REVIEW ARTICLE
Anim Ind Technol 2024;11(1):1-11
https://doi.org/10.5187/ait.2024.11.1.1

축산기술과 산업
Animal Industry and Technology
pISSN 2383-5761 eISSN 2383-6385

A review on improving weaned pigs' growth performance and gut health using nutritional strategies

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Received: Mar 29, 2024
Accepted: Apr 17, 2024

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Abstract

During the post-weaning period, pigs are exposed to weaning stress due to environmental, social, and nutritional reasons. Weaning stress reduces feed intake and body weight and causes diarrhea by proliferating harmful bacteria in the intestines. Also, oxidative stress and decreased intestinal barrier function inhibit nutrient absorption and increase intestinal permeability, resulting in increased morbidity and mortality in weaned pigs. Gut health is very important for improving metabolism, immunity, and growth performance in weaned pigs. Overcoming post-weaning stress and establishing a healthy gastrointestinal tract are very important, as they relate to the nutritional metabolism and growth performance of growing-finishing pigs. As the use of antibiotics as growth promoters in diets was banned, and the zinc oxide content used to prevent weaned pigs' diarrhea was restricted to prevent environmental pollution, interest continues to focus on nutritional ways to improve weaned pigs' growth performance and gut health. Therefore, this paper aims to explain the effects of various nutritional strategies on improving weaned pigs' growth performance and gut health and examine the brief mechanisms of each nutritional strategy.

Keywords: Weaned pig, Growth performance, Gut health

INTRODUCTION

Gut health is very important for improving metabolism, immunity, and growth performance in weaned pigs [1]. Gut health could be defined as improving nutrient absorption, strengthening the intestinal barrier function, stabilizing the intestinal microflora etc. [2]. Establishing a healthy gastrointestinal tract in weaned pigs is also related to nutrient metabolism and growth performance in growing-finishing pigs [3]. Therefore, numerous studies have been published to improve the gut health of weaned pigs for growing the swine industry, and research is being conducted for new nutritional strategies.

During the post-weaning period, pigs are exposed to weaning stress due to environmental, social, and nutritional reasons [4]. Weaning stress reduces feed intake and body weight and causes diarrhea by proliferating harmful bacteria in the intestines [5,6]. Also, oxidative stress and decreased intestinal barrier function inhibit nutrient absorption and increase intestinal permeability, resulting in increased morbidity and mortality in weaned pigs [7,8]. As a result, weaning stress reduces the production efficiency of pigs, increases production costs, and causes economic losses for farms [9]. As the use of antibiotics as growth promoters in diets was banned [10], and the zinc oxide content used to prevent weaned pigs' diarrhea was restricted to prevent environmental pollution [11], interest continues to focus on ways to improve weaned pigs' growth performance and gut health.

Therefore, this paper aims to explain the effects of various nutritional strategies on improving weaned pigs' growth performance and gut health and examine the brief mechanisms of each nutritional strategy.

BLACK SOLDIER FLY LARVAE

Black soldier fly larvae (*Hermetia illucens* L.) have the highest potential as a feed raw material worldwide and are emerging as a substitute for existing animal protein sources [12–14]. Black soldier fly larvae can be easily bred using organic waste resources such as food waste and vegetable by-products [12,15]. Because they have a short lifespan compared to other livestock and grow very quickly, they are attracting attention as an environmentally sustainable resource with low greenhouse gas emissions and high feed conversion and protein production efficiency [13,16]. Since black soldier flies are not pests, they do not act as vectors for disease transmission, and compared to other dipteran species, they do not have many harmful bacteria, so they have an advantage in terms of safety [17,18].

Kim et al. [19] reported that black soldier flies have high intestinal amylase, lipase, and protease activities. This works when decomposing organic waste, helping to efficiently convert organic matter into nutrients such as amino acids, proteins, chitin, and vitamins [12]. Although it varies depending on the processing method, the average crude protein (CP) content of black soldier fly larvae is approximately 46% [20–22], which is higher than soybean meal (44%–46%) and lower than fishmeal (67%) [23,24]. In particular, it is reported that black soldier fly larvae have a rich amino acid profile compared to soybean meal and fishmeal [25]. Leucine, lysine, and valine are reported to be higher in content compared to soybean meal, but methionine and tryptophan are reported to be lower in content compared to fish meal [26,27]. With these similar nutritional components with soybean meal or fishmeal, black soldier fly diets for weaned pigs did not show a significant difference in nutrient digestibility from soybean meal- or fishmeal-based diet, suggesting that it does not have a negative effect on weaned pigs [14,28,29]. Lauric acid and chitin, which are included in black soldier fly larvae, can improve weaned pigs' gut health and immunity [29,30]. Lauric acid accounts for approximately 52% of the total monounsaturated fatty acids in black soldier fly larvae [31]. Lauric acid has an antibacterial effect on both gram-negative and gram-positive bacteria and helps improve the intestinal environment by reducing intestinal pH [13,32]. Chitin, which contains approximately 4%–7% in black soldier fly larvae, is not biodegradable, promotes hindgut fermentation of short-chain fatty acids, and has an immune-modulating effect [26,33]. Additionally, chitin acts as a prebiotic and helps prevent pathogenic bacteria from increasing in the intestines [34]. In weaned pigs infected with *Escherichia coli*, the main cause of diarrhea due to post-weaning stress, when fish meal in the

Competing interests
No potential conflict of interest relevant to this article was reported.

