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Short Communication

Effect of *Lactobacillus plantarum* on noxious gas emission and carcass quality grade in finishing pigs

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This study investigated the effects of LactoPlanta® (*Lactobacillus plantarum* (*L. plantarum*), 2.0 × 10^9 colony forming units (CFU)/kg) on reduction of noxious gas emission in pig houses as well as improvement of carcass weight and quality in finishing pigs. A total of 850 finishing pigs were assigned to four treatment groups: control (CON, basal diet) (n=190), LP-0.1, 0.1% LactoPlanta® (n=210), LP-0.2, 0.2% LactoPlanta® (n=230), and LP-0.4, 0.4% LactoPlanta® (n=220). Ammonia and hydrogen sulfide concentrations were significantly reduced in all treatment groups compared to CON. Mercaptan contents and carcass weights of LP-0.2 and LP-0.4 were significantly decreased compared to CON, whereas there were no significant differences between LP-0.1 and CON. Carcass weight of LP-0.1 was slightly higher than that of CON, but there was no significant difference. However, carcass weights of LP-0.2 and LP-0.4 were significantly higher than that of CON (P<0.05). The prevalence of grade A carcasses in groups administered with *L. plantarum* (46.7~63.3%) was higher than that in CON (43.3%) and increased in a dose-dependent manner. Based on the results of this study, *L. plantarum* could be an effective candidate to reduce noxious gas emissions in finishing pig houses as well as improve carcass weight and quality in finishing pigs.

Key words: ammonia, hydrogen sulfide, mercaptan, carcass weight, meat quality grade

In human and veterinary medicine, antibiotics are used to treat and prevent disease as well as promote growth of food animals [1]. However, repeated use of antibiotics has led to the emergence of antibiotic-resistant bacteria, antibiotic residues in edible animal products, and disturbance of normal intestinal microflora [2, 3]. As a result, many countries have banned or strictly limited the use of antibiotics in the livestock industry. The global trend of restricting use of antibiotic growth promoters in animal production has necessitated the development of valid alternatives to maintain the productivity and sustainability of food animals [4].

To address increased rates of mortality and morbidity due to bans against in-feed antibiotics, numerous alternatives and replacements have been proposed [5]. These include antibacterial vaccines, immunomodulatory agents, bacteriophages and their lysins, antimicrobial peptides (AMPs), pro-, pre-, and synbiotics, plant extracts, inhibitors for bacterial quorum sensing (QS), biofilm and virulence, and feed enzymes [6].

In the last 20 years, probiotics have been used as an alternative to antibiotics in animal nutrition [7-9]. Probiotics are included in a group of non-pathogenic organisms that consist of strains of the genera *Lactobacillus*, *Bifidobacterium*, and *Bacillus* [10, 11].

Lactobacillus spp. are one of the most beneficial probiotics and are tolerant to bile salts and low pH conditions [12]. *Lactobacillus plantarum* (*L. plantarum*) has antagonistic potential against intestinal pathogens due to the production of lactic acid and/or bactericidal compounds [13].

Although many previous studies have explored the effects of *L. plantarum* on modulation of gut microflora and prevention of diarrhea in pigs [14-16], information on the emission of noxious gases and carcass quality grade is still limited. Thus, the objective of this study was to evaluate the efficacy of *L. plantarum* SY-99 isolated from salted seafood on the emission of noxious gases and

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carcass quality grade in finishing pigs.

A total of 850 finishing pigs ((Landrace × Yorkshire) × Duroc) with an initial body weight (BW) of 90.3 ± 4.59 kg were subjected to a 4-week experiment designed to evaluate the effects of dietary supplementation with LactoPlanta® (*Lactobacillus plantarum*, 2.0×10^9 colony forming units (CFU)/kg, Dae Han New Pharm Co. Ltd, Seoul, Korea) on the reduction of noxious gas emission and improvement of meat quality grade. Four finishing pig houses were randomly assigned to treatment groups with 10 pigs housed in each pen. All pigs were housed in an environmentally-controlled room. Each pen was equipped with a one-sided self-feeder and a nipple waterer to allow the pigs *ad libitum* access to feed and water throughout the duration of the experimental period. The target room temperature and humidity were 25 ± 2°C and 60 ± 10%, respectively. The dietary treatments evaluated in this study included: 1) CON (basal diet) (n=190), 2) LP-0.1 (basal diet + 0.1% LactoPlanta® (2.0×10^6 CFU as *L. plantarum*)) (n=210), 3) LP-0.2 (basal diet + 0.2% LactoPlanta® (4.0×10^6 CFU as *L. plantarum*)) (n=230), and 4) LP-0.4 (basal diet + 0.4% LactoPlanta® (8.0×10^6 CFU as *L. plantarum*)) (n=220). Each of the treatments was added to the basal diet, and all diets were provided in meals formulated to meet or exceed NRC [17] requirements (Table 1).

