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Review Article

Using probiotics to improve swine gut health and nutrient utilization☆

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ABSTRACT

To maintain a healthy gut is definitely key for a pig to digest and absorb dietary nutrients efficiently. A balanced microbiota (i.e., a healthy micro-ecosystem) is an indispensable constituent of a healthy gut. Probiotics, the live microorganisms which, when administered in adequate amounts, confer good health benefits onto the host, are a category of feed additives that can be used to replenish the gut microbial population while recuperating the host immune system. Besides their antitoxin and diarrhea reduction effects, dietary supplementation of probiotics can improve gut health, nutrient digestibilities and, therefore, benefit nutrient utilization and growth performance of pigs. Current knowledge in the literature pertinent to the beneficial effects of utilizing various probiotics for swine production has been comprehensively reviewed, and the safety and the risk issues related to probiotic usage have also been discussed in this paper. Considering that the foremost cost in a swine operation is feed cost, feed efficiency holds a very special, if not the paramount, significance in commercial swine production. Globally, the swine industry along with other animal industries is moving towards restricting and eventually a total ban on the usage of antibiotic growth promoters. Therefore, selection of an ideal alternative to the in-feed antibiotics to compensate for the lost benefits due to the ban on the antibiotic usage is urgently needed to support the industry for profitable and sustainable swine production. As is understood, a decision on this selection is not easy to make. Thus, this review paper aims to provide some much needed up-to-date knowledge and comprehensive references for swine nutritionists and producers to refer to before making prudent decisions and for scientists and researchers to develop better commercial products.

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1. Introduction

A major task of raising pigs for producing pork is to feed the pigs. The cost on feed represents more than two-thirds of the total operation cost in pig production. Therefore, enhancing feed efficiency (i.e., the efficiency of converting feed mass into pig body mass) is very critical for the profitability of producing pigs (Patience, 2012). To enhance the feed efficiency, that is to improve the metabolic utilization of dietary nutrients by a pig, relies heavily on a healthy gut or gastro-intestinal tract (GIT), because only a healthy gut can result in a better feed digestion and a better nutrient absorption via its epithelial membranes (Ewing, 2008; Willing et al., 2012).

Beyond its physiological function as the alimentary canal for nutrient digestion and absorption, pig's GIT is also one of the largest organs that helps animal's immune function, because by nature the gut is animal's first line of defense against the microbial pressure from its environment, especially the invasive pathogens from the GIT lumen (Veizaj-Delia and Pirushi, 2012). Activation of the GIT immune system incurs the direct cost of producing a diverse set of specialized immune cells (comprising more than 70% of the body's immune cells) and signaling molecules, as well as the losses in the efficiency of GIT digestive function (Willing et al., 2012). Therefore,

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only a healthy gut can lead to a healthy pig, allowing a pig to thrive throughout its lifespan well without sickness or falling back. And only a healthy pig can utilize dietary nutrients efficiently for tissue accretion, and lead to a better production performance and, thus, a higher return on investment for swine producers. In this regard, ensuring a healthy gut is an "all-the-time deal" in swine production practices (Taylor-Pickard and Spring, 2008; Hubbard Feeds, 2014).

2. Microbiota and a healthy gut

Like for all mammals including humans, a healthy gut of a pig is inhabited with hundreds of species of microorganisms, which together form a microbial community often referred to as microflora or, more appropriately, microbiota (Jonsson and Conway, 1992; Leser et al., 2002; Sears, 2005; Fouhse et al., 2016). Microorganisms begin to colonize the sterile gut of a newborn pig right after birth, a process called microbial succession. A fully developed microbiota in a gut is established within weeks after birth (Tortuero et al., 1995; Bauer et al., 2006; Kim and Isaacson, 2015). An established gut microbiota is a complex micro-ecosystem composed of approximately 1,014 microorganisms (most of them are bacteria), which co-exist with the pig as the host (Kim and Isaacson, 2015). When this co-existence (also known as symbiosis) is balanced, the gut of the pig will be normal and healthy, and functions well (Willing et al., 2012). Animals raised in the absence of bacteria show profound retardation in the development of adult gut morphology, digestive physiology, and normal immune function (Kenny et al., 2011).

Management of intestinal micro-ecosystem is one of the common strategies applied to prevent diarrhea, improve health status, and enhance growth performance of pigs in modern intensive production systems (Williams et al., 2001; Bauer et al., 2006; Zimmermann et al., 2016). Under natural environments, harmful microorganisms can enter and colonize the pig GIT (called dysbiosis) and produce waste products which are toxic and can lead to gas bloating, diarrhea, constipation, ulcers, or more serious events like poisoning (Cho et al., 2011). In this situation, the pig cannot utilize dietary nutrients efficiently and cannot grow well (Willing et al., 2012). A more detailed discussion regarding the role of gut microbiota in swine health and disease can be found in a recent review article authored by Fouhse et al. (2016).

