Effect of medium chain fatty acids (MCFA) and probiotic (*Enterococcus faecium*) supplementation on the growth performance, digestibility and blood profiles in weanling pigs

S. Mohana Devi, I.H. Kim

Dankook University, Cheonan, Chungnam, Republic of Korea

ABSTRACT: The objective of the present study was to evaluate the effects of MCFA and probiotic (*Enterococcus faecium* DSM 7134) supplementation on growth performance, nutrient digestibility, blood profiles, faecal score, excreta microbiota, and excreta noxious gas emission in weanling pigs. A total of 140 weanling pigs [(Yorkshire × Landrace) × Duroc] were allotted to four treatments groups of seven replicates/treatment and five pigs/replicate. The four experimental diets included: CON diet (basal diet); T1 (CON + MCFA 0.2%); T2 (CON + probiotic 0.01%) and T3 (CON + MCFA 0.2% + probiotic 0.01%). Growth performance, average daily gain (ADG), average daily feed intake (ADFI), gain-to-feed ratio (G : F), Nutrient digestibility: dry matter (DM), nitrogen (N), energy were determined along with blood profiles: glucose, blood urea nitrogen (BUN), creatinine, high density lipoprotein (HDL), low density lipoprotein (LDL), total cholesterol, triglyceride, Excreta bacteria: *Lactobacillus, E. coli,* Excreta gas emission: NH_3, H_2S, total mercaptans, acetic acid and faecal scores. Overall, average daily gain (ADG) and G : F in T2 and T3 treatment groups was higher than in T1 and controls. In blood profiles, glucose levels were found to be increased in week two and six in the treatment groups compared to controls. In addition, the nutrient digestibility of DM, N and energy were found to be increased significantly in T2 and T3 when compared to T1 and controls. There was no significant difference observed between the groups for faecal score, microflora and noxious gas emission. In conclusion, dietary MCFA and probiotic supplementation in weanling pigs are efficacious alternatives to antibiotics, and can improve health status and performance.

Keywords: MCFA; pigs; performance; digestibility; probiotics

Antibiotics have been commonly used as growth promoters in animal feed (Barton 2000). However, in 2006, the use of antibiotics as growth promoters was forbidden in the EU (Chen et al. 2005) and as an expansion of this policy to other countries can now be expected, intensive research is focused on the development of alternative strategies with the aim to maintain animal health and performance (Chen et al. 2005; Bomba et al. 2006; Castillo et al. 2008). According to Giang et al (2010), piglets fed with probiotic complex diets had higher feed intake, daily gain and better feed conversion after weanling. Likewise, Inclusion of *Enterococcus faecium* (10^8 CFU/g) significantly improved growth and feed conversion ratio in weanling pigs (Malloa et al 2010). Our previous studies have confirmed that the efficacy of probiotics in pigs was influenced by dietary energy and nutrient density (Meng et al. 2010; Yan and Kim 2013).

The weanling period is one of the most critical stages in the life cycle of pigs as animals show many social, environmental, and dietary changes in a short span of time. The combination of these circumstances generally results in disease for most animals, mostly different bacterial and viral illnesses (Wallgren and Melin 2001). Early-weaned piglets are exposed to several stress factors, with nutrition, aetiology and indoor housing environment particularly implicated (Laine et al. 2008). Organic acids have been suggested to improve performance in pigs (Partanen and Mroz 1999), and such substances were shown to be effective against post-

weaning diarrhoea caused by enterotoxigenic *E. coli* k88 (ETEC) (Tsiloyiannis et al. 2001). Patterson and Burkholder (2003) suggested that the use of probiotic microorganisms and prebiotic substrates could exert beneficial effects in animals. Administration of a probiotic in a high-nutrient-density diet could be more effective with respect to the gastrointestinal environment and subsequent nutrient utilisation in pigs than a low-nutrient-density diet (Meng et al. 2010; Yan and Kim, 2013). Yan and Kim (2013) also reported that coefficient of apparent ileal digestibility (CAID) was increased by the administration of probiotics (*Enterococcus faecium* DSM 7134, 2.0×10^9 CFU/kg diet) in finishing pig diet.

