ADVANCED DIETARY SYSTEM WITHOUT ANTIBIOTICS IN KOREA'S SWINE INDUSTRY

Subramaniam Mohana Devi and In Ho Kim*
Department of Animal Resource & Science,
Dankook University, No.29 Anseodong, Cheonan,
Choongnam 330-714 South Korea
*Corresponding Author: In Ho Kim
e-mail: inhokim@dankook.ac.kr

ABSTRACT

Antibiotic growth promoters have been widely used in the livestock industry due to their excellent health and growth promotion properties. Recently, the application of dietary supplementation similar to antibiotic had received considerable attention in the pig industry. Dietary supplementation with probiotics like Bacillus subtilis and Enterococcus faecium, prebiotics like Levan-type fructan and essential oils of herbal extract, organic acids and Medium Chain Triglycerides has been used as an alternative source for antibiotics in recent swine industry. An increased interactive effect between energy and nutrient density diet and probiotic was observed on the ADG and G:F ratio, faecal lactobacillus, apparent total tract digestibility and faecal noxious gas content. The beneficial effect of dietary supplementation in pigs could be enhanced with the high energy and nutrient density diets and improves the productivity of animals by producing various useful metabolites under optimal culture conditions. Dietary supplementation with levan-type fructan can improve growth performance, digestibility and fecal Lactobacillus counts, and has a beneficial effect on immune response during an inflammatory challenge in growing pigs and our recent study suggests that levan may have some growth promoting effects similar to antibiotics. Feeding is often the only diversion for pigs. In Korea's Swine industry, both in small and large farms, we use auto feeding and shoulder feeding system for the welfare of sows. Stocking density has a significant impact on growth performance of pigs. Body weight gain and feed intake were decreased when pigs were raised in pens with high stocking density compared with those bred in low stocking density pens. Creep feeding increased growth and feed intake of pigs after weaning. Thus several studies indicate that, dietary supplementation with alternative feed additives (i.e., probiotics, prebiotics, essential oils, organic acids and Medium Chain Triglycerides) similar to antibiotic, can increase growth performance in pigs which in turn improves anti-oxidant, anti-inflammatory and immune-modulatory effects in pigs.

Keywords: Feed Additives, Probiotics, Prebiotics, Essential Oil, Feeding System, Korea Swine Industry

INTRODUCTION

Recent concerns regarding antibiotic resistance and the use of probiotic agents in livestock have resulted in a demand for alternative strategies to improve animal production and health without the need for antibiotics. During the last decade, antibiotic growth promoters have been widely used in the livestock industry due to their excellent health and growth promotion properties. However, owing to the decrease of therapeutic effectiveness of antibiotics for treatment of bacterial infection in humans, the use of antibiotics as feed additives for livestock was completely banned in the European Union in 2006. Therefore, considerable efforts have been devoted towards developing alternatives to stabilize the health and growth performance in livestock. Because of the ban on the sub therapeutic use of antibiotics in some countries, various natural materials such as probiotics, prebiotics, organic acids, zinc, and plant extracts, have been tested as alternatives to antibiotics.

REPLACEMENT FOR ANTIBIOTICS

Probiotics

Recently, the application of probiotics had received considerable attention in the discussion about developing suitable alternative for antibiotic growth promoters in the pig industry (Chen *et al.* 2006; Meng *et al.* 2010; Yan and Kim 2011). However, the effect of probiotics supplementation in practice is highly inconsistent because of the different diet composition, strain differences, dose level, age of the animal, as well as its interactions with environmental factors (Khan *et al.* 2011). Dietary supplementation with *B. subtilis* was found to reduce NH3 emissions in poultry houses by improving the utilization of nitrogen (N). In addition, supplementation of the diets of pigs with *Bacillus spp.* was found to have the potential to reduce malodor in pig feces (Chen *et al.* 2006). Our previous studies indicate that administration of a probiotic in a high-nutrient-density diet could be more effective than a low-nutrient-density diet on the gastrointestinal environment and subsequent nutrient utilization in pigs (Yan and Kim 2013).

Meng *et al.* (2010) also suggested that nutrient density could influence the effect of probiotics in growing pigs (Table 1). It has been suggested that probiotics require some nutrient and energy cost because of their effect on immune cell development and function. It has been recently suggested that dietary *Enterococcus faecium* DSM7134 increased ADG and feed conversion ratio in weaned pigs and finishing pigs. Dietary *E. faecium* DSM 713 increased ADG and feed conversion ratio in weaned pigs and finishing pigs, and it was also suggested that *E. faecium*, normal components of the swine intestinal microbiota, could produce lactic acid to reduce the pH value of the intestinal content and inhibit the development of invasive pathogens. According to Zhang and Kim (2014), the ADG and G:F increased ($p > 0.05$) more dramatically in pigs fed with HD diet with probiotic and an increased - fecal *Lactobacillus* population was observed in pigs fed with probiotic supplemented diets at both week 2 ($p<0.01$) and week 4 ($p = 0.01$) and fecal *E.Coli* decreases ($p = 0.01$) at week 4. In addition, fecal NH3 content also decreases with probiotic treatments (Table 2).

