OPEN ACCESS Freely available online

Journal of Probiotics & Health

Review Article

Latest Reports on the Use of Lactic Acid Bacteria to Enhance Nutrient Consumption and Gut Health in Pigs

Saddam Hussein[1], Seria Masole Shonyela[1], Abdelaziz Hussein[2], Jiang Hailong[1*]

[1]College of Animal Science and Technology Jilin Agricultural University, Changchun, Jilin, 13018, China; [2]Regional Centre for Food and Feed, Agricultural Research Centre, Giza, 12619, Egypt

ABSTRACT

The lactic acid bacteria strains (LAB), mainly *Lactobacillus* strains, endorse intestinal and serum immune responses to gastrointestinal diseases such as diarrhoea reduction effects and antitoxin rotavirus. Supplementation of diet with LAB can benefit growth performance; nutrient utilisation and nutrient digestibility therefore enhance gut health of pigs. Understanding in the narrative related to the advantageous consequences of consuming a range of LAB for swine production has been widely reviewed, and the hazard and the safety related issues to to use of LAB have also been considered in this review.

Taking into consideration that the primary cost in a swine business is feed effectiveness, feed cost, holds an exceptionally, if not the supreme, consequence in industrial pig production. Worldwide, in accompany with other animal industries the swine industry is affecting towards the long run a total ban and in control on the usage of antibiotic growth promoters. For that reason, the selection of a perfect substitute to the in-feed antibiotics to reimburse for the vanished profits because of the ban on the usage of antibiotic is immediately required to maintain the business for the sustainable and advantageous swine production.

Keywords: Lactic acid bacteria; Nutrient consumption; Gut health; Pigs

INTRODUCTION

The most consumed animal protein around the world is pork but there are a number of key factors to think about before making a decision to farm pigs. The most important assignment of growing pigs for pork production is to feed the pigs.Porcine gastroenteritis and diarrhoea are main causes of piglet mortality that consequently lead to overwhelmingly economic loss to the pig farmers. Antibiotics have been broadly considered for growth approval and avoidance of diarrhoea in pigs given that a normal additive used in livestock feeds antibiotics give enhances economic competence. But, the harmful effects of antibiotics have turned out to be gradually more prominent. Consumers are more and more worried concerning antibiotic residues in meat products. The expenditure of the entire process cost in pig production on feed corresponds to above two-thirds. As a result, to increase the value of feed efficiency to yield a better financial return is very significant for the productivity of pigs.At the present time, probiotics from Lactic acid-producing bacteria have been identified as non-pathogenic microorganisms and are broadly used as feed additives in livestock animals. The purpose of their use is to prevent diseases through the preservation of a healthy gastrointestinal environment, to improve production performance and enhanced intestinal function. To improve the feed effectiveness and to develop the metabolic consumption of nutrients by a pig depend greatly on gastro-intestinal tract (GIT) or a healthy gut. This is due to a reason that only a healthy gut can an enhanced absorption of nutrient through its epithelial membranes and result in a improved feed digestion. The role of GIT as the alimentary canal for nutrient absorption and digestion, GIT is as well one of the main organs that assist immune efficiency. This is due to that naturally the gut is the vanguard of host defence in opposition to the microbial stress from its situation, particularly the pathogens from the lumen. The initiation of the GIT immune system acquires the straight cost of generating a different situation of particular immune

Correspondence to: Jiang Hailong, College of Animal Science and Technology Jilin Agricultural University, Changchun, Jilin, 13018, China, Tel: 15044147293; E-mail: alhusseinsaddam94@yahoo.com

Received: July 03, 2020; **Accepted:** July 20, 2020; **Published:** July 29, 2020

Citation: Hussein S, Shonyela SM, Hussein A, Hailong J (2020) Latest Reports on the Use of Lactic Acid Bacteria to Enhance Nutrient Consumption and Gut Health in Pigs. J Prob Health. 8: 220. DOI: 10.35248/2329-8901.20.8.220

cells and signalling molecules, as well as inefficiency of GIT digestive function [1].