The fatty acids found in medium-chain triglycerides (MCTs) are medium-chain fatty acids (MCFAs), such as caproic acid (c6), caprylic acid (c8), capric acid (c10) and lauric acid (c12). These are digested, absorbed and metabolised differently from long-chain fatty acids (LCFAs), 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). In addition, MCFAs have antibacterial function similar to short-chain fatty acids (Skrivanova et al. 2006).

Enterococcus faecium are regarded as normal components of the intestinal microbiota of swine and therefore *E. faecium* DSM 7134 was used in the present study. Cernauskiene et al. (2011) reported that *E. faecium* could produce lactic acid to reduce the pH value of the intestinal content and inhibit the development of invasive pathogens. Yan and Kim (2013) and Chen et al. (2006) reported that dietary supplementation of *E. faecium* DSM 7134 and *E. faecium* SF68 reduced faecal NH_3 and H_2S emissions, respectively.

So far there is a general lack of information about the optimum dose of MCFA and therefore, we conducted experiments to evaluate the effects of the inclusion of MCFA and probiotic (*Enterococcus faecium* DSM 7134) in the diet of weanling pigs. The main objective of the present study was to evaluate the effects of MCFA and probiotic supplementation on growth performance, nutrient digestibility, blood profiles, faecal score, excreta microbiota, and excreta noxious gas emission in weanling pigs.

MATERIAL AND METHODS

Experimental design, animals and dietary treatments. The experimental protocols describing the management and care of animals was reviewed and approved by the Animal Care and Use Committee of Dankook University. A total of 140 weanling pigs [(Yorkshire × Landrace) × Duroc] were allot-

Table 1. Ingredients and nutrient composition of experimental diets for weanling pigs

	Phase 1 (pre-starter) weeks 1–2 high	Phase 2 (starter) weeks 3–6 high
Ingredients		
Extruded Corn	47.39	58.19
Soybean Meal (Dehulled)	16.00	24.00
LT Fish meal	8.00	3.92
Soy oil	2.82	2.11
Limestone	0.88	0.80
MCP	0.93	
DCP		1.27
Salt		0.20
Sweet Whey Protein	11.10	3.50
Lactose	7.60	2.70
Plasma powder	4.00	2.00
L-Lysine – HCL	0.26	0.35
DL-Met	0.27	0.27
Threonine	0.15	0.19
Choline Chl 50%	0.20	0.10
Vitamin premix	0.20	0.20
Mineral premix	0.20	0.20
Total	100.00	100.00
Nutrients		
Protein	20.50	20.00
Fat	5.40	4.80
Fibre	1.73	2.31
Ash	5.31	4.81
Calcium	0.80	0.75
Phosphorus	0.70	0.65
DE	3900.00	3700.00
Lys	1.62	1.51
Met	0.68	0.64
Lactose	15.00	5.00

Provided per kg of premix: vitamin A, 11 025 IU; vitamin D_3, 1103 IU; vitamin E, 44 IU; vitamin K, 4.4 mg; riboflavin, 8.3 mg; niacin, 50 mg; thiamine, 4 mg; d-pantothenic, 29 mg; choline, 166 mg; and vitamin B_{12}, 33 µg

Provided per kg of complete diet: Cu (as $CuSO_4 \cdot 5H_2O$), 12 mg; Zn (as $ZnSO_4$), 85 mg; Mn (as MnO_2), 8 mg; I (as KI), 0.28 mg; and Se (as $Na_2SeO_3 \cdot 5H_2O$), 0.15 mg

ted to four treatment groups with seven replicates/treatment and five pigs/replicate. Pigs were randomly allotted to four experiment diets according to their initial BW. Each pen was equipped with a one-sided, stainless steel self-feeder and a nipple drinker that allowed access to feed and water *ad libitum*. All pigs were housed in an environmentally-controlled room, which provided 0.26 × 0.53 m^2 space for each pig. Dietary treatments consisted of: CON diet (basal diet) (Table 1); T1 (CON + MCFA 0.2%); T2 (CON + probiotic 0.01%) and T3 (CON + MCFA 0.2% + probiotic 0.01%). Diets (Table 1) were formulated to meet or exceed the nutrient requirements recommended by the NRC (1998).