Choi *et al.* (2009), who reported that the inclusion of wood vinegar would increase the amino acid and energy digestibility of weaning pigs by modulating the intestinal microflora. Simitzis *et al.* (2008) documented that phenolic compounds were absorbed and entered the systemic circulatory system after ingestion and had significant antioxidant activity in lamb meat. Previous study also reported that the inclusion of phenolic compound in animal diets led to a greater oxidative stability. B-glucans are structural components of the cell wall of many bacteria, fungi and yeasts, as well as cereal grains such as barley and oats. β-glucans have been well studied in human and animal subjects and their immunity enhancing effects have been noted (Volman *et al.* 2008). Zhang *et al.* (2008), who reported that β-glucan derived from the yeast *S. cerevisiae* supplemented in diets at 50 mg/kg and 75 mg/kg significantly, improved BW and BWG. Kefir is a popular traditional Middle Eastern beverage. It is the product of fermentation of milk with kefir grains and other cultures prepared from grains. Kefir grains contain a complex mixture of lactobacilli, bacteria and yeasts, such that it contains beneficial yeast as well as probiotic bacteria found in yogurt (Otles and Cagindi 2003). Thus, kefir can be defined as a probiotic food ingredient and feed additive. Many studies on the influence of feed supplements mainly focus on their effects on human health and growth rate in pigs.

Prebiotics

Due to the recent ban on the use of dietary antibiotics worldwide, prebiotics had been used as antibiotic growth promoter alternatives to improve the health and growth performance of animals. Zhao *et al.* (2012) reported that dietary supplementation with 1 g levan/kg increased the ATTD of DM compared with non- supplementation treatment in weanling pigs. Several researchers have reported that prebiotics have a positive effect on growth performance without adverse effects on mortality in chickens and pigs (Hooge *et al.* 2004). Several researchers also reported the positive effects of lactulose on colonic metabolism in human, rat, mouse and pig. Lee *et al.* (2009) also demonstrated that supplemental 0.2% synbiotics increased DM and CP digestibility in early-weaning pigs.

Levan-type fructan is considered to be a prebiotic and has a variety of nutritional and pharmaceutical functions (Zhao *et al.* 2012) and having health-promoting effects. Inulin is increasing mineral absorption and improving immune response (Morris and Morris 2012). Use of prebiotics or fermentable sugars may improve the population of useful microbes in the gastrointestinal tract. Fructan supplementation improved growth performance and ATTD of DM and GE, and the fecal microbial balance, and inhibited the fecal *E. coli* and furthermore, fructan may decrease fecal noxious gas emissions in finishing pigs (Zhao *et al.* 2013).The dietary supplementation with 0.10% levan type fructan improved growth performance, digestibility of N and GE, and fecal *Lactobacillus* counts, and had a beneficial effect on the immune response (Table 3) during an inflammatory challenge (Li and Kim 2013). Fructan supplementation improves growth performance and nutrient digestibility, increases fecal *Lactobacillus* concentration, and decreases *E. coli* concentration and noxious gas emission in finishing pigs (Zhao *et al.* 2013). Our recent study suggests that, levan may have some growth promoting effects (Table 4) similar to antibiotics in weanling pigs (Zhang and Kim 2014).

Table 1. Effects of supplementation of high- and low-nutrient-density on total tract digestibility and meat quality in growing-finishing pigs. (Source: Meng *et al.* 2010)

Item	High		Low			P-value		
	+ Pro	− Pro	+ Pro	− Pro	SE[2]	Density	Pro	Density × Pro
0 to 5 wk								
ADG, g	885	820	830	740	21	<0.05	<0.01	0.59
ADFI, g	1,956	1,910	1,905	2,045	37	0.28	0.24	0.18
G:F	0.452	0.429	0.436	0.362	0.015	<0.05	<0.05	0.12
6 to 10 wk								
ADG, g	868	850	808	745	13	<0.01	<0.05	0.29
ADFI, g	2,414	2,369	2,294	2,283	47	0.06	0.56	0.70
G:F	0.360	0.359	0.352	0.326	0.007	<0.05	0.11	0.13
0 to 10 wk								
ADG, g	877	835	819	743	15	<0.01	<0.01	0.40
ADFI, g	2,185	2,139	2,100	2,164	31	0.35	0.77	0.72
G:F	0.401	0.390	0.390	0.343	0.008	<0.01	<0.01	0.07
DM								
wk 5	80.1	77.9	77.1	75.4	1.9	0.56	0.64	0.07
wk 10	79.2	75.7	70.2	66.0	2.0	<0.01	0.87	0.06
N								
wk 5	75.9	72.1	70.1	64.2	2.0	<0.05	<0.01	0.10
wk 10	74.8	73.1	65.2	54.5	2.4	<0.01	0.05	<0.01
Energy								
wk 5	79.2	77.2	72.6	70.2	1.0	<0.01	<0.01	<0.05
wk 10	78.0	76.1	74.4	70.3	1.9	<0.01	0.31	0.07
Meat quality score[3]								
Color	3.75	3.13	2.63	1.88	0.15	<0.01	<0.01	0.64
Marbling	1.50	1.63	1.50	2.25	0.10	<0.05	<0.01	0.54
Firmness	2.13	1.50	1.63	2.25	0.20	0.56	1.00	<0.01
Meat color[4]								
Lightness	47.78	48.76	54.81	57.62	0.86	<0.01	0.05	0.37
Redness	17.84	16.03	16.99	16.30	0.32	0.40	<0.01	0.12
Yellowness	5.65	6.05	7.13	7.60	0.36	<0.01	0.26	0.92
WHC,[5] %	52.42	48.19	54.74	48.84	2.79	0.61	0.10	0.78
Drip loss, %	20.16	35.24	15.78	15.26	4.64	<0.05	0.17	0.54
Cook loss, %	18.17	17.06	18.52	18.54	0.61	0.18	0.41	0.32
pH	6.06	5.70	5.67	5.65	0.10	0.05	0.08	0.16
LM area,[6] cm^2	42.72	40.78	39.91	38.45	1.64	<0.05	0.43	0.26
TBARS,[7] mg of malonaldehyde/kg	0.06	0.05	0.04	0.04	0.00	0.80	0.13	0.52

