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Effect of Dietary Grape Pomace Fermented by *Saccharomyces boulardii* on the Growth Performance, Nutrient Digestibility and Meat Quality in Finishing Pigs

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ABSTRACT : Fifty-six [(Duroc×Yorkshire)×Landrace] pigs with an average initial BW of 19.3±0.17 kg were used in this 15-wk growth experiment to investigate the effects of grape pomace fermented by *Saccharomyces boulardii* on pig growth performance, nutrient digestibility and quality attributes of pork. Pigs were allotted to 2 dietary treatments (7 replications) based on their initial BW in a randomized complete block design. The experimental treatments were: i) control (CON; basal diet), ii) FGPP (CON+30 g/kg fermented grape pomace product). Dietary FGPP improved ($p<0.05$) average daily gain (ADG), coefficient apparent total tract digestibility (CATTD) of dry matter (DM) and nitrogen (N) during 35-70 d of the experiment. Similarly, pigs fed the FGPP supplemented diet had a higher N digestibility ($p<0.05$) in the finisher phase (day 71-105). Dietary FGPP increased ($p<0.05$) the marbling score, the redness (a*) and yellowness (b*) values, as well as the anti-oxidative ability (lower TBARS). The inclusion of FGPP reduced palmitic acid (C:16:0), stearic acid (C:18:0), arachidic acid (C:20:0) and SFA levels ($p<0.05$) in subcutaneous fat. An increased ($p<0.05$) linoleic acid (C18:2n6), total PUFA and PUFA/SFA ratio were observed in the FGPP group. Dietary FGPP supplementation decreased the arachidic acid (C:20:0) level in longissimus muscle (LM). In conclusion, dietary inclusion of FGPP at the level of 30 g/kg improved the growth performance, nutrients digestibility and altered the fatty acid pattern in the subcutaneous fat as well as some attributes of pork meat. (**Key Words :** Grape Pomace, Growth Performance, Meat Quality, Pig)

INTRODUCTION

Grape pomace (GP), which is the residue that remains after juice extraction by pressing grapes in the wine industry, is rich in various flavonoids including monomeric phenolic compounds such as (+)-catechins, (-)-epicatechin and dimeric, trimeric (-)-epicatechin-3-O-gallate (Sáyago-Ayerdi et al., 2009). It is well proved that GP could inhibit the oxidation of fish lipids, frozen fish muscle, and the chicken breast (Pazos et al., 2005; Mielnick et al., 2006; Brenes et al., 2008). Goñi et al. (2007) also suggested that GP could be considered as a good alternative to α-tocopheryl acetate supplementation to feedstuff. However, results of GP utilization on growth performance in livestock were inconsistent. For example, Hughes et al. (2005) found addition of grape seed extract (90.2% total phenolics) at the level of 30 g/kg decreased the growth performance in chickens. However, Brenes et al. (2008) and Goñi et al. (2007) found GP supplementation enhanced anti-oxidant capacity without any negative effect on growth performance in broilers (4.86% total phenolics; added at 30 g/kg). The reason is believed to be the different amount of phoyphenols in GP, which could bind with the digestive enzymes and proteins located at the luminal side of the intestinal tract (Jansman et al., 1989). Therefore, a proper dosage for the supplementation of livestock should be evaluated.

Previously, it is well accepted that the fermentation could provide several advantages such as improved flavor and enrichment with desirable metabolites generated by the microorganisms (Buckenhüskes et al., 1990). Various studies also suggested yeast products and yeast culture have the ability to improve the growth performance, nutrient digestibility and health condition in pigs feeding industry (Mathew et al., 1998; Kamm et al., 2004). Our experiment was concerned about a fully dried fermented grape pomace fermented by *Saccharomyces boulardii* based on corn-soybean meal medium (FGPP), which is expected to have both the beneficial effect of GP and yeast culture in pigs.

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Moreover, studies conducted on the GP has mainly concentrated on the potential for antioxidative ability (Goñi et al., 2007; Brenes et al., 2008; Sáyago-Ayerdi et al., 2009), But a study regarding the effect of GP on the fatty acid composition of pork is limited, and only Yi et al. (2009) examined the fatty acid composition of the winemaking pomace powder and suggested there were a larger proportions of PUFA (