Source of probiotic. The probiotic preparation used in the current experiments was provided by a commercial company (Bonvital, Schaumann Agri International GmbH, Pinneberg, Germany). This product was composed of *Enterococcus faecium* DSM 7134. The MCFA (FAro 612) is a mixture of MCFA 8–10, silica acid and cream flavour. The active substances present in it are 58% MCFA, caprylic and capric acid (palm kernel), 42% silicic acid and cream flavour. MCFA is a combination of caproic acid (c6), caprylic acid (c8), capric acid (c10) and lauric acid (c12). MCFA is present in milk fat, coconut and palm kernel fat as triglycerides and after technological refinery steps it is converted to MCFA. The MCFA exerts broad antibacterial activity by inhibiting bacterial growth. Free MCFA represent a novel solution for the regulation and inhibition of gram-positive and gram-negative bacteria in the digestive tract of pigs.

Experimental procedures. The experiments were conducted over a period of six weeks (42 days). The parameters measured were body weight, feed intake, GF, nutrient digestibility, blood profiles, faecal score, excreta microbiota and excreta noxious gas contents. Body weight was measured at the end of Week 2 and 6 of the experimental period, and feed consumption was recorded on a per pen basis during the experiment to calculate the average daily gain (ADG), average daily feed intake (ADFI) and gain-to-feed ratio (G : F). Nutrient digestibility of DM, gross energy and N was determined. Titanium oxide was added to the feed at 0.2% dosage (2 kg/t of feed) and for a duration of five days as an indigestible marker for digestibility determination.

Fresh faecal grab samples collected from two pigs per pen were mixed and pooled, and a representative sample was stored in a freezer at –20 °C until analysed. Before chemical analysis, the faecal samples were thawed and dried at 70 °C for 72 h, after which they were finely ground to a size that could pass through a 1-mm screen. All feed and faecal samples were then analysed for DM, gross energy, and N following the procedures outlined by the AOAC (2003). For the blood profile, two pigs from each pen were randomly selected and blood samples were collected via anterior vena cava puncture on Day 14 and 42. At the time of collection, blood samples were collected into both non-heparinised tubes and vacuum tubes containing K_3EDTA (Becton, Dickinson and Co., Franklin Lakes, NJ) to obtain serum and whole blood, respectively. After collection, serum samples were centrifuged (3000 × *g*) for 15 min at 4 °C. The concentrations of glucose, BUN, creatinine, HDL, LDL, total cholesterol and triglyceride in the blood serum were determined using an automatic blood analyser (ADVIA 120, Bayer, NY).

Total bacteria, including *Lactobacillus*, *Escherichia coli* (*E. coli*) were determined on fresh morning faecal samples at the end of the experiment. Faecal microbiota was determined by serial dilution (10^{-1} to 10^{-7}) in anaerobic diluent before inoculation onto Petri dishes of sterile agar. *Lactobacilli* and *E. coli* present in the fresh faecal samples were enumerated. The selective medium for *Lactobacillus* was Rogosa SL agar (Rogosa; Difco Laboratories, Detroit, MI, USA) and for *E. coli* it was Mac Conkey agar. After inoculation, all the dishes were inverted and incubated anaerobically at 37 °C for 48 h. The enumerated colony counts were presented as $\log_{10}$ transformed data. At the end of the experiment, 300 g fresh excreta samples were collected randomly from each cage. Samples were kept in sealed containers and were immediately stored at –4 °C. Subsamples of excreta were taken and stored in 2.6-L plastic boxes in duplicate. Thereafter, plastic boxes were sealed carefully. Each box had a small hole in the middle of the wall on one side, which was sealed with adhesive plaster. The samples were permitted to ferment for five days at room temperature (25 °C). After the fermentation period, gas detection emission was detected using a Gastec (Model GV-100) gas sampling pump. Levels of NH_3, H_2S, mercaptans and acetic acid were measured within the scope of 5.0–100.0 (No. 3La, detector tube; Gastec Corp.), 2.0–20.0 (4LK, detector tube; Gastec Corp.), 0.5–120.0 (No.70 L and 70, detector tube; Gastec Corp.) and 2.0–50.0 (No. 81 L, detector tube; Gastec Corp.) ppm. Prior to the measurements, slurry samples were shaken manually for approximately 30 s in order to disrupt any crust formation on the surface of the slurry sample and to homogenise them. The adhesive plasters were punctured, and 100 ml of headspace air were sampled