For that reason, the use of LAB probiotics in animal feeds has augmented very much in the most recent years since they are mainly linked with improving animal performance and eliminating diseases. Besides, the common of the presently used probiotics are depends on lactic acid bacteria; mostly *Lactobacillus sp.* and *Enterococcus sp*.Healthy pig can lead to an improved performance production and utilise well dietary nutrients for tissue growth; hence super benefit to swine producers [2]. Many researchers have illustrated the advantageous outcomes of LAB probiotic. These consist of the enhancement of intestinal mucosal immunity, preserving intestinal wall role, prevention of pathogens in the GIT and guideline of the intestinal microflora. This current work aims to systematically review and bring up to date the proof on the efficiency of using LAB in animal diets.

ROLE OF THE GUT MICROBIOTA IN THE HEALTH AND DISEASES OF PIGS

The genetic variety of the gut microbiota contributes to the growth of the animal and general metabolic needs and production of volatile fatty acids, improvement of immune system, production of vitamin K, cellulose digestion and gives the host with various advantageous roles as well as re-process of bile salts.As a result, the intestinal microbiota of animals has been the focus of study for several years. Compared to all mammals as well as humans, a healthy gut of a pig is colonised with many of species of microorganisms, which collectively form a microbial community, called microbiota.The pig intestinal tract harbours a diverse and complex microbial which involved in energy harvest and storage in addition to a diversity of metabolic role for instance absorbing undigested carbohydrates and fermenting. Possibly still more prominently, the gut microbiota work together with the immune system, providing signals to endorse the usual growth of immune utility and the maturation of immune cells. Microorganisms start on to inhabit the sterile gut of a new-born piglet, microbial sequence. A completely improved microbiota in a gut is recognized not beyond weeks following birth. After this co-existence is equilibrium, the gut of the pig will be healthy and common, and functions well. Animals grow up in the lack of bacteria for weighty retardation in the standard immune function, digestive physiology and improvement of adult gut morphology. One of the general approaches useful to avoid diarrhoea, increase health status, and improve growth performance of pigs in up to date intensive production systems is the controlling of intestinal micro-ecosystem. At normal environments, dangerous microorganisms can come in and inhabit the pig GIT (dysbiosis) and produce misuse products which can cause ulcers, gas bloating and are toxic, constipation and diarrhea. Probiotics additives in basal diet enhance faecal microbial count, intestinal morphology and growth performance in pigs. In this condition, the pigs cannot grow well because they cannot utilise well dietary nutrients. Fouhse and Pluske, in their review article, detailed information concerning the function of gut microbiota in swine health. In GIT the developments of nutrient digestion, in the easiest mode, comprise microbial fermentation of feedstuffs and enzymatic hydrolysis. Though a pig depends greatly on the endogenous digestive enzymes process of nutrient hydrolysis, the microbial fermentation contributes a massively particularly in the hind gut. To the host the gut microbiota gives a significant support in areas including co-factor and vitamin production, feed components detoxification, covering the gut with a helpful microbiota to physically prohibited pathogens, being used of indigestible feed ingredients, production of natural antifungals and antibiotics, support of anti-inflammatory response, and preservation of gut wall function. For that reason, we consider the management of the gut microbiota as a likely therapeutic alternative to treat chronic gastrointestinal disease [3-6].

