by pathogens in the intestinal tract of the pigs. The other option is to use cereal grains containing specific fibers that have prebiotic

effects in the hind gut of pigs. Barley, oats, and naked oats seem to contain such fibers and the inclusion of these grains in dits fed to weanling pigs may, therefore, improve performance and intestinal health of the pigs.

Table 2. Effects of grain source in starter diets fed to weanling pigs from day 0 – 7 post-weaning [a,b]

Item	Grain source: Corn	Sorghum	oats	Naked oats
Average daily gain, g	95 [x]	74 [x]	81 [x]	129 [y]
Average daily feed intake, g	160 [x]	146 [x]	145 [x]	195 [y]
Average gain:feed ratio, g/g	0.60 [xy]	0.51 [x]	0.55 [x]	0.66 [y]

[a] Data from Stein and Kil, 2006.
[b] Values are means of six pens per treatment with 5 pigs per pen.
[xy] Values lacking a common superscript letter are different ($P < 0.05$).

Restricted Feeding

Feeding weanling pigs a restricted amount of feed will reduce intestinal problems and incidences of diarrhea compared with pigs that are allowed to consume their diets on an ad libitum basis (Goranson et al., 1995). The reasons for this observation have not been elucidated, but it is possible that reduced feed intake results in less undigested feed entering the large intestine, and, therefore, less fermentable substrate for the pathogens in the intestines. Restricted feeding also results in a reduced pH in the intestinal tract, which may prevent pathogens from colonizing in the upper gut. Feeding as often as 4 to 6 times per day may be required during the initial two weeks post-weaning to prevent pigs from developing diarrhea. Usually, this can be accomplished by feeding the pigs on a floor-mat during this period. For older pigs, restricted feeding is usually not practical because most feeding systems are based on ad libitum intake of feed.

Functional Proteins

Protein is added to diets for pigs to provide amino acids that can be used for tissue protein synthesis. However, it is recognized that certain proteins may have functions other than strictly providing amino acids and several proteins are believed to improve the immune status of weanling pigs. For example, it has been shown that the dietary inclusion of spray dried plasma may improve the immune status of weanling pigs (Touchette et al., 2002; Bosi et al., 2004), which reduces the pigs' susceptibility to E.coli infections (Bosi et al., 2001; van Dijk et al., 2002, Owusu-Asiedu et al., 2003). The immunoglobulins that are present in spray dried plama are the functional units that provide the improved immunity (Pierce et al., 2005). Spray dried plasma also has been shown to down-regulate the inflammatory process in healthy pigs (Touchette et al., 2002; Bosi et al., 2004), which in turn may contribute to increased feed intake and direction of nutrients towards gain of body weight. It is, therefore, not surprising that reviews of a large number of studies in which spray dried plasma was included in diets fed to weanling pigs has shown that plasma increases average daily growth rate by approximately 25% (Coffey et al., 2001; van Dijk et al., 2001). Spray dried plasma is, therefore, commonly included in diets fed to weanling pigs.

If it is correct that it is the immunoglobulins in spray dried plasma that provide the improvement in pig immunity then it would be expected that other sources of immunoglobulins also can improve the immune status of pigs. The most abundant source of immunoglobulins is immunoglobulins from dairy cows that are present in

the whey protein fration of cows' milk. It has been demonstrated that the inclusion of whey proteins in diets fed to weanling pigs may improve performance (Nessmith et al., 1997; Grinstead et al., 2000). However, in a recent analysis of data from 11 experiments in which whey proteins had been used, it was shown that the average improvement in growth rate obtained by the addition of whey proteins to diets fed to weanling pigs is only 4% (Pettigrew, 2006).

Egg proteins also contain immunoglobulins and the inclusion of dried whole eggs to diets fed to weanling pigs may also improve pig performance (Schmidt et al., 2003; Hong et al., 2004). If hens are immunized against certain pathogens, they will produce antibodies against these pathogens and the antibodies will be present in the eggs from these hens. It is, therefore possible to increase the concentrations of antibodies in eggs against certain pathogens and if these eggs are fed to weanling pigs, the pigs will gain an improvement in their immune status. It has been demonstrated that if eggs containing high concentrations of antibodies against E.coli are fed to weanling pigs, these pigs will experience fewer cases of E.coli associated diarrhea (Yokoyama et al., 1997; Marquardt et al., 1999). There are, however, relatively large costs involved in the production of these eggs, and this practice is, therefore, not widely used in the industry.

Because of the positive effects of adding immunoglobulin containing proteins to diets fed to weanling pigs, it is a common practice to use at least one of the above proteins in starter diets, which improves the pigs immune status. The greatest improvements in immune status and average daily gain are obtained when spray dried plasma is used, but other proteins may also provide benefits.

Conclusion

A variety of strategies are needed to successfully wean pigs. The most effective way to reduce diarrhea in pigs is to reduce the crude protein content of the diets and to change the use of ingredients towards more barley and oats and less wheat and corn. Future developments likely will focus on identifying other means to improve the immune status of weanling pigs. The positive responses and dramatic improvements in growth rates obtained with functional proteins demonstrate that it is possible to influence the immune status of pigs in ways that enable pigs to resist pathogens and become less susceptible to diseases. As the pigs' genome becomes mapped and knowledge about the genomics involved in enhancing the immune system of pigs becomes available, more opportunities for feeding the pigs' immune system may become available. The genomics of beneficial enteric microbes as well as pathogens also will be elucidated, which may further improve the chance of creating diets that will improve the pigs' immune system.

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