Table 2. Effect of MCFA and probiotic supplementation on growth performance in weanling pigs

Items	CON	T1	T2	T3	SE
0–2 weeks					
ADG (g)	351[b]	354[ab]	388[a]	397[a]	17
ADFI (g)	480	479	477	477	21
G/F	0.740[b]	0.743[ab]	0.813[a]	1.130[a]	0.039
2–6 weeks					
ADG (g)	452[b]	468[ab]	482[a]	487[a]	23
ADFI (g)	729	725	723	727	22
G/F	0.620[b]	0.644[ab]	0.668[a]	0.669[a]	0.022
0–6 weeks					
ADG (g)	418[b]	430[ab]	441[a]	444[a]	17
ADFI (g)	646	643	641	644	16
G/F	0.649	0.666	0.688	0.689	0.021

CON = basal diet; T1 = CON + MCFA 0.2%; T2 = CON + probiotic 0.01%; T3 = CON + MCFA 0.2% + probiotic 0.01%; SE = standard error

[a,b]means in the same row with different superscripts differ significantly($P < 0.05$)

approximately 2.0 cm above the slurry surface. Two samples from each pen were measured and averages were calculated.

Statistical analyses. Data were analysed using a randomised complete block design following GLM procedures of SAS, with each pen regarded as the experimental unit. The means of the treatments were compared using Duncan's multiple range test. Variability in the data was expressed as the pooled SE and the level of significance was set at 0.05.

RESULTS

Growth performance

The growth performance of weanling pigs is presented in Table 2. The treatments significantly increases the ADG and G/F compared to the CON over the six weeks of the experiment. Overall ADG and G/F values in T2 and T3 treatment groups were higher ($P < 0.05$) than in T1 and CON treatments.

Table 3. Effect of MCFA and probiotic supplementation on blood profiles in weanling pigs

Item	CON	T1	T2	T3	SE
2 weeks					
BUN (mg/dl)	10.2	9.9	10.6	11.2	1.1
Creatinine (mg/dl)	0.44	0.38	0.37	0.43	0.08
Uric acid (mg/dl)	1.3	14	13	1.4	0.1
AST (IU/l)	82	83	78	79	3.3
ALT (IU/l)	55	58	56	60	4
Glucose (mg/dl)	98[b]	99[b]	102[ab]	107[a]	2
6 weeks					
BUN (mg/dl)	11.3	11.8	11.6	12.6	0.6
Creatinine (mg/dl)	1.06	1.07	1.07	1.11	0.02
Uric acid (mg/dl)	0.3	0.3	0.3	0.3	0.03
AST (IU/l)	78	77	78	79	5
ALT (IU/l)	54	57	55	56	8
Glucose (mg/dl)	95[b]	98[ab]	100[ab]	106[a]	3

CON = basal diet; T1 = CON + MCFA 0.2%; T2 = CON + probiotic 0.01%; T3 = CON + MCFA 0.2% + probiotic 0.01%; SE = standard error

[a,b]means in the same row with different superscripts differ significantly ($P < 0.05$)

Table 4. Effect of MCFA and probiotic supplementation on faecal microflora in weanling pigs

Items (log_{10} CFU/g)	CON	T1	T2	T3	SE
Lactobacillus	7.73	7.79	7.81	7.88	0.06
E. coli	6.15	6.13	6.11	6.06	0.09

CON = basal diet; T1 = CON + MCFA 0.2%; T2 = CON + probiotic 0.01%; T3 = CON + MCFA 0.2% + probiotic 0.01%; SE = standard error

Blood profiles

The concentrations of serum BUN, creatinine, uric acid, AST, ALT and glucose were determined after Weeks 2 and 6. The level of glucose was found to be significantly increased in treatment groups (T1, T2 and T3) when compared to the control ($P < 0.05$) after two weeks. Likewise, after six weeks, glucose levels were significantly elevated in the treatment groups when compared to the control ($P < 0.05$; ANOVA). AST and ALT levels were not found to be significantly changed in treatment groups when compared with the controls after either two or six weeks (Table 3).

Faecal microflora and faecal score

Supplementation of MCFA with probiotic in the treatment groups (T1, T2 and T3) did not elicit any significant differences when compared to the control (Table 4). There was also no significant difference found in faecal score from Day 1 to Day 7 in weanling pigs from the treatment groups when compared to the controls (Table 5).