[1]Ninety six pigs with an initial BW of 47.50±1.14 kg. Each mean represents 6 pens, with 2 gilts and 2 barrows/pen. High = high-energy and high-nutrient-density diet plus (+) or minus (−) 0.2% Pro; low = low-energy and low-nutrient-density diet plus (+) or minus (−) 0.2% Pro.
[2]Pooled SE.
[3]Color score: 1 = pale gray, to 5 = dark purplish red; marbling score: 1 = devoid to practically devoid, to 5 = moderately abundant or greater; firmness core: 1 = very soft and very watery, to 5 = very firm and dry (National Pork Producers Council, 1991).
[4]Lightness = measure of lightness to darkness (larger number indicates a lighter color); redness = measure of redness (larger number indicates
a more intense red color); and yellowness = measure of yellowness (larger number indicates more yellow color).
[5]WHC = water-holding capacity.
[6]LM area = LM area at the 10th rib.
[7]TBARS = 2-thiobarbituric acid-reactive substances.

Table 2. Effects of Bio Plus 2B® supplementation on growth performance and coefficients of total tract apparent digestibility (CTTAD) on dry matter (DM) and nitrogen (N) in growing pigs.

Item	CON[a]	B0.05 [a]	B0.1 [a]	B0.2 [a]	SE[b]	P-values [c]	
						L	Q
ADG, kg	0.769	0.785	0.782	0.798	0.0221	0.08	0.53
ADFI, kg	1.491	1.499	1.536	1.560	0.0232	0.03	0.72
G:F	0.516	0.524	0.509	0.516	0.0167	0.12	0.57
DM	0.821	0.817	0.813	0.811	0.0062	0.23	0.94
N	0.829	0.822	0.833	0.844	0.0091	0.19	0.35

(Source: Wang *et al.* 2009)

Table 3. Effects of levan-type fructan and *Escherichia coli* lipopolysaccharide (LPS) challenge on rectum temperature, serum cortisol, TNF-α, IL-6, and IGF-I concentrations in growing pigs

LPS			Levan-type fructan			P-value		
Items	**With**	**Without**	**With**	**Without**	**SE**	**LPS**	**Fruton**	**Interaction**
Temperature, °C								
Initial	40.4	40.2	40.3	40.3	0.16	0.37	0.59	0.55
2h	41.4	40.3	41.0	40.7	0.50	0.02	0.28	0.02
2 h	41.4	40.3	41.0	40.7	0.50	0.02	0.28	0.62
4 h	41.5	40.1	40.8	40.8	0.57	0.02	0.64	0.01
6 h	41.1	40.3	40.6	40.9	0.41	0.11	0.75	0.62
8 h	40.9	40.4	40.7	40.6	0.34	0.28	0.79	0.40
Cortisol, μg/Dl								
Initial	3.4	4.8	3.9	4.3	1.24	0.08	0.56	0.15
2 h	13.7	5.1	7.6	11.1	1.24	<0.01	0.83	<0.01
4 h	15.2	6.3	9.8	11.7	1.39	<0.01	0.72	<0.01
6 h	17.2	6.8	11.1	12.9	3.14	<0.01	0.46	0.03
8 h	13.9	7.1	8.6	12.4	1.65	<0.01	0.03	0.02
TNF-α, PG/mL								
Initial	174	168	175	167	16	0.13	0.53	0.09
2 h	1,605	176	963	819	122	<0.01	0.07	<0.01
4 h	1,890	178	869	1199	132	<0.01	0.02	<0.01
6 h	1,995	179	947	1227	102	<0.01	0.03	<0.01
8 h	1,884	136	845	1176	262	<0.01	0.02	<0.01
IL-6, PG/mL								
Initial	16	16	14	18	1.5	0.83	0.69	0.06
2 h	5,472	17	2,585	2,904	221	<0.01	0.73	<0.01
4 h	5,929	16	2,695	3,250	291	<0.01	0.21	<0.01
6 h	5,412	15	2,040	3,387	364	<0.01	<0.01	<0.01
8 h	3,967	17	1,675	2,309	257	<0.01	0.02	<0.01
IGF-I, ng/mL								
Initial	200.3	155.8	169.3	186.8	26.2	0.34	0.48	0.02
2 h	181.2	151.9	175.4	157.6	18.9	0.29	0.72	0.15
4 h	181.6	145.9	161.9	165.6	16.2	0.10	0.25	0.33
6 h	172.2	128.3	148.7	151.8	24.0	0.63	0.43	0.87
8 h	147.5	121.7	135.5	133.7	21.5	0.41	0.59	0.92

(Source: Li *et al.* 2013)

