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Factors Affecting Small Intestine Development in Weanling Pigs

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Summary and Implications

The pig faces significant biological and environmental challenges after weaning. A great deal of information is available on behavior, environment, health, and nutrition of the newly weaned pig; however, newly weaned pigs still suffer a growth lag. The pig's small intestinal structure and function is altered during the days that follow weaning. As a consequence, the digestive and absorptive capacity of weanling pigs is decreased during this period and this may be partially responsible for the post weaning growth lag. Additionally, health benefits may be associated with an improved small intestinal structure and function. The goal of this article is to review some of the potential causes of changes in small intestinal structure and outline some potential nutritional modifications that have been suggested to attenuate the negative changes in small intestinal structure and function.

Small Intestinal Changes

The lumen (inside) lining of the small intestine is comprised of very small finger-like projections called villi. Microvilli are “micro” finger-like projections attached to the villi. The villi and microvilli function to increase surface area that augment the absorptive efficiency of the small intestine. Crypts of Lieberkuhn (or simply “crypts”) are tubular depressions found between the villi and are the source of new cells that migrate to the villi. A portion of the digestive and all of the absorptive capacity of the small intestine occurs near and around the villi

and crypts. In the weanling pig, villi atrophy (digress) and crypts undergo hyperplasia (increased number of cells). When the villi are digressed, the cells associated with the crypt attempt to begin to rebuild the villi. This is appropriate because the cells residing on the periphery of the villi originate from the crypt. This regeneration phenomenon is thought to cause a temporary (until the structure is rebuilt) decrease in digestive and absorptive capacity.

These changes may affect the growth and(or) health status of the newly weaned pig. Therefore, a means to alter the villi digression and crypt hyperplasia may be advantageous to both growth and health of newly weaned pigs. The remainder of this article will highlight several factors known to be associated with the changes in intestinal morphology and function and will outline some proposed nutritional modifications that may improve the intestinal maladies following weaning.

Factors Associated With Small Intestinal Changes

Pathogenic Bacteria

Enteric bacteria colonized in the small intestine have a profound influence on the structure and digestive/absorptive capacity. Typically haemolytic *E. coli* is one of the most prevalent bacterial species and these bacteria are suggested to be a causative factor of villi atrophy and crypt hyperplasia. In experimental conditions, the presence of *E. coli* resulted in shorter villi, deeper crypts, and reduced carbohydrate digestive enzyme activity. Additionally, the absorption of fluid and electrolytes has shown to be decreased in pigs inoculated with *E. coli*. The presence of pathogenic bacteria in the

small intestine does affect villus height and crypt depth (and associated digestion/absorption); however, this does not entirely explain the decreased nutrient absorption in weanling pigs. For example, Figure 1 illustrates the effect of weaning on both *E. coli*-inoculated and control pigs. Clearly, the *E. coli*-inoculated pigs absorbed less fluid; however, decreased absorption was also observed for weaned animals compared to unweaned animals. Additionally, changing the diet of germ-free pigs from milk to a dry diet has been shown to decrease villus height, crypt depth, and carbohydrate digestive enzyme activities, suggesting that enteric pathogens are not the only causative factor changing gut morphology. Moreover, it is not known whether the presence of pathogens in the small intestine is a cause or effect of changes in small intestinal morphology.

Stressors of Weaning

Because the lag in performance and changes in gut morphology occur after weaning, some researchers have suggested that the psychological stress of weaning (e.g., displacement from sow, new environment, new pen mates) causes gut morphological changes. This theory is plausible, but not all of the observed changes in small intestinal morphology have been associated with weaning stress. For example, there seems to be no relationship between plasma cortisol (an indicator of acute stress) concentrations and poor growth rate and (or) decreased villus height in weaned pigs. Also, research suggests that weaned pigs fed sow milk have similar small intestinal morphology as their unweaned counterparts. This implies that the act of weaning may be less important than changes in diet-related factors. However, it should

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be noted that the proposed theory of psychological stress at weaning (contributing to changes in small intestinal morphology) may be confounded with other factors at weaning (e.g., pathogen exposure, diet, low feed intake, etc.). Therefore, it is difficult to sort out the potential of psychological stress contributing to the changes in gut morphology.