Funding sources
Not applicable.

Acknowledgements
Not applicable.

Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Chang S, Song D, Cho J.
Data curation: Chang S, Song D, Cho J.
Formal analysis: Song D.
Methodology: Chang S.
Software: Song D.
Validation: Cho J.
Investigation: Chang S, Song D, Cho J.
Writing - original draft: Chang S, Song D, Cho J.
Writing - review & editing: Chang S, Song D, Cho J.

Ethics approval and consent to participate
This article does not require IRB/IACUC approval because there are no human and animal participants.

diet was replaced with black soldier fly larvae, *Lactobacillus* increased, and *Streptococcus* decreased in the intestine [35]. Chitosan and lactate in black soldier fly larvae have antioxidant properties and can increase beneficial bacteria in the intestines by promoting mucin expression [36]. Accordingly, the increased *Lactobacillus* prevents damage to intestinal epithelial cells caused by *E. coli* and increases the expression of tight junction proteins zonula occluden-1 and occludin [37]. Therefore, the intestinal barrier function is strengthened, the proliferation of harmful bacteria is suppressed, and the expression of genes related to intestinal development increases, showing the effect of improving weaned pigs' gut health [38]. It has been reported that there is no difference in weaned pigs' growth performance compared to the fishmeal-based diet or other existing diet when feeding a black soldier fly larvae diet [35,36,39]. However, since the improvement of weaned pigs' gut health potentially means improved immunity and robustness, the use of black soldier fly larvae in the diet is considered to have sufficient potential as a protein raw material without negative effects on weaned pigs. However, since the nutrient composition may vary depending on the rearing and processing method of black soldier fly larvae, additional research is needed to establish black soldier fly larvae production technology and to investigate the mechanism in the weaned pigs' body according to feeding black soldier fly larvae.

FEED ADDITIVES

Probiotics

One of the best alternatives to antibiotics is probiotics, which are live cultures of beneficial bacteria that help regulate the microbiota in the intestines [40]. Probiotics have been used in animal studies in recent years, and several studies have shown that dietary supplementation with probiotics mitigates post-weaning diarrhea in pigs (Table 1) [41]. The use of probiotics in pigs can enhance the gut microbiota, enhance immunity regulation, improve barrier function, increase nutrient digestibility, and consequently improve growth performance [42]. It is difficult to determine the mechanism underlying the gastrointestinal effects of probiotics, since it can exert their benefits in different ways. Even strains from the same species can possess totally different

Table 1. **Effects of probiotics on intestinal health in weaned pigs**

Probiotics	Dosage	Duration of study (days)	Positive performance	Reference
Lactobacillus plantarum BG0001	0.2% (1.30 × 10^7 CFU/g)	42	Increased ADG and G:F; increased fecal *Lactobacillus* count; reduced *Escherichia coli* count	[66]
L. plantarum JL01 and *L. rhamnosus* GG ATCC53103	10 mL (0.5 × 10^9 CFU/mL *L. plantarum* JL01 and 0.5 × 10^9 CFU/mL *L. rhamnosus* GG ATCC53103)	28	Increased G:F; reduced IL-1β in serum, jejunum, ileum, and cecum, TNF-α in serum, jejunum, and ileum, IL-6 in serum and cecum, and IFN-γ in serum	[67]
L. plantarum CAM6	5 mL	28	Increased ADG; increased concentration of serum β-hydrobutyrate and total IgA	[68]
Bacillus subtilis	1 × 10^6 CFU/g	42	Increased growth performance; decreased TNF-α and increased IL-2 and IL-10	[69]

CFU, colony forming unit; ADG, average daily gain; G:F, feed efficiency; IL-1β, interleukin-1β; TNF-α, tumor necrosis factor-α; IL-6, interleukin-6; IFN-γ, interferon-γ; IgA, immunoglobulin A; IL-2, interleukin-2; IL-10, interleukin-10.

properties and clinical effects. Song et al. [43] have reported that *Pediococcus pentosaceus* and *P. acidilactici* improved average daily gain and feed efficiency. Additionally, multi or mono supplementation of *P. pentosaceus* and *P. acidilactici* groups increased villus height compared to non-supplementation group. According to Wang et al. [44], dietary supplementation of *P. acidilactici* and *Lactobacillus fermentum* increased concentration of volatile fatty acids, such as acetate and propionate, and had greater abundance of *Lactobacillus* in intestine. Probiotics protect mucosal barriers in piglets mainly by stimulating the release of mucin and antimicrobial peptides, promoting fluid absorption and reducing fluid secretion, and increasing intestinal tight junction protein expression [45]. In addition, further *in vivo* information could extend the application of probiotic strains to the production of different animals.