Before and after administration of LactoPlanta® for 4 weeks, ammonia (NH_3), hydrogen sulfide (H_2S), and carbon dioxide (CO_2) were detected using a portable multiple gas detector (MultiRAE®, HiMax Tech. Co. Ltd., Seoul, Korea) at pig noise height at three points (entrance, middle, and end of swine house passage). After the experiment, finishing pigs were slaughtered at a slaughterhouse. Carcass weights were measured, and carcass quality grade was decided by quality judgment. In addition, the prevalence of grade A carcasses in each group was presented as a percentage. Concentrations of noxious gas emission and carcass weights in each group are presented as the mean ± standard deviation (SD), and all data were analyzed using one-way analysis of variance (ANOVA) (SAS Institute, NC, USA) followed by a two-tailed Student's *t*-test when ANOVA yielded statistically significant differences ($P<0.05$).

Table 2 presents the effect of LactoPlanta® on the reduction of noxious gas emissions in pig houses. The concentration of hydrogen sulfite in LP-0.1 was significantly reduced compared to CON ($P<0.05$). Concentrations of other noxious gases were slightly reduced compared to CON, but no significant difference was observed. In LP-0.2, concentrations of all detected-noxious gases were significantly reduced compared to CON (ammonia and carbon dioxide, $P<0.05$; hydrogen sulfide, $P<0.001$). In LP-0.4, concentrations of all noxious gases were significantly reduced compared to CON ($P<0.001$).

In a previous study on early-finishing pigs treated with 0.1 and 0.2% *Agariemycetes* (1.0×10^7 CFU/g), concentrations of ammonia and hydrogen sulfide were significantly reduced compared to the control group ($P<0.05$) [18]. In another previous study [19], levels of ammonia and hydrogen sulfide in growing pigs supplemented with 0.2% probiotics from anaerobic bacteria with prebiotics were lower compared to pigs treated with 0.15% antibiotics, although no significant difference was observed. Furthermore, Chao and Kim [20] reported that in weanling pigs treated with 0.1 and 0.2% probiotics (*Lactobacillus reuteri* and *Lactobacillus plantarum* complex), concentrations of ammonia, hydrogen sulfide, and mercaptan were significantly reduced compared to the control group ($P<0.05$).

Results from previous studies can be attributed to several aspects, such as the age of animals, strain of bacte-

Table 1. Basal diet composition

Ingredients	Content (%)
Corn	61.60
Soybean meal	13.56
Wheat	10.00
Animal fat	3.36
Rice bran	3.00
Molasses	2.50
Lupin, seed	2.00
Rapeseed meal	2.00
Tricalcium phosphate	0.79
Limestone	0.63
Salt	0.25
Vitamin/mineral premix[1)]	0.20
L-lysine HCl	0.06
Antioxidant (ethoxyquin 25%)	0.05
Chemical composition[2)]	
ME, kcal/kg	3,260
Crude protein, %	14.00
Lysine, %	0.70
Calcium, %	0.60
Phosphorus, %	0.50

[1)] Supplied per kg diet: vitamin A, 9,000 IU; vitamin D3, 1,200 IU; vitamin E, 40 IU; vitamin K (menadione bisulfate complex), 3.0 mg; vitamin B2, 5.2 mg; vitamin B_6, 2.6 mg; vitamin B_{12}, 26 µg; niacin, 32 mg; d-pantothenic acid (as d-calcium pantothenate), 20 mg; Cu, 15 mg; Fe, 70 mg; Zn, 50 mg; Mn, 50 mg; I, 0.5 mg; Co, 0.3 mg and Se, 0.2 mg.
[2)] Calculated values.

ria, and addition level. The present experiment observed reduced ammonia, hydrogen sulfide, and mercaptan concentrations in groups treated with *L. plantarum* (11.8~39.7, 14.0~57.6, and 7.3~42.1%, respectively) compared to CON. These reduced concentrations of ammonia, hydrogen sulfide, and mercaptan are slightly lesser than those reported by Jung et al. [18]. However, these reduced ranges of detected gas levels in LP-0.2 and LP-0.4 are higher than those reported by Chao and Kim [20], and the reduced hydrogen sulfide concentration in the present study is lower than that reported by Chu et al. [19].