Feed Intake and Adaptation to Solid Food

Decreased feed intake is usually observed in newly weaned pigs. To illustrate this point, Figure 2 summarizes several data sets showing typical voluntary energy intake of newly weaned pigs. Note that metabolizable energy intake is not equal to preweaning intake until at least 10 days postweaning. Obviously, pigs need to consume nutrients to grow, but these changes in nutrient intake may also contribute directly to changes in morphology and function of the small intestine. The presence of feed in the small intestine is a potent stimulus of cell division and growth. There is a positive relationship between dry matter intake and villus height. Similarly, it has been shown that restricted feeding and intravenous feeding results in villus atrophy. This suggests that “feeding” the small intestine is important in maintaining a viable small intestine morphology and function. Additionally, other factors associated with gastrointestinal changes are often confounded with the occurrence of low feed intakes.

Dietary Factors

Specific components of certain feedstuffs may contribute to the negative changes in small intestinal morphology. There is general agreement that soybean meal causes negative changes in small intestinal morphology. Proteins found in soybean meal have been shown to cause an immunogenic reaction or a “gut allergy” in pigs exposed to soybean meal. This

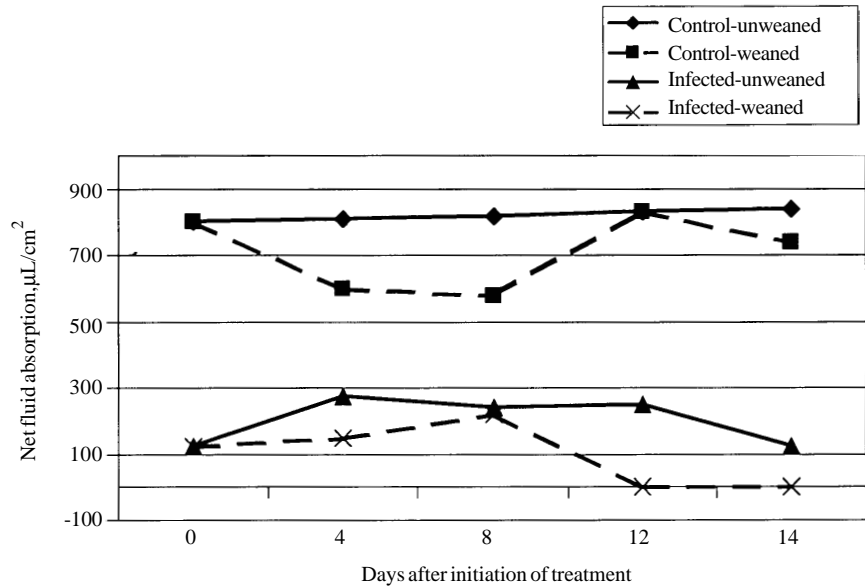


Figure 1. Fluid absorption of control and infected, and weaned and unweaned pigs.

Res. Vet. Sci. 56:379-385.

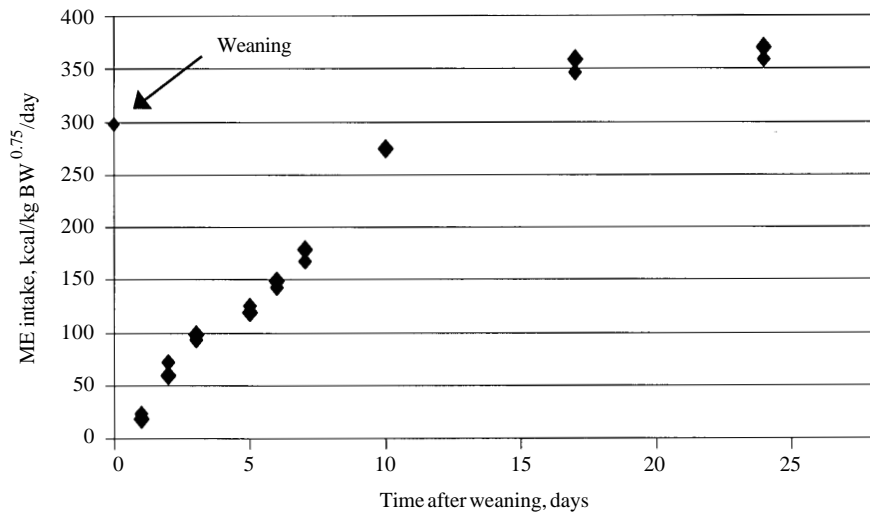


Figure 2. Energy intake of weaned pigs.

Livest. Prod. Sci. 38:79-90.

“gut allergy” has been associated with villus atrophy. For this reason, nutritionists often limit the amount of soybean meal in weaned pig diets. However, some debate exists whether the initial research (linking soybean meal and villus atrophy) is confounded by low feed intakes after weaning because low feed intakes may contribute to the atrophy of villus and therefore a depression in growth. Other antinutritional

compounds such as lectins and tannins have been implicated as factors related to villus atrophy after weaning.