Table 4. Effects of levan on growth performance in weanling pigs

Item	-Levan		+ Levan		SEM	P-Value	
	ANT	+ ANT	ANT	+ANT		Levan	ANT
D 0-14							
ADG, g[c]	238	271	269	300	13.2	<0.05	<0.05
ADG, g[c]	308	334	325	351	22.4	0.73	0.62
G:F[c]	0.773	0.811	0.828	0.855	0.026	0.86	0.91
D 15-28							
ADG, g	436	516	489	512	21.4	0.47	<0.05
ADG, g	740	737	776	783	38.5	0.68	0.93
G:F	0.589	0.700	0.630	0.654	0.018	0.27	<0.05
D 0-28							
ADG, g	337	393	379	406	18.2	<0.05	<0.05
ADG, g	524	535	551	567	33.3	0.78	0.61
G:F	0.643	0.735	0.688	0.716	0.020	0.54	<0.05

(Source: Zhang and Kim 2014).

EO led to a significant increase in the digestibility of DM, N and energy at the end of the 6th week, which was in agreement with Cho *et al.* (2006), who reported that the digestibility was increased by the essential oil supplementation. Kwon *et al.* (2005) suggested that a plant mixture had positive effects on meat quality in a growing–finishing pig. Jang *et al.* (2007) also suggested that EO can stimulate activities and secretion of digestive enzymes including amylase and pancreas, respectively. Dietary supplementation with CHE could increase blood erythrocytes counts and improve meat quality in growing-finishing pigs (Zhou, *et al.* 2013). The *Coptis Chinesis* has good antioxidant properties (Wang *et al.* 2008), which can reduce the oxidative stress on meat.

Organic acid

The use of acidifiers as potential alternatives to antibiotics in the diets of swine has been evaluated, and many studies have confirmed their positive effects on growth performance in post weaning pigs (Partanen and Mroz 1999). Acidifiers may function by exerting antimicrobial activity that can reduce the pathogenic flora of the gut, which would have beneficial effects on the utilization of nutrients (Walsh *et al.* 2007). Phenyl lactic acid (PLA) is an organic acid that is produced as a result of phenylalanine metabolism, and recently, it has been found in the culture of a strain of *Lactobacillus plantarum.* In addition to its antimicrobial effects, l-PLA is also utilized as a source of phenylalanine for pigs and has shown to be capable of replacing 70.1% of the phenylalanine while promoting the growth performance of chicks and mice (Wang *et al.* 2009).

The addition of organic acids to pig diets has been examined for decades, and it has been clearly demonstrated that the addition of organic acids can improve the growth performance of early weaned pigs. For example, Walsh *et al.* (2007) demonstrated that addition of 0.4% organic acid blend (fumaric, lactic, propionic, citric, and benzoic acids) to the diets of nursery pigs resulted in better growth rate, feed intake, and feed efficiency. Overland *et al.* (2007) reported that pigs fed different organic acids (1.0% formic acid, 0.85% benzoic acid, or 0.85% sorbic acid) had fewer lactic acid bacteria in the gastrointestinal tract. Several feed additives including acidifiers, enzymes, probiotics, plant extracts have been introduced in the pig industry as nutritional tools to improve the growth performance of growing-finishing pigs. BA is an acidifier which has also been reported to have positive effects on reducing ammonia emission and increasing weight gain in pigs (Cheong 2006).

Medium Chain Triglycerides (MCT)

Medium-chain triglycerides (MCTs) are high-chain (6 to 12 carbons) fatty acid esters of glycerol. The fatty acids found in MCTs are called medium-chain fatty acids (MCFAs), such as caproic acid (C6), caprylic acid (C8), capric acid (C10) and lauric acid (C12). They are digested, absorbed and metabolized differently from long-chain fatty acids (LCFAs), which include fatty acids of 12 to 22 carbons, because MCFAs are absorbed directly into portal circulation and transported to the liver for rapid oxidation (Odle 1998). MCFAs can rapidly supply energy for the newborn piglets (Lee and Chiang 1994). Also, MCFAs were reported to have antibacterial function as the similar way showing by the short-chain fatty acids (Skrivanova *et al.* 2006).

FEEDING SYSTEM FOR SOW WELFARE AND STOCK DENSITY TO IMPROVE HEALTH STATUS OF PIG

Feeding is often the only diversion for pigs in an industrial farm environment. The EU directive 2001/88/EG regulates that, from January 2013, every pregnant sow must be group housed. Electronic feeding is a common feeding technique for group housing. The animal recognition and management is performed using radio-frequency identification (RFID) earmarks. Use of electronic feeding stations (ESF), allows accurate individual sow feeding to occur, while easy identification of sick or off-feed sows can occur quickly. Generally, sows housed in a group will be tagged individually with ear tag transponders and have access to an electronic feeder station. Only one sow is allowed to consume feed at a time, and when the sow's daily allotment of feed has been consumed, no more feed is dispensed. Sows are not fed at once; therefore, aggression and fighting occur while sows are waiting their turn to enter the feeder. This system does require a much greater level of management, especially when initially training gilts and sows to utilize the ESF, and a backup plan is needed in case the feeding system should fail. In Korean Swine industry, both in small and large farms, we use auto feeding and shoulder feeding system for the welfare of sows.

Sow Group system

Growing pigs are often kept in barren, crowded conditions on slatted concrete floors without straw for bedding or rooting. These pigs have no access to outdoors and will never experience fresh air or daylight. They are unable to behave naturally and are likely to be bored and frustrated. They tend to fight and to bite each other, sometimes causing severe injury. About 70% of the breeding sows are kept in stalls during gestation. The ongoing welfare debate about stall housing has led to the examination of alternative housing systems for breeding sows.