NEW STATUS REGARDING THE STRATEGY TO PROTECT HEALTHY GUT MICROBES FROM ANTIBIOTICS

The bacteria in animal intestines are really vital for several reasons of health but Antibiotics are used in animal production for three major reasons: used as therapeutics to deal with established infections, used as prophylactics to control the spread of pathogenic diseases in clinically healthy animals, and used as growth promoters to enhance feed conversion and body-weight gain. Antibiotic use and dietary aspects can modify the composition of gut microbes and securely reduce bacterial multiplicity, posing a severe threat to animal health by rising host susceptibility to dangerous pathogens for example Salmonella or can lead to diabetes, obesity, gastrointestinal cancer and chronic inflammatory bowel diseases. Even though the current rigorous methods have highly developed swine production proficiency, they additionally generate appropriate circumstances for spread and conduction of dangerous pathogens, which lead to pathogenic tension to the pig. Many options are being studied to develop the resistance of pigs against gut pathogens. Besides, the early weaning starts of age at 14 to 21 days extensively assumed in the industry decreases the possibility of piglets to be infected by the pathogens from lactating sows. However, this way as well removes piglets of additional chances to obtain a defensive gut microbiota from the sow, and become unprotected against the immigration by pathogenic microorganisms. Even if it is likely that 3 weeks are long enough for microbes to be recognized in the gut, up to date manipulation awareness is to improved results to accomplish a proportion gut microbiota that is a healthy gut micro-ecosystem mostly approved for animals to grow by digesting feed and absorb nutrients. It is acknowledged that the gut microbiota can be managed with nutritional approaches by means of feed additives for instance enzymes, antibiotics, inorganic and organic acids, probiotics, mold inhibitors, botanical products, and prebiotics [7]. The use of antibiotics has been an increasingly essential measurement of current swine process worldwide. The use of antibiotics in pig production is not just for the prophylactic and therapeutic uses, as well for the management at sub-therapeutic stages to become stable increase pig growth performance. In truth, the apply of antibiotics in swine production is the mainly studied of all livestock species for the reason that the sub-therapeutic use of antibiotics can significantly develop pig growth rate, decrease mortality and morbidity, and enhance reproduction performance and meat production. For the reason that the sub-therapeutic use of

antibiotics can increase livestock growth performance and, as a result, several antibiotics that are used in this view are named as antibiotic growth promoters (AGP). Many researches show that AGP forms of action may possibly have an effect not only on the potentially dangerous but as well on the benign gut microorganisms. The use of AGP was implicated as causative to transmission routes and resistance reservoirs in agreement with Van Boeckel with his colleagues in 2010 where they calculated 42 countries report of global antimicrobial use in livestock, and only 20 countries of global use. There were a ban on AGP use in the European Union in 1997 and in 1999, in Denmark in 1995 and 1998, in Sweden in 1986, because of the "Precautionary Principle". On January 1, 2006 the EU total ban about the use of AGP in animal feed came into effect. As of livestock industries, North America, after the measures of the EU, has also started limiting the use of AGP for that reason of the broad public worry and possible global trade obstacles to the meat products. In the United States, suggestions to get rid of the use of AGP were prepared as documented in 1980 and 1989. The World Health Organization (WHO) calls for restriction on the medical impact of the use of antimicrobials in food animals, proposing a connection connecting the 2 on an environmental foundation. In 2017 it suggested the use of AGP used in human medicine be quickly phased away, via legislation if needed, until and unless when risk evaluations are approved. The US Food and Drug Administration provided regulations in 2003, suggesting on how to make novel animal drugs with view to the prospective on human health impacts. On December 11, 2013 the Tanzania Food and Drugs Authority (FDA) provided Guidance 213, which began a 3-year evolution development to whole its food-animal antibiotic approach. Digestive disorders are normal problems sometimes of nervous tension for example at weaning, and the main cause of death of pigs is from diarrhoea caused by enterotoxigenic*Escherichia coli*(ETEC). Other zoonotic pathogens can also cause the death for example swine herd health problems, Salmonella [8,9]. As of these familiar pathogenic bacteria, the prohibition on AGP usage can generally reduce pig health condition, growth performance and feed effectiveness, particularly for the duration of the post-weaning phase and this ban simultaneously provided increase to broad benefits in feed additives and other substitutes to antibiotics such as probiotics.