Sow milk (and colostrum) is a nearly perfect food for young pigs, therefore the compounds and nutrients in sow milk serve as excellent references as we formulate dry feed diets for weanling pigs. For example, it has been known for some time that weanling pigs require a high dietary con-



centration of lactose because sow milk contains high concentrations of lactose. Other nutrients and growth factors/hormones found in milk could be responsible for maintaining the integrity of the small intestinal morphology and function. The lack of these compounds or reduction in their concentration could be responsible for the changes observed in the small intestine after weaning.

Hormones found in sow milk may contribute to small intestine morphology integrity. For these hormones to influence the integrity of the small intestine, at least four criteria must be met. First, the hormone of interest must be present in sow milk. Secondly, the receptor (i.e., site where the hormone binds to initiate a physiological change) for the hormone must be present in the lumen of the small intestine. Thirdly, the presence of the hormone must elicit a physiological response (e.g., increased villus height, increased enzyme activity, etc.). Lastly, the digestive processes must not alter the hormone.

Several hormones have been reported to influence small intestinal morphology. Epidermal growth factor (EGF), insulin-like growth factors (IGF-I and IGF-II), and insulin are hormones that influence growth of tissues, including the gastrointestinal tract. All of these hormones have been found in sow milk. These hormones seem to have a positive influence on the small intestinal morphology. Additionally, research on investigating the resistance of the hormones to digestive processes has been initiated. For example, recent research suggests that one-half to two-thirds of the EGF exposed to weanling pig digestion is still intact, and a significant portion of that may be biologically active at the site of the small intestine. There is little doubt that these hormones are important for gut development while pigs are suckling, and they may be useful for implementing in postweaning pig diets in the future.

Other compounds present in milk have been associated with improved gastrointestinal morphology. Polyamines (e.g., putrescine, spermine, spermidine) are compounds that are important for cellular proliferation and differentiation. Both the enzyme responsible for synthesizing polyamines and polyamines themselves have been shown to increase in concentration before and during an increased proliferation of cells. There has been limited discussion about whether the pig synthesizes an adequate supply of polyamines. Therefore, some researchers have attempted to answer whether supplementing polyamines in the diet improves gastrointestinal morphology and (or) growth. In chicks, spermidine supplementation seems to improve growth; however, large doses may be toxic. Young swine and preruminant calves have shown some improvement in small intestinal proliferation when fed supplemental polyamines. Polyamines are natural compounds and typical feedstuffs contain polyamines; however, the concentration of these compounds in feedstuffs is unknown and (or) their effects on pig metabolism have not been extensively studied. Considering the limited amount of data, more research regarding whether dietary polyamines improve small intestinal morphology is needed before any conclusions can be drawn.

Recently, glutamine has received attention as a modifier of gastrointestinal growth. Glutamine is considered a nonessential amino acid for swine. However, glutamine has been recognized by the human health community to help maintain gastrointestinal growth during intravenous feeding and after gastrointestinal surgery. Rapidly dividing cells, including the absorptive and immune cells of the small intestine, prefer glutamine (compared to glucose) as an energy source. Additionally, it seems that free (unbound to protein) glutamine is the most abundant amino acid in sow milk, particularly in late lactation (tested on day 22

and 29). The addition of 1% crystalline glutamine to a corn-soybean meal diet has been reported to partially prevent villous atrophy in the jejunum (mid portion of the small intestine) on the seventh day after weaning. Other recent research has confirmed that supplemental glutamine improves small intestinal morphology in pigs. However, previous research used crystalline glutamine. This form of glutamine is expensive and basically unavailable to the feed industry at this time. Therefore, there is a need to identify whether glutamine from intact protein from typical feedstuffs (e.g., soybean meal, spray-dried porcine plasma, fish meal, dried skim milk, etc.) is as effective in stimulating a response as is crystalline glutamine. Glutamine appears to be an effective way to help optimize the growth of the small intestine after weaning; however, a more applicable method to analyze and include glutamine in the diet must be pursued.

Conclusions

Many of the factors that are associated with changes in the small intestinal morphology may be inter-related. Understanding how these factors alter the growth of the small intestine of weanling pigs may lead to developments that improve growth and (or) pig health. This is particularly important with increasing pressure to limit the use of antibiotics/growth promotants in pig diets. Future experiments at the University of Nebraska will be investigating the importance of the integrity of the gastrointestinal tract relative to overall growth and potentially develop methods to improve the integrity of the weaned pig's small intestine after weaning.

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