Stock density

Stocking density (i.e., the number of animals per pen) is an important determinant of barn design. Growth performance of pigs housed individually in ideal experimental environments is generally higher than that of their commercial group-housed counterparts (Kerr *et al.* 2005). Stocking density has a significant impact on growth performance of pigs. Body weight gain and feed intake were decreased when pigs were raised in pens with high stocking density compared with those bred in low stocking density pens (Cho *et al.* 2010). Under commercial conditions, because marginal profit increases with the size of pig operations (Martin and Kruja 2000), the pork industry is shifting toward larger production units. Housing pigs in large numbers and groups is a means of reducing housing costs and simplifying some aspects of management challenges. The provision of an adequate space allowance gives pig a sufficient space for drinking, lying and feeding. High stocking density may cause a behavioral problem for pigs. At higher stocking densities, the likelihood of heightened aggression, competition and disease outbreak rapidly rises, and when this happens, the negative relationship between space and growth becomes even worse (Lebret *et al.* 2006). Curtis (1996) reported that the reduction in feed intake found in large groups of pigsmay be caused by an increase in social pressure in larger as compared to smaller groups.

Stressors existing in swine production systems would include cold/hot environmental temperatures. These stressors cause growth retardation, changes in hormone release, increases in disease susceptibility, and/or behavioral changes. Also, physiological response to stressors (such as heat and spacial restriction) results in activation of the sympathetic nervous system and release of catecholamines and then glucocorticoids reduce body weight (Breinekova *et al.* 2006). Pig performance being subjected to stressors is common in commercial swine production. Stress may cause oxidative changes due to an increase in reactive oxygen species (ROS) or a decrease in the antioxidant status (Lykkesfeldt and Svendsen 2007).

Effect of stocking density on reproductive performance

Rutledge (1980) reported that there was gilts allowance in small groups (six pigs) with an average of 11 piglets given birth to whereas gilts reared in a larger group (ten pigs) had an average of ten pigs given birth to. Kuhlers *et al.* (1985) selected gilts at about 30 kg and reared them in pens of eight or 16 pigs. Gilts reared in the smaller groups were more than the total pigs given birth to with 1.0. When comparing gilts raised in litters of either five or ten pigs, Kirkpatrick and Rutledge (1988) found that gilts in small litters had 1.1 more embryos at day 30 post-mating.

Effect of stocking density on growth performance

Stocking density has a significant impact on growth performance. Stocking rate can have a major effect on feed intake as shown by Brumm and Gonyou (2001) who found that a major response to space restrictions was a decrease in feed intake. Stocking density allowances were seen excessively in pigs which have been shown to be necessary for maximum performance (Edwards *et al.* 1988).When growing-finishing pigs are given less than optimal space per pig, feed intake always decreases (Brumm *et al.* 2001), often resulting in a reduction in average daily gain (ADG), with variable effects on the gain: feed ratio (G: F). Social interaction with another pig reduces growth performance and feed intake regardless of stocking density. Swine producers try to maximize profits by minimizing both performance retardation and underutilized space. Crowding stress deleteriously affects the growth performance of pigs.

Creep feeding

Generally, creep feeding begins largely as an exploratory or social activity, and is then increasingly driven by nutrient demand as the piglet's mature (Pajor *et al.* 1991). English (1981) have suggested that sufficient intake of creep feed during lactation created a gradual transition at weaning and reduced the occurrence of post-weaning disorders. Pajor *et al.* (1991) reported that difference in the absolute amount of creep feed consumption before weaning resulted in differences on the performance. Therefore, indentifying factors that can increase creep feed consumption may elicit positive effect of creep feed on nursery performance.

Piglets are given creep feed to fill the gap between their increasing nutrients requirement and nutrients supplied by the lactating sow because of the declining milk production, which may be insufficient to meet the steadily increasing demands from growing piglet. Generally, commercial recommendations on when to initiate creep feeding as early as 2 to 3 day of age to induce piglets to consume solid feed and achieve greater total creep feed consumption throughout lactation. Various studies have demonstrated the beneficial effect of creep feed on post-weaning performance, which is highly dependent on the absolute amount of creep feed consumption (Carstensen *et al.* 2005). Recently, Sulabo *et al.* (2010) suggested creep feeding duration for 13 day (lactation period = 21 d) produced 10% unit more eaters than litters fed creep feed for 6 and 2 day. Therefore, the duration of creep feeding could be an important factor in stimulating more pigs to consume more creep feed and subsequently greater daily gains. Therefore, creep diet composition could be a factor affecting piglet during lactation. It is well suggested that organoleptic properties of the feed may be a dietary factor that can reduce feed neophobia and influence the creep feed consumption. Feed flavors are commonly used in nursery diets to improve diet acceptance and stimulate feed intake (Sulabo *et al.* 2010). Langendijk *et al.* (2007) also found administration of flavor to the creep feed may enhance post weaning responses when the same flavor is added to the nursery diets. Therefore, providing flavors to the creep feed may be a new method to improve pre- and post-weaning feed intake and performance.