The processes of nutrient digestion in pig GIT, in the simplest way, include enzymatic hydrolysis and microbial fermentation of feedstuffs. Although pigs rely heavily on the process of nutrient hydrolysis by endogenous digestive enzymes, the microbial fermentation (especially, in the hind gut) contributes a great deal (Williams et al., 2001). The gut microbiota provides a critical support to the host in areas including vitamin and co-factor production, usage of otherwise indigestible feed ingredients, detoxification of feed components, coating the gut with a benign microbiota to physically exclude pathogens, production of natural antibiotics and antifungals, maintenance of gut barrier function, and promotion of anti-inflammatory response (Kenny et al., 2011). Therefore, the composition of gut microbiota significantly impacts on gut health, dietary nutrient utilization, and whole body health of the pig.

3. Strategies for promoting gut health and regulation on antibiotic usage

Although the modern intensive systems have advanced swine production efficiency, they also create suitable conditions for propagation and transmission of harmful bacteria or pathogens, which cause pathogenic stress to the pig (Lee et al., 2016). The early weaning practice (at 14 to 21 days of age) widely adopted in the industry reduces the chance of young piglets to be infected by the pathogens from lactating sows, but this practice also deprives piglets of more opportunities to acquire a protective gut microbiota from the mother, leaving the GIT unprotected against the colonization by pathogenic microorganisms (Guerra and Castro, 2009). Although it is not impossible that 3 weeks are long enough for microbes to be established in a piglet's gut, a modern management interest is to better solutions to achieve a well-balanced gut microbiota that is a healthy gut micro-ecosystem optimal for animal to digest feed, absorb nutrients, and grow tissues (Taras et al., 2007).

As is known, the gut microbiota can be manipulated by dietary means using feed additives such as organic and inorganic acids, enzymes, antibiotics, prebiotics, probiotics, mold inhibitors, botanical products (de Lange et al., 2010; Le Bon et al., 2010; Heo et al., 2013; Sezen, 2013). The use of antibiotics has been an integral part of modern swine operation worldwide ever since early 1950s (Dibner and Richards, 2005). Veterinary uses of antibiotics in pig production include not only the therapeutic and prophylactic uses, but also the administration at subtherapeutic levels to stabilize the gut microbiota and enhance pig growth performance (Adjiri-Awere and van Lunen., 2005; Guerra and Castro, 2009). In reality, the use of antibiotics in swine production is the most studied of all livestock species because the subtherapeutic use of antibiotics can greatly improve pig growth rate, reduce morbidity and mortality, and improve production and reproduction performance (Cromwell, 2002; Thacker, 2013). Because the subtherapeutic use of antibiotics can promote animal growth performance and, therefore, many antibiotics that are used in this regard are referred as antibiotic growth promoters (AGP; Dibner and Richards, 2005; Guerra and Castro, 2009).

Nevertheless, research on the AGP modes of action showed that they may affect not only the potentially harmful but also the benign gut microorganisms (Adjiri-Awere and van Lunen, 2005; Dibner and Richards, 2005; Guerra and Castro, 2009). Therefore, there are 2 major concerns regarding the use of AGP for farm animals. One is the chemical residues from such antibiotics which may be found in animal products as foreign substances that should not have any place in the food chain. The other is that the antibiotics used for animals were the same as those used in human medicine (Casewell et al., 2003; Dibner and Richards, 2005). The use of AGP was then incriminated as contributing to selection pressure, resistance reservoirs, and transmission routes (Gersema and Helling, 1986; Wegener, 2003). Following the ban on AGP use in Sweden in 1986, and the ban on avoparcin and virginiamycin in Denmark in 1995 and 1998, respectively, the European Union (EU) banned the use of avoparcin in 1997 and the four remaining AGP (bacitracin, spiramycin, tylosin, and virginiamycin) in 1999, on the basis of the "Precautionary Principle" (Casewell et al., 2003; Dibner and Richards, 2005). The EU total ban on the use AGP in animal feed entered into effect on January 1, 2006 (European Commission, 2005).

North America, following the actions of the EU, has started moving towards restricting or a total ban on the use of AGP because of the general public concern and potential international trade barriers to the meat products from livestock industries. In the United States (US), recommendations to reduce or eliminate the use of AGP were made in 2 reports by the Institute of Medicine in 1980 and 1989, respectively, in one report by the Council for Agricultural Science and Technology in 1981, and in another by the Committee on Drug Use in Food Animals in 1998 (Dibner and Richards, 2005). The World Health Organization (WHO) published a report in 1997 on the medical impact of the use of antimicrobials in food animals, suggesting a link between the 2 on an epidemiological basis (Dibner and Richards, 2005). WHO suggested again in

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