Nutrient digestibility

The ATTD of dry matter (DM), nitrogen and energy in weanling pigs fed with T2 and T3 treatments showed higher values (Table 6) when compared with weanling pigs fed with T1 and CON treatments, after both two and six weeks.

Gas emission

Supplementation with dietary MCFA and probiotic did not result in any reduction in mercaptan, hydrogen sulphide and acetic acid emission in weanling pigs, but did elicit a significant decrease in ammonia in T2 and T3 (Table 7). Slight differences were observed among the treatments but these were not significant ($P > 0.05$) when compared to controls and among the different treatments.

DISCUSSION

Any tool which contributes to providing high quality nutrients for the human diet is of great use

Table 5. Effect of MCFA and probiotic supplementation on faecal score (day) in weanling pigs

Day	CON	T1	T2	T3	SE
1	3.1	3.1	3.1	3.1	0.1
2	3.1	3.2	3.2	3.2	0.1
3	3.2	3.3	3.2	3.2	0.1
4	3.1	3.2	3.2	3.2	0.1
5	3.2	3.3	3.3	3.3	0.2
6	3.2	3.3	3.3	3.3	0.2
7	3.2	3.3	3.3	3.2	0.2

CON = basal diet; T1 = CON + MCFA 0.2%; T2 = CON + probiotic 0.01%; T3 = CON + MCFA 0.2% + probiotic 0.01%; SE = standard error

Faecal scores: 1 = hard, dry pellet; 2 = firm, formed faeces; 3 = soft, moist faeces that retains shape; 4 = soft, unformed faeces that assumes shape of container; 5 = watery liquid that can be poured

Table 6. Effect of MCFA and probiotic supplementation on nutrient digestibility in weanling pigs

Items (%)	CON	T1	T2	T3	SE
2 weeks					
Dry Matter	82.11^{b}	82.97^{ab}	84.40^{ab}	85.42^{a}	0.88
Nitrogen	80.93	81.01	82.72	83.29	0.84
Energy	82.15^{b}	82.71^{ab}	84.80^{a}	84.91^{a}	0.85
6 weeks					
Dry Matter	75.86^{c}	79.48^{b}	79.19^{b}	80.96^{a}	0.25
Nitrogen	75.63^{c}	78.54^{b}	78.94^{b}	81.17^{a}	0.45
Energy	76.40^{c}	79.81^{b}	79.45^{b}	81.12^{a}	0.27

CON = basal diet; T1 = CON + MCFA 0.2%; T2 = CON + probiotic 0.01%; T3 = CON + MCFA 0.2% + probiotic 0.01%; SE = standard error

^{a,b}means in the same row with different superscripts differ significantly ($P < 0.05$)

Table 7. Effect of different type of MCFA and probiotic supplementation on faecal gas emission in weanling pigs

Items (ppm)	CON	T1	T2	T3	SE
NH_3	10.3^{a}	10.1^{a,b}	9.2^{a,b}	8.4^{b}	0.7
R.SH	3.3	2.9	2.8	2.8	0.3
H_2S	5.9	5.3	5.3	5.1	0.4
Acetic acid	0.7	0.6	0.6	0.5	0.1

CON = basal diet; T1 = CON + MCFA 0.2%; T2 = CON + probiotic 0.01%; T3 = CON + MCFA 0.2% + probiotic 0.01%; SE = standard error

^{a,b}means in the same row with different superscripts differ significantly ($P < 0.05$)