CONCLUSION

In conclusion, prebiotic, probiotic, essential oil, organic acid and MCT supplementation improved growth performance and nutrient digestibility, increased the fecal *Lactobacillus* concentration, and decreased the *E. coli* concentration and noxious gas emission in finishing pigs. Stocking density has a significant impact on growth performance of pigs. Body weight gain and feed intake were decreased when pigs were raised in pens with high stocking density compared with those bred in low stocking density pens. Creep feeding increased growth and feed intake of pigs after weaning. Dietary supplementation with alternative feed additives would increase growth promoting effects similar to antibiotics in pig industry. Future researches are needed to evaluative this performance by conducting experiments using alternative supplementation.

REFERENCE

Anna, Z., K. Edyta, R. Eugenius and P. Grela. 2009. The effect of a herbal extract used in pig fattening on the animals' performance and blood components. *Annales Universitatis mariae curie skłodowska lublin polonia* 27-33.

Breinekova, K., M. Svoboda, M. Smutna and L. Vorlova. 2006. Markers of acute stress in pigs. *Physiology Research* 56: 323–329.

Brumm, M.C and H.W. Gonyou 2001. Effects of facility design on behavior and feed and water intake. Swine Nutrition, *A. J. Lewis, L. L. Southern (ed), CRC Press*, New York. pp. 499–518.
Carstensen, L., A. K. Ersboll, K. H. Jensen and J. P. Nielsen. 2005. *Escherichia coli* post-weaning diarrhea occurrence in piglets with monitored exposure to creep feed. *Veterinary Microbiology* 110:113-123.
Chen, Y.J., B.J. Min J.H. Cho, O.S. Kwon, K.S. Son, H.J. Kim and I.H. Kim. 2006. Effects of dietary Bacillus-based probiotic on growth performance, nutrients digestibility, blood characteristics and fecal noxious gas content in finishing pigs. *Asian-Australiasian Journal of Animal Science* 19:587-592.
Cheong, J.Y 2006. Effects of various alternative growth promoters on growth performance, apparent digestibility and fecal characteristics in growing-finishing pigs. Master thesis, University name, City, County.
Cho, J. H., H. J. Monegue, M. D. Lindemann and G. L. Cromwell. 2010. Influence of crowding stress during the nursery period on growth performance of gilts and barrows. *Journal of Animal Science* 88:736.
Cho, J. H., Y. J. Chen, B. J. Min, H. J. Kim, O. S. Kwon, K. S. Shon, I. H. Kim, S. J. Kim and A. Asamer. 2006. Effects of essential oils supplementation on growth performance, IgG concentration and fecal noxious gas concentration of weaned pigs. *Asian-Australasian Journal of Animal Science* 19:80-85.
Choi, J.Y., P.L. Shinde, I.K. Kwon, Y.H. Song and B.J. Chae. 2009. Effect of Wood Vinegar on the Performance, Nutrient Digestibility and Intestinal Micro flora in Weanling Pigs. http://www.highbeam.com/doc/1G1-195919166.html.
Craveiro, A. A., A. G. Fernandes, C. H. S. Andrade, F. J. A. Matos and J. W. Alencar. 1977. Óleosessenciais de canelassilvestresregionais. *Ciênc Cult (SaoPaulo)* 29:455.
Curtis, S.E 1996. Effects of environmental design on the pig's voluntary feed intake. In: Proc. Pork Industry Conference. *Univers Illinois* 60–73.
Czech, E., E. Kowalczuk and R. Grela. 2009. The effect of a herbal extract used in pig fattening on the animals' performance and blood components. *Annales Universitatis Mariae Curie-Sklodowska* 27: 25–33.
Edwards, S.A, A.W. Armsby and H.H. Spechter.1988. Effects of floor area allowance on performance of growing pigs kept on fully slatted floors. *Animal Production* 46: 453–459.
Hooge, D. M., H. Ishimaru and M.D. Sims. 2004: Influence of dietary Bacillus subtilis C-3102 spores on live performance of broiler chickens in four controlled pen trials. *Journal of Applied Poultry Science* 13: 222-228.
Jang, I.S., Y.H. Ko, H.Y. Yang, J.S. Ha, J.Y. Kim, S.Y. Kang, D. H. Yoo, D.S. Nam, D.H. Kim and C.Y. Lee. 2004. Influence of essential oil components on growth performance and the functional activity of the pancreas and small intestine in broiler chickens. *Asian-Australasian Journal of Animal Science* 17 (3): 394–400.
Jang, I.S., Y.H. Ko, S.Y. Kang and C.Y. Lee. 2007. Effect of a commercial essential oil on growth performance, digestive enzyme activity and intestinal microflora population in broiler chickens. *Animal Feed Science Technology* 134: 304–315.
Jee, Y. C., A. L. Jung, B. L. Jee, J. Y. Sook and C. L. Seung. 2010. Anti-inflammatory activity of *Houttuyniacordata* against lipoteichoic acid-induced inflammation in human dermal fibroblasts. *Chonnam Medical Journal* 46:140-147.
Kerr, C. A., L. R. Giles, M. R. Jones and A. Reverter. 2005. Effects of grouping unfamiliar cohorts, high ambient temperature and stocking density on live performance of growing pigs. *Journal of Animal Science* 83:908-915.
Khan, S.H., M. Atif, N. Mukhtar, A. Rehman and G. Farid. 2011. Effects of supplementation of multi-enzyme and multispecies probiotic on production performance, egg quality, cholesterol level and immune system in laying hens. *Journal of Applied Animal Research* 39:386-398.
Kim, J. S., Y. S. Kwon, W. J. Chun, T. Y. Kim, J. Sun, C. Y. Yu and M. J. Kim. 2010. *Rhusverniciflua*Stokes flavonoid extracts have anti-oxidant, anti-microbial and -glucosidase inhibitory effect. *Food Chemistry* 120:539-543.
Kirkpatrick, B.W and J.J. Rutledge 1988. Influence of prenatal and postnatal fraternity size on reproduction in swine. *Journal of Animal Science* 66: 2530–2537.
Kong, X. F., G. Y. Wu, Y. P. Liao, Z. P. Hou, H. J. Liu, F. G. Yin, T. J. Li, R. L. Huang, Y. M. Zhang, D. Deng, P. Kang, R. X. Wang, Z. Y. Tang, C. B. Yang, Z. Y. Deng, H. Xiong, W. Y. Chu, Z. Ruan, M. Y. Xie and Y. L. Yin. 2007. Effects of Chinese herbal ultra–fine powder as a dietary additive on growth performance, serum metabolites and intestinal health in early-weaned piglets. *Livestock Science* 108:272-275.
Kuhlers, D.L., S.B. Jungst, D.N. Marple and C. Hardin Rahe 1985. The effect of pen density during rearing on subsequent reproductive performance in gilts. *Journal of Animal Science* 61: 1066–1069.
Kwon, O.S., J.H. Cho, B.J. Min, H.J. Kim, Y.G. Chen, J.S. Yoo, I.H. Kim, J.C. La and H.K. Park. 2005. Effect of supplemental medicinal plants (Artemisia, Acanthopanax and garlic) on growth performance, IGF-1 and meat quality characteristics in growing–finishing pigs. *Korean Journal for Food Science of Animal Resource* 25: 316–321.
Langendijk, P., J. E. Bolhuis and B. F. A. Laurenssen. 2007. Effects of pre- and post-natal exposure to garlic and aniseed flavor on pre- and post-weaning feed intake in pigs. *Livestock Science* 108:284-287.