Enzymes + prebiotics

During weaning period, the diet of piglet transfer from sow milk to corn-soybean meal-based diets. The Diets with antinutritional factors can adversely affect the growth performance of weaned piglets. It has been shown that corn-soybean meal diets contain significant amounts of non-starch polysaccharides (NSP) derived from plant cell walls, mainly arabinoxylan in corn and xylan in soybean meal [46]. Supplementation of enzymes like xylanase (XYL) to animal diets helps break down complex NSP into oligosaccharides, which gut bacteria can easily ferment, promoting better digestion [47]. Moreover, xylo-oligosaccharides, specifically those with a degree of polymerization between 2 and 6, have been found to improve intestinal health and stimulate the immune system in animals, serving as effective prebiotics [48,49]. Stimbiotics (STB), a novel type of feed additive combining XYL and xylo-oligosaccharides (XOS), have been introduced (Table 2). STB is effective in breaking down arabinoxylans and supplying short-chain oligosaccharides [50]. According to Chen et al. [51], supplementation of XYL or XOS improved nutrient digestibility by lowering viscosity of excreta, and increased concentration of short fatty chain acid in cecal. Therefore, STB may have a positive impact by encouraging the proliferation of helpful bacteria that break down dietary fiber, potentially leading to an increase in the production of short chain fatty acid. This process can help weaned piglets derive energy from their feed, thereby enhancing their growth and boosting their immune system.

Phytogenic feed additives

Phytogenic feed additives can be defined as natural active compounds of plant origin that have a positive effect on the growth and health of animals [52]. The main functions of phytogenic

Table 2. **Effects of stimbiotic on intestinal health in weaned pigs**

Dosage (%)	Duration of study (days)	Positive performance	Reference
0.05	17	Increased growth performance; decreased incidence of diarrhea; improved neutrophils and lymphocytes; upregulated the expression of CLDN-1	[70]
0.01	42	Increased ADG in poor sanitary conditions; decreased plasma TNF-α content	[71]
0.01	42	Increased growth performance; increased plasma IgA and IgG	[46]

CLDN-1, claudin-1; ADG, average daily gain; TNF-α, tumor necrosis factor-α; IgA, immunoglobulin A; IgG, immunoglobulin G.

 https://doi.org/10.5187/ait.2024.11.1.1

feed additives include improving feed palatability, stimulating the secretion of digestive enzymes, regulating intestinal microflora, and having antibacterial and anti-inflammatory effects [53–55]. Phytogenic feed additives are rich in various bioactive ingredients such as thymol and carvacrol, which have antibacterial, anti-inflammatory, and antioxidant properties [56]. There are many studies that phytogenic feed additives can improve growth performance and the intestinal environment [57–59]. According to a previous study, supplementation of 200 mg/kg or 400 mg/kg of essential oil in the diet increased the expression levels of occludin and zonula occluden-1 in the jejunum [60,61]. Thymol, carvacrol, and cinnamaldehyde in essential oils increase the expression of tight junction proteins and form intestinal barrier integrity [62]. Also, it increases mucin expression and increases the number of goblet cells, which maintain the intestinal mucosa and play a role in preventing pathogen invasion [63]. Trudeau et al. [64] reported that supplementation with an herbal blend or garlic increased the relative abundance of *Lactobacillus*, which means improvement of the intestinal microbiota of weaned pigs. Through this, phytogenic feed additives could improve weaned pigs' gut health and even improve growth performance [60,65].

CONCLUSION

When feeding black soldier fly larvae diet, the secretion of leptin, an appetite-suppressing hormone, decreases, and palatability increases through glutamine contained in black soldier fly larvae. Chitin and lauric acid promote microbial fermentation in the intestines to produce short-chain fatty acids such as butyric acid. It is used as an energy source for intestinal epithelial cells and is involved in intestinal villus development and the reduction of oxidative stress. Supplementation of probiotics in weaned pigs produces antibacterial peptides, which reduce intestinal pH and inhibit the growth of harmful bacteria. By promoting the expression of tight junction proteins and anti-inflammatory cytokines, it could alleviate intestinal barrier damage caused by post-weaning stress and improve immunity. Supplementation of STB breaks down NSP in a diet, removes anti-nutritional factors, and improves nutrient digestibility. Also, XOS can improve intestinal morphology and intestinal microflora by promoting the growth of beneficial bacteria in the intestines and inducing the proliferation of intestinal epithelial cells. Supplementation of phytogenic feed additives reduces oxidative stress in the body through antibacterial and antioxidant effects and promotes intestinal epithelial cell proliferation. It establishes intestinal barrier integrity through increased goblet cells and tight junction protein expression. Also, it improves the intestinal microbiota and reduces post-weaning diarrhea by inhibiting the growth of harmful bacteria in the intestines. Overall, the nutritional strategies covered in this paper can help improve the gut health of weaned piglets, and further research is needed to identify more precise mechanisms.

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