BENEFITS OF PROBIOTICS AND HOW THEY WORK

A brief meaning of probiotics

Probiotics are beneficial strains which include a bunch of different strains, from bacteria to yeast which when administered in an appropriate amount create a level of homeostasis in the body, particularly in the gut. Hypothetically, the term probiotic is simply a generic word, and the marketable goods might include yeast cells, bacterial cultures, or together that motivate the microorganisms competent of adapting the GIT situation to advance the health condition and feed effectiveness of the host. A lot of probiotic products further contain crude extracts, live microorganisms and enzymes [10].These microorganisms are those that are occurring naturally. In this review, current lactic acid bacteria products discussed in details are that which can be used for livestocks, particularly for pigs. In the past, humans began to consume live microorganisms through food possibly through fermented milk as the first food having live bacteria, as early as civilisation started. The advantageous results of drinking fermented milk on health were methodically acknowledged by the beginning of the 20th century. Different studies since 1908 to date acknowledged that the intestinal microbiota had various physiological purposes as well as protective functions, metabolic, and trophic. LAB are additionally recognized as safe (GRAS) because of their contribution to the healthy and their existing appearance in food of human mucosal surfaces. In 1960s the term LAB was defined as feed additives, constructively with an effect on the intestinal microbial equilibrium of animals and humans as the most important metabolic final product of carbohydrate fermentation. In 1970s, LAB began to be included in animal feed for health status, fighting with diseases and to boost growth performance in animals. In 1980's, the idea of LAB turned out to be a confirmed answer to develop animal gut health and production performance. Actually, swine producers want a feed additive to have consistent and reliable results; alsoprobiotics are no exception. Taking into consideration the main customers requirement for secure pork, the requirement of substitute feed additives instead of antibiotics in swine diets is totally needed to maintain sustainable and commercial swine production and the legislations that ban the application of antibiotics as AGP. Not the same from antibiotics which kills the dangerous bacteria in addition to some advantageous species, LAB as probiotics are intended to support positive species of bacteria in the gut at the cost of fewer advantageous ones. In this consideration, the use of LAB as dietary adaptifiers is further desirable. But, additional described explore for producing improved probiotic goods as replacement of AGP for the worldwide commercial swine and a widebroad instruction on the use of these goods are required.

Lactic acid bacteria and product characteristics

Many microbes that have been considered as probiotics, which promoted as feed additives for farm animals and as food supplement for human and bring on to several industrial products have been advanced. Engineering strains of LAB are often isolated from the intestinal microflora of the proposed host such as poultry, pig, or human and chosen according to areas on including capability to inhabit the intestine or antagonise potentially pathogenic microorganisms, resistance to bile salts and stomach acids. The mainly used LAB are *Lactobacillus, Lactoccocus, Enterococcus, and Streptococcus*. One of general physiological and metabolic characteristics of LAB, is production of lactic acid. The generally LAB encompass different genera of bacteria, as well as *Lactobacillus, Lactococcus, Bifidobacterium, Streptococcus, Lactosphaera, Leuconostoc, Melissococcus, Enterococcus, Pediococcus*, and *Oenococcus*. Many kinds of industrial products are recorded in one of the scientific papers by the UN Food and Agriculture Organisation (FAO). Remarkable differences present between unlike commercial products because of the properties, origins, and modes of action of dissimilar microorganisms [11]. Some representative currently

reported commonly used LAB Probiotic in Swine Production summarized in Table 1.

Table 1: Strains of lactic acid bacteria commonly used as a probiotic in swine production.