Lebret, B., M.C. Meunier-Salaün, A. Foury, P. Mormède, E. Dransfield and J.Y. Dourmad. 2006. Influence of rearing conditions on performance, behavioral, and physiological responses of pigs to preslaughter handling, carcass traits, and meat quality. *Journal of Animal Science* 84: 2436–2447.

Lee, H. F. and S. H. Chiang. 1994. Energy value of medium-chain triglycerides and their efficacy in improving survival of neonatal pigs. *Journal of Animal Science* 72:133-138.

Lee, J.S., I.S. Kim, J.H. Kim, J.S. Kim, D.H. Kim and C.Y. Yun. 2008. Suppressive effects of HouttuyniacordataThunb (Saururaceae) extract on Th2 immune response. *Journal of Ethnopharmacology* 117: 34:40.

Lee, S. J., N.H. Shin, J.U. Ok, H.S. Jung, G.M. Chu, J.D. Kim, I.H. Kim, S.S. Lee. 2009. Effects of dietary synbiotics from anaerobic microflora on growth performance, noxious gas emission and fecal pathogenic bacteria population in weaning pigs. *Asian-Australian Journal of Animal Science* 22: 1202:1208.

Li, J. and I. H. Kim. 2013. Effects of levan-type fructan supplementation on growth performance, digestibility, blood profile, fecal microbiota, and immune responses after lipopolysaccharide challenge in growing pigs. *Journal of Animal Science* 91:5336-5343

Lykkesfeldt, J and O. Svendsen. 2007. Oxidants and antioxidants in disease: oxidative stress in farm animals. *Vet J* 173: 502–511.

Martin, L and Z. Kruja. 2000. The Western Canada Advantage Advances in Pork Production. *Banff Pork Seminar* 11: 17–36

Meng, Q.W., L. Yan, X. Ao, T. X. Zhou, J. P. Wang, J. H. Lee, and I. H. Kim. 2010. Influence of probiotic in different energy and nutrient density diets on growth performance, nutrient digestibility, meat quality, and blood characteristics in growing finishing pig. *Journal of Animal Science* 88: 3320–3326.

Morris, C. and G. Morris. 2012. The effect of inulin and fructo-oligosaccharide supplementation on the textural, rheological and sensory properties of bread and their role in weight management. *A review Food Chemistry* 133:237-248.

Odle, J. 1998. Medium-chain triglycerides: a unique energy source for neonatal pigs. *Pig News Info* 20:25-32.

Ooi, L. S., Y. Li, S. L. Kam, H. Wang, E. Y. Wong and V. E. Ooi. 2006. Antimicrobial activities of cinnamon oil and cinnamaldehyde from the Chinese medicinal herb *Cinnamomum cassia* Blume. *American Journal of Chinese Medicine* 34:511-522.

Otles, S and O. Cagindi. 2003. Kefir: a probiotic dairy-composition, nutritional and therapeutic aspects. *Pakistan Journal of Nutrition* 2: 54–59.

Overland, M., N. P. Kjos, M. Borg, E. Skjerve, and H. Sorum. 2007. Organic acids in diets for entire male pigs: Effect on skatole level, microbiota in digesta, and growth performance. *Livestock Science* 115:169-178.

Pajor, E. A., D. Fraser and D. L. Kramer. 1991. Consumption of solid food by suckling piglets: Individual variation and relation to weight gain. *Applied Animal Behaviour Science* 32:139-155.

Partanen, K., and Z. Mroz. 1999. Organic acids for performance enhancement in pig diets. *Nutrition Research Review* 12:117–145.

Rutledge, J.J. 1980. Fraternity size and swine reproduction. I. Effect on fecundity of gilts. *Journal of Animal Science* 51: 868–870.

Simitzis, P.E., S.G. Deligeorgis, J.A. Bizelis, A. Dardamani, I. Theodosiou and K. Fegeros. 2008. Effect of dietary oregano oil supplementation on lamb meat characteristics. *Meat Science* 79: 217-223.

Skrivanova, E., M. Marounek, V. Benda and P. Brezinia. 2006. Susceptibility of *escherichia coli*, *salmonella sp.* and clostridium perfringens to organic acids and monolaurin. *Veterinary Medicine Czech* 51:81-88

Sulabo, R. C., M. D. Tokach, E. J. Wiedmann, J. Y. Jacela, J. L. Nelssen, S. S. Dritz, J. M. DeRouchey and R. D. Goodband. 2010. Effects of varying creep feeding duration on preweaning performance and the proportion of pigs consuming creep feed. *Journal of Animal Science* 88:3154-3162.

Volman, J.J., J.D. Ramakers and J.Plat. 2008. Dietary modulation of immune function by β-glucans. *Physiology and behavior* 94: 276–284.

Walsh, M. C., D. M. Sholly, R. B. Hinson, K. L. Saddoris, A. L. Sutton, J. S. Tadcliffe, R. Odgaard, J. Murphy, and B. T. Richert. 2007. Effects of water and diet acidification with and without antibiotics on weanling pig growth and microbial shedding. *J Anim Sci* 85:1799-1808.

Wang, Q., H. J. Kim, J. H. Cho, Y. J. Chen, J. S. Yoo, B. J. Min, Y. Wang and I. H. Kim. 2008. Effects of phytogenic substances on growth performance, digestibility of nutrients, fecal noxious gas content, blood and milk characteristics and reproduction in sows and litter performance. *Journal of Animal Feed Science* 17:50-60.

Wang, Y., Y. J. Chen, J. H. Cho, J. S. Yoo, Q. Wang, Y. Huang, H. J. Kim and I. H. Kim. 2007. The effects of dietary herbs and coral mineral complex on growth performance, nutrient digestibility, blood characteristics and meat quality in finishing pigs. *Journal of Animal Feed Science* 16:397-407.

Windisch, W., K. Schedle, C. Plitzner and A. Kroismayr. 2008. Use of phytogenic products as feed additives for swine and poultry. *Journal of Animal Science* (86): 140–148.

Yan, L and I. H. Kim. 2013. Effect of probiotics supplementation in diets with different nutrient densities on growth performance, nutrient digestibility, blood characteristics, faecal microbial population and faecal noxious gas content in growing pigs. *Journal of Applied Animal Research* 41:23–28.

Yan, L., J. P. Wang, H. J. Kim, Q. W. Meng, X. Ao, S. M. Hong and I. H. Kim. 2010. Influence of essential oil supplementation and diets with different nutrient densities on growth performance, nutrient digestibility, blood characteristics, meat quality and fecal noxious gas content in grower–finisher pigs. *Livestock Science* 128:115-122.

Yan, L., Q. W. Meng and I. H. Kim. 2011. The effect of an herb extract mixture on growth performance, nutrient digestibility, blood characteristics and fecal noxious gas content in growing pigs. *Livestock Science* 141:143-147.

Yan, L., Q. W. Meng and I. H. Kim. 2012. Effect of an herb extract mixture on growth performance, nutrient digestibility, blood characteristic, and fecal microbial shedding in weaning pigs. *Livestock Science* 145:189-195.

Zhang, B.Y.,Y. Guo and Z. Wang. 2008. The modulating effect of β-1,3/1,6-glucan supplementation in the diet on performance and immunological responses of broiler chickens. *Asian-Austrasian Journal of Animal Science* 21: 237-244.

Zhang Z.F. I.H. Kim. 2014. Effects of levan supplementation on growth performance, nutrient digestibility and fecal dry matter content in comparison to apramycin (antibacterial growth promoter) in weanling pigs. *Livestock Science* 159: 71–74.

Zhao, P. Y., J. H. Jung, and Kim, I. H. 2012. Effect of mannan oligosaccharides and fructan on growth performance, nutrient digestibility, blood profile, and diarrhea score in weanling pigs. *J Anim Sci* 90:833-839.

Zhao, P. Y., J. P. Wang and I. H. Kim. 2013. Evaluation of dietary fructan supplementation on growth performance, nutrient digestibility, meat quality, fecal microbial flora, and fecal noxious gas emission in finishing pigs. *Journal of Animal Science* 91:5280–5286.

Zhao, P.Y., J.H. Jung and I.H. Kim. 2012. Effect of mannan oligosaccharides and fructan on growth performance, nutrient digestibility, blood profile, and diarrhea score in weanling pigs. *Journal of Animal Science* 90: 833–839.

Zhang Z.F. and I.H. Kim. 2014. Effects of Enterococcus faecium DSM 7134 supplementation in different energy and nutrient density diets on growth performance, nutrient digestibility, blood profiles, fecal microbiota and fecal noxious gas contents in weanling pigs. *Livestock science* In press.