It has been suggested that harmful fecal gas emissions from animals are related to the intestinal microflora ecosystem [21]. Therefore, in the current study, the reduced noxious gas emissions can be attributed to improvement of intestinal microbial balance as a result of dietary supplementation with *L. plantarum* [19].

Carcass weights and prevalence of grade A carcasses are shown in Table 3. The carcass weight of LP-0.1 slightly increased compared with CON, although there was no significant difference. However, in LP-0.2 and LP-0.4, carcass weights significantly increased compared with CON ($P<0.05$). The prevalence of grade A carcasses in groups administered with *L. plantarum* (46.7~63.3%) was higher than that in CON (43.3%) and increased in a dose-responsive manner.

In finishing pigs administered with 0.2% probiotic complex for 58 days, carcass weights slightly increased compared with the control group, and the prevalence of grade A carcasses (46.7%) was higher than that of the control group (33.3%) [22].

Suda et al. reported that weaned piglets fed *L. jensenii* 6.0×10^{10} CFU per day for 15 weeks showed no significant difference in carcass weight, and the prevalence of grade A carcasses (25.6%) was higher than that of the control group (20%) [23]. Furthermore, in growing finishing pigs treated with a probiotic mixture (7.5×10^8 CFU/g) containing *Lactobacillus* spp. for approximately 15 weeks, carcass weights were not significantly elevated compared with that of the control group, and the prevalence of grade A carcasses (23.8%) was higher than that of the control group (4.8%). Considering the probiotic strain, addition level, and administration period, the effect of *L. plantarum* on carcass weight in this study was superior to results from previous studies. Further, the prevalence of grade A carcasses in LP-0.2 and LP-0.4 was similar to the results of Kim et al. [22] but higher than those reported by Suda et al. [23] and Yang et al. [24]. The mechanism of *L. plantarum* for promotion of pig growth and pork quality might be related to inhibition of the growth of opportunistic pathogens and promotion of increased villus height [25].

In conclusion, the results of this study demonstrate that *L. plantarum* could be an effective candidate for reduction of noxious gas emission in finishing pig houses, in addition to the improvement of carcass weight and quality in finishing pigs.

Table 2. Effect of LactoPlanta® on reduction of noxious gas emission in pig houses

Gas	Administration			
	CON	LP-0.1	LP-0.2	LP-0.4
Ammonia (ppm)	21.11 ± 1.47	16.51 ± 1.12*	13.43 ± 0.85**	10.72 ± 0.78**
Hydrogen sulfide (ppb)	207.4 ± 23.8	159.4 ± 29.6*	121.7 ± 15.8**	87.9 ± 9.9**
Mercaptan (ppm)	3.42 ± 0.47	2.73 ± 0.36	2.25 ± 0.28*	1.58 ± 0.21**

Data are expressed as mean ± S.D.
CON, basal diet; LP-0.1, basal diet + 0.1% LactoPlanta®; LP-0.2, basal diet + 0.2% LactoPlanta®; LP-0.4, basal diet + 0.4% LactoPlanta®.
*$P<0.05$ as compared with the control group.
**$P<0.01$ as compared with the control group.

Table 3. Effect of LactoPlanta® on increase in carcass weight and prevalence of grade A carcasses

Items	Administration			
	CON	LP-0.1	LP-0.2	LP-0.4
Carcass weight (kg)	85.2 ± 3.7	86.3 ± 4.1	87.5 ± 4.3*	88.1 ± 4.5*
Grade A (%)	43.3	46.7	56.7	63.3

Data are expressed as mean ± S.D.
CON, basal diet; LP-0.1, basal diet + 0.1% LactoPlanta®; LP-0.2, basal diet + 0.2% LactoPlanta®; LP-0.4, basal diet + 0.4% LactoPlanta®.
*$P<0.05$ as compared with the control group.

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