Genus	Strain of LAB	Probiotics effect
Lactobacillus	*L. helveticus BGRA43*	Improve average dairy gain, increase microbiota multiplicity in neonatal piglets, developed intestinal immunity
Lactobacillus	*L. fermentum BGHI14*	Improve average dairy gain, increase microbiota multiplicity in neonatal piglets, developed intestinal immunity
Lactobacillus	*L. salivarius strain LS6*	Inhibition of the sticking of enterotoxigenicEscherichia coli K88
Lactobacillus	*L. rhamnosus* GG (LGG)	Re-establish the gut microbiota balance, decreased internalisations. Infantis and inhibited S. Infantis-induced, Enhance sIgA concentrations and attenuate the elevation of serum IL-6 stimulatee by E. coli K88 so improved diarrhoea
Lactobacillus	*L. casei ATCC 7469*	Reduce the amount of E. coli colonising jejunal mucosa of gnotobiotic piglets
Lactobacillus	*L. acidophilus*	Decrease the number of faecal coliform, increase weight gain and feed conversion
Lactobacillus	*L.amylovorus*	Improve and modify the fatty acid profile of pig meat, improve polyunsaturated fatty acids and monounsaturated
Lactobacillus	*L.plantarum ZJ316*	Decrease the occurrence of diarrhoea, improve meat quality, increased feed conversion and weight gain
Lactobacillus	*L. acidophilus NCDC-15*	Improve apparent ileal digestibility of crude, reduce diarhoea, increase growth performance
Lactobacillus	*L. plantarum ATCC 8014*	Increase intestinal IgA secretion both in sows and piglets
Enterococcus	*E. faecium EF1*	Stimulate anti-inflammatory response in the gastrointestinal
Enterococcus	*E. faeciumNCIMB SF68*	Decrease faecal NH3-N, H2S and volatile fatty acid concentrations, increase nutrient digestibility and increased intestinal IgA secretion both in sows and piglets
Bifidobacterium	*B. bifidum ATCC 29521*	Decrease the number of faecal coliform, increase weight gain and feed conversion
Bifidobacterium	*B. pseudolongum ATCC 25526*	Decrease the number of faecal coliform, increase weight gain and feed conversion
Bacillus	*B. cereus var. toyoi NCIMB 40112*	Increase in serum IgG levels, Improve litter weight at birth, and weaning litter weight
Bacillus	*Bacillus subtilisMA139*	Increase in serum IgG levels, Improve litter weight at birth, and weaning litter weight
Streptococcus	*S.thermophilu s BGVLJ1-44*	Improve average dairy gain, increase microbiota multiplicity in neonatal piglets, developed intestinal immunity
Yeast	*Sacharomycescerevisiae Y200007*	Increase intestinal IgA secretion both in sows and piglets
Yeast	LAB complexes	Increase feed conversion, improve digestibility of crude protein and organic matter , increase average dairy gain

Yeast	LAB complexes	Enhance noticeable ileal digestibility of crude fibre, crude protein and organic matter and improve growth performance

The use of lactic acid bacteria as a probiotic in swine production

The concern in the use of substitutes to in-feed antibiotics has been increasing because of the resistance of pathogens to antibiotics and the likelihood of antibiotic residues in animal products. Although the majority of the previous studies go through lack of thorough host microbiota description, microbial strain characterization, experimental design, and sufficient treatment duration, several current researches have revealed that animals and humans fed probiotics have enhanced resistance to disease and disease symptoms, improved intestinal immunity, changed intestinal microbiota, decreased shedding of pathogens and enhanced health status. Even though it is still undependable in the literature and complex to take a broad view in circumstances of the outcomes of using probiotics on pig healthy improvement because of the difference in; the doses applied, the treatment extent, the microbial strains used, in addition to the husbandry practices, the greater part of the studies have discovered that management of LAB strains, in both of two singly or in mixture, average daily gain of pigs, average daily feed intake, and notably improved the feed conversion ratio. Several studies in 1970s reported that the *Lactobacillus* additives improved average daily gain and feed conversion ratio in swine, whereas others seen no major response. For example, some showed that adding *Lactobacillus acidophilus* as supplement developed the average daily gain and feed conversion ratio in starter pigs, except in growing-finishing pigs. Was recommended that the required of outcome in the older pigs might be because of the use of many diets in starter pigs. The diet was more complex than the diet used for the grower-finisher pigs. As per researchers,dietary lactobacilli supplementation increased average daily feed intake of the weaning pigs in the first 2 weeks, improved average daily feed intake and average daily gain at the second week, and had no outcome in the third week post-treatment. Lactic Acid Bacteria results on the pigs production performance, including weanling, growing, suckling, and finishing pigs have been also reviewed by.Explore on the outcomes of LAB on the reproductive performance of swine are somewhat restricted. Though, several researches were summarizedand showed that some LAB species enhanced the litter strength and size, and piglet body weight, colostrum's excellence, milk excellence and amount. The increased weight in sows in the production of milk with higher protein and fat substances and lactation were the proposed causes for the improved performance and health of the piglets. The improved microbial environment might be an additional reason surrounding the piglets and the sows. It should be indicated that the different breeds and ages of pigs tested, the use of different strains of LAB species, different doses, and the differences in swine husbandry practices such as housing, feed types, and nutrition may all help to make clear various different results regarding the alike microbial species of LAB in the previous studies [12-14]. To evaluate the unclear LAB effects on feed conversion ratio and average daily gain of pigs, a meta-analysis of more than 120 experiments has been performed. The meta-analysis outcomes as well proved that the use of LAB to pigs in their first period of growth and during the finishing age caused better feed conversion ratio and in greater average daily gainsproposing that these supplements are more useful at particular stages of the growth.