in livestock production (Mohana Devi et al. 2014b). Due to the concerns over food safety, the use of antibiotics as growth promoters has been forbidden in the EU since January 2006 (Regulation 1983/2003/EC) and was banned in July 2011 in Korea. A large number of alternatives have been proposed including enzymes, probiotics, prebiotics, phytogenic agents, and dietary acidifiers (Partanen and Mroz 1999). In recent times, the application of probiotics, in particular, has received significant attention in the pig industry (Chen et al. 2006; Meng et al. 2010; Yan et al. 2010; Yan et al. 2011). Probiotics are live microbial additives which affect the gut flora in a way that is beneficial to the host animal by improving the intestinal microbial balance (Fuller 1992). However, the probiotic supplementation in practice is highly inconsistent because of different diet compositions, differences in strains, dose levels, age of the animals, and interactions with environmental factors (Loh et al. 2008; Khan et al. 2011). According to Mountzouris et al. (2010), the effect of probiotics could be affected by various factors, for example, the quality of feed components and anti-nutritional compounds. Meng et al. (2010) also suggested that nutrient density could influence the effect of probiotics in growing pigs. Mohana Devi et al. (2014a) reported that supplementation of protein sources in growing pig diets improved their growth rate and feed intake. It has been suggested that probiotics require some nutrients and energy for their effect on immune cell function (Fuller 1989; FAO 2002). According to Mountzouris et al. (2010), the beneficial functions of probiotics require a nutrient and energy cost because of the growth and proliferation of live microbes.

Growth performance

Dietary probiotic supplementation and a high nutrient diet was shown to improve growth performance and nutrient digestibility in growing pigs (Yan and Kim 2013). In the present study, the T2 and T3 treatments supplemented with probiotics significantly increased average daily gain (ADG) and G/F compared to the T1 and CON groups over a period of six weeks. Overall ADG and G/F values in T2 and T3 probiotic treatment groups were also found to be higher than for T1 and CON treatments. Yan et al. (2010) also reported that increased nutrient density improved ADG in growing-finishing pigs. Lojanica et al. (2010) and Cernauskiene et al. (2011) have suggested that dietary *E. faecium* DSM 7134 increases ADG and feed conversion ratio in weanling and finishing pigs. According to Yan and Kim (2013), *E. faecium* DSM 7134 led to an enhanced ADG and G : F ratio.

Nutrient digestibility

In the report of Beaulieu et al. (2009), high energy diets resulted in increased energy intake and consequently improved growth performance in pigs. Meng et al. (2010) also reported that the effect of probiotics on nutrient digestibility (N and energy) could be enhanced with high nutrient density diets, and that this may be due to the positive effect of probiotics on the microflora balance in the gut. Thus, our study is in agreement with the above

findings in which the ATTD values of dry matter (DM) in weanlings fed with T2 and T3 treatments were higher when compared with weanling pigs fed with T1 and CON diets after both two and six weeks. Yan et al. (2010) reported that increased nutrient density improved ADG in the growing-finishing pigs.

Blood profiles

The concentrations of serum BUN, creatinine, uric acid, AST, ALT and glucose were analysed after Weeks 2 and 6. The levels of glucose were found to be significantly increased in treatment groups (T1, T2 and T3) when compared to the control in the two week trial. In the six week trial, glucose levels were also found to be increased in the treatments when compared to the control group. AST and ALT levels were not found to differ substantially from the controls in the treatment groups after both two and six weeks. According to Hong et al. (2012), addition of MCT in weanling pig diet can improve ADG and digestibility during a period of two weeks, but shows little effect on blood characteristics. Our study is in agreement with the report of Yan and Kim (2013) where no differences were observed in blood characteristics. These results are also consistent with our own earlier study Chen et al. (2006), in which no differences were observed after probiotic supplementation in pigs.

Faecal microflora and faecal score

The presence of *Lactobacillus* in the gastrointestinal tract is believed to be beneficial for the pig. However, in the current study, supplementation of MCFA with probiotics in the treatment groups (T1, T2 and T3) did not result in any significant differences compared to the control. There was also no significant difference in faecal score from Day 1 to Day 7 in weanling pigs in the treatment groups when compared to the control. *E. faecium* harbours an inhibitory substance, which functions as a probiotic bacterial inhibitor of Streptococcal mutans (Kumada et al. 2009). Cernauskiene et al. (2011) also suggested that *E. faecium* are normal components of the swine intestinal microbiota, which could produce lactic acid to reduce the pH of the intestinal content and prevent the development of invasive pathogens. The levels of faecal lactobacilli were shown to be increased by dietary probiotic supplementation (Yan and Kim 2013). Ferket et al. (2002) proposed that probiotics indirectly reduce environmental pollutants by improving feed efficiency, nutrient retention and intestinal microbiotia.

Gas emission

During recent years, different dietary strategies have been successfully employed to reduce gas emissions in piglet production. Here, we assessed mean gas emissions after different dietary treatments. Dietary MCFA with probiotics did not elicit any reduction in mercaptan, hydrogen sulphide and acetic acid emission, but did result in a significant decrease in ammonia emission in weanling pigs. Slight differences were observed among the treatments but these were not significant when compared to each other or with respect to the control. It is possible that with a higher proportion of MCFA, NH_3, mercaptan, hydrogen sulphide and acetic acid emission reduction would have been significant. Indeed, faecal noxious gas content was reported to be reduced after probiotic supplementation (Yan and Kim, 2013). According to Ferket et al. (2002), faecal noxious gas content is related to intestinal microflora in the gastrointestinal tract of pigs. Our previous study has suggested that increased nutrient digestibility could be considered as a reason for the reduced noxious gas content (Yan et al. 2010; Yan et al. 2011).

CONCLUSION

In conclusion, our results suggest that dietary supplementation with MCFA along with probiotic in weanling pigs can improve growth performance, increase nutrient digestibility and enhance biochemical profiles, in a manner comparable to antibiotic treatments. We suggest that the ability of the active compounds to persist for longer along the gastrointestinal tract allowed them to act synergistically. Since there is an urgent need for growth promoters other than antibiotics, dietary probiotics may become a common and efficacious alternative for improving health status and performance in pigs. The beneficial effects of probiotic supplementation in pigs could be improved with high energy and nutrient dense diets. Thus, dietary

MCFA and probiotics represent viable alternatives to antibiotics in weanling pigs, and can improve health status and performance.

REFERENCES

AOAC, Association of Official Analytical Chemists (2003): Official Methods of Analysis, 23rd ed. Association of Official Analytical Chemists, Washington, DC, USA.

Barton MD (2000): Antibiotic use in animal feed and its impact on human health. Nutrition Research Reviews 13, 279–299.

Beaulieu AD, Williams NH, Patience JF (2009): Response to dietary digestible energy concentration in growing pigs fed cereal grain-based diets. Journal of Animal Science 87, 965–976.

Bomba A, Jonecova Z, Koscova J, Nemcova R, Gancarikova S, Mudronova D, Scirankova L, Buleca V, Lazar G, Posivak J, Kastel R, Marekova M (2006): The improvement of probiotics efficacy by synergistically acting components of natural origin: a review. Biologia 61, 729–734.

Castillo M, Martin-Orue SM, Taylor-Pickard JA, Perez JF, Gasa J (2008): Use of mannan-oligosaccharides and zinc chelate as growth promoters and diarrhea preventative in weaning pigs: Effects on microbiota and gut function. Journal of Animal Science 86, 94–101.

Cernauskiene J, Bartkevieitute Z, Hammerer J, Kozlowski K, Jeroch H (2011): The effect of "Bonvital", a probiotic product containing Enterococcus faecium on the fattening performance, carcass characteristics and meat quality of pigs under production conditions. Veterinary Medicine and Zootechnics 54, 20–25.

Chen YJ, Kwon OS, Min BJ, Son KS, Cho JH, Hong JW, Kim IH (2005): The effects of dietary Biotite V supplementation as an alternative substance to antibiotics in growing pigs. Asian Australasian Journal of Animal Sciences 18, 1642–1645.

Chen YJ, Min BJ, Cho JH, Kwon OS, Son KS, Kim IH, Kim SJ (2006): Effects of dietary Enterococcus faecium SF68 on growth performance, nutrient digestibility, blood characteristics and faecal noxious gas content in finishing pigs. Asian Australasian Journal of Animal Sciences 19, 406–411.

FAO (2002): Drafting guidelines for the evaluation of probiotics in food. Report of a joint FAO-Who Working Group, London.

Ferket PR, van Heugten E, van Kempen TATG, Angel R (2002): Nutritional strategies to reduce environmental emissions from nonruminants. Journal of Animal Science 80, E. Suppl. 2, E168–E182.

Fuller R (1989): Probiotics in man and animals. Journal of Applied Bacteriology 66, 365–378.

Fuller R (ed.) (1992): Probiotics. The Scientific Basis. Chapman and Hall, London.

Giang HH, Viet TQ, Ogle B, Lindberg JE (2010): Effects of different probiotic complexes of lactic acid bacteria on growth performance and gut environment of weaned piglets. Livestock Science 133, 182–184.

Hong SM, Hwang JH, Kim IH (2012): Effect of medium-chain triglyceride (mct) on growth performance, nutrient digestibility, blood characteristics in weanling pigs. Asian Australasian Journal of Animal Sciences 25, 1003–1008.

Khan SH, Atif M, Mukhtar N, Rehman A, Farid G (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.

Kumada M, Motegi M, Nakao R, Yonezawa H, Yamamura H, Taqami J, Senpuku H (2009): Inhibiting effects of Enterococcus faecium non-biofilm strain on Streptococcus mutans biofilm formation. Journal of Microbiology, Immunology and Infection 42, 188–196.

Laine TM, Lyytikainen T, Yliaho M, Anttila M (2008): Risk factors for post-weaning diarrhoea on piglet producing farms in Finland. Acta Veterinaria Scandinavica 50, 21.

Lee HF, Chiang SH (1994): Energy value of medium-chain triglycerides and their efficacy in improving survival of neonatal pigs. Journal of Animal Science 72, 133–138.

Loh TC, Lee TM, Foo HL, Law FL, Rajion MA (2008): Growth performance and faecal microflora of rats offered with metabolites from lactic acid bacteria in drinking water. Journal of Applied Animal Research 34, 61–64.

Lojanica M, Manojlovie M, Jeremic D, Petronijevie S (2010): The effect of probiotic Enterococcus faecium DSM 7134 in the weaned pigs nutrition. Biotechnology in Animal Husbandry 26, 57–64.

Malloa JJ, Rioperezb J, Honrubiaa P (2010): The addition of of enterococcus faecium to diet improves piglets intestinal microbiota and performance. Livestock Science 133, 176–178.

Meng QW, Yan L, Ao X, Zhou TX, Wang JP, Lee JH, Kim IH (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.

Mohana Devi S, Devi US, Kim IH (2014a): Evaluation of dietary sources of protein on growth performance in pigs. Veterinarni Medicina 59, 247–253.

Mohana Devi S, Balachandar V, Lee SI, Kim IH (2014b): An outline of meat consumption in the Indian population – A pilot review. Korean Journal for Food Science of Animal Resource 34, 507–515.

Mountzouris KC, Tsitrsikos P, Palamidi I, Arvaniti A, Mohnl M, Schatzmayr G, Fegeros K (2010): Effect of probiotic inclusion levels in broiler nutrition on growth performance, nutrient digestibility, plasma immunoglobulins, and cecal microflora composition. Poultry Science 89, 58–67.

NRC (1998): Nutrient Requirements of Swine. 10th ed. National Academy Press. Washington DC, USA.

Odle J (1998): Medium-chain triglycerides: a unique energy source for neonatal pigs. Pig News and Information 20, 25N–32N.

Partanen KH, Mroz Z (1999): Organic acids for performance enhancement in pig diets. Nutrition Research Reviews 12, 117–145.

Patterson JA, Burkholder KM (2003): Application of prebiotics and probiotics in poultry production. Poultry Science 82, 627–631.

Skrivanova E, Marounek M, Benda V, Brezinia P (2006): Susceptibility of Escherichia coli, Salmonella sp. and Clostridium perfringens to organic acids and monolaurin. Veterinarni Medicina 51, 81–88.

Tsiloyiannis VK, Kyriakis SC, Vlemmas J, Sarris K (2001): The effect of organic acids on the control of porcine post-weaning diarrhea. Research in Veterinary Science 70, 287–293.

Wallgren P, Melin L (2001): Weaning systems in the relation to disease. In: Varley MA, Wiseman J (eds.): The Weaner Pig. CABI Publishing, Nottingham, UK. 309–324.

Yan L, Kim IH (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, Meng QW, Wang JP, Kim IH (2010): Effects of dietary soybean hulls and Lactobacillus reuteri on growth performance, nutrient digestibility and noxious gas mission from feces and slurry in finishing pigs. Wayamba Journal of Animal Science 2, 53–56.

Yan L, Meng QW, Kim IH (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.

Received: 2014–08–30
Acepted after corrections: 2014–11–10

Corresponding Author:

In Ho Kim, Dankook University, Department of Animal Resource and Science, No.29 Anseodong, Cheonan, Chungnam 330–714, Republic of Korea
E-mail: inhokim@dankook.ac.kr