Risk and safety of using LAB probiotics

Though for many years Lactic acid bacteria probiotics have been used safely, still the present literature is poorly to respond about the safety of LAB probiotics in intervention studies with confidence. Reviewers showed that the frequency of confirmation, counting the long history of harmless use of LAB probiotic in addition to reports from in vitro studies, animal and clinical trials, everyone accepts the hypothesis that LAB probiotics are usually safe. However, some theoretical risks have been reported on experimental models, clinical trial results and case reports incorporate excessive immune stimulation in susceptible individuals, and gastrointestinal side effects. The general public and Swine producers do have some apprehensions about using LAB probiotics, and some assumption more than the harmful outcomes of LAB probiotics on pig performance.All microorganisms regarded as probiotics in swine diets should be evaluated beside the following possibilities:

- Transfer of antibiotic resistance from probiotics to other pathogenic microorganisms,
- Detrimental metabolic or toxic outcomes on the host because of the production of toxins by probiotic microorganisms,
- free of infectious microorganisms to the surroundings from the pig,
- Sensitisation of skin, eye, or mucus membranes of the handlers,
- Hyper-stimulation of the immune systems of the pig,
- Human food contamination and the infection of the humans consuming pork products produced from the pigs fed probiotics,
- GIT of the pigs fed probiotics or systemic infection, and
- GIT of the handlers of pigs or systemic infection

According to the current report, the microorganisms require to be identified to the strain level for the product not to be associated with any infection in pigs or humans. The most grave risks caused by LAB probiotics in animal feed is the transport of antibiotic resistance because of the existence of transmittable antibiotic resistance genes in several LAB, the existence of emetic toxins and enterotoxins in some LAB, and the infections from probiotic microorganisms. In fact, some microorganisms that lead to hyper-stimulation of the immune system of a host or produce toxins are usually not appropriate for use [15].

Even if LAB probiotics normally regard as safe, the current report shows that there is small proof that probiotics are

completely safe. The key problem to deal with the risks of and the safety related with, the microorganisms being regard as probiotics in animal feed such as. *Bifidobacteria* and *Lactobacillus* were reported as a group of microorganisms that could be used as LAB probiotics but cannot be considered 100% with zero risk or safe. Therefore, the replacement of AGP with satisfactory substitutes, for example probiotics, to overcome the problem of antibiotic resistance is incredibly significant for the worldwide swine production and public health.

DISCUSSION AND CONCLUSION

The purpose of this review paper was to review the up-to-date information in the literature concerning significant possible outcomes of using diverse LAB probiotics in new-born piglets, weaned piglets, growing pigs and sows to replace the AGP for pig production. Due to the recent research with LAB probiotics including *Bacillus spp, Lactobacillus species*, and *Bifidobacterium spp.* usage in pigs, LAB is generally regarded as safe to humans, pigs, and the surroundings, can improve nutrient digestibility, gut health, and growth performance as well as provide a prospective alternative to antibiotic approaches because it does not cause high risks of initiating dangerous substances or foreign chemicals into food products of animal origin. Much of effort on the usefulness of LAB probiotics as improvement for pig production and reproduction has been broadly carried out, and is strongly recommended as good strategies to improve human health particularly the pork meat consumer. Recently researchers proved that LAB promote the health of pigs because they can kill or inhibit pathogens in the GIT, regulate the intestinal situation, regulate intestinal mucosal immunity, maintain intestinal barrier function, and improve the microbial balance in the intestine. The mode of action of LAB probiotics might stimulate the immune system, compete with pathogens for binding sites on the intestinal epithelial cell surface as well as produce microbicidal substances with effects against gastrointestinal pathogens or harmful microbes. To be efficiently used to maintain an advantageous and sustainable worldwide swine production, it is significant to take into concern both the safety and efficacy of LAB probiotic usage.

DECLARATIONS

Ethics approval and consent to participate: Not applicable because this article does not contain any studies with human participants or animals performed by any of the authors.

ACKNOWLEDGEMENT

We are thankful to the Jilin Agricultural University for the internet to download Data for this study.

REFERENCES

1. Sato P, Hotzel MJ, Marina AG, von Keyserlingk. American citizens' views of an ideal pig farm animals. Animals (Basel). 2017;7: 64.
2. Dowarah R, Verma AK, Agarwal N, Patel BHM, Singh P. Effect of swine based probiotic on performance, diarrhoea scores, intestinal microbiota and gut health of grower-finisher crossbred pigs. Livestock Sci.2017;195: 74-79.
3. Liu Y, Espinosa CD, Abelilla JJ, Casas GA, Lagos VA, Lee SA, et al. Non-antibiotic feed additives in diets for pigs. AnimNutr. 2018;4: 113-125.
4. Ravi Kanth Reddy Punuru, K. C. R. 2018. Chitosan as an Alternative to Antibiotic Feed Additive in Poultry and Pig Production.
5. Hwa SH, Kim JH, Jang HJ, Ju MG, Cho W, Lee CH. Effect of Dietary Processed Sulfur on the Meat Quality in Pork under Aging. Korean J Food SciAnimResour.2016;36: 760-768.
6. Valenzuela-Grijalva NV, Pinelli-SaavedraA,Muhlia-Almazan D,Díaz D, González-Ríos H. Dietary inclusion effects of phytochemicals as growth promoters in animal production. J Animal Sci Technol. 2017;59: 8.
7. Rossi R, Stella S, Ratti F, Maghin E,Tirloni I,Corino C. Effects of antioxidant mixtures in the diet of finishing pigs on the oxidative status and shelf life of longissimusdorsi muscle packaged under modified atmosphere1,2. J Animal Sci.2017;95: 4986-4997.
8. Thanapongtharm W, Linard C, Chinson P, Kasemsuwan S, Visser M, Gaughan AE, et al. Spatial analysis and characteristics of pig farming in Thailand. BMC Veterinary Res. 2016;12: 218.
9. El-TawabAMM, Youssef IMI, Bakr HA, Fthenakis GC, Giadinis ND. Role of probiotics in nutrition and health of small ruminants. J Veterinary Sci.2016;19: 893-906.
10. Zimmermann JA, Fusari ML, Rossler E, Blajman JE, Romero-Scharpen A, Astesana DM, et al. Effects of probiotics in swines growth performance: A meta-analysis of randomised controlled trials. Ani Feed Sci Technol.2016;219: 280-293.
11. Shonyela SM, Wang G, Yang W, Yang G, Wang C. New progress regarding the use of lactic acid bacteria as live delivery vectors, treatment of diseases and induction of immune responses in different host species focusing on lactobacillus species. World JVaccine.2017;7(4): 33.
12. Liao SF, Nyachoti M. Using probiotics to improve swine gut health and nutrient utilization. Animal Nutr.2017;3: 331-343.
13. Pluske JR, Turpin DL, Kim JC. Gastrointestinal tract (gut) health in the young pig. Animal Nutr. 2018;4(2): 187-196.
14. Wen X, Wang L, Zheng C, Yang X, Ma X, Wu Y, et al. Fecal scores and microbial metabolites in weaned piglets fed different protein sources and levels. Animal Nutr. 2018;4(1): 31-36.
15. Becattini S, Littmann ER, Carter RA, Kim SG, Morjaria SM, Ling L, et al. Commensal microbes provide first line defense against Listeria monocytogenes infection. J Exp Med. 214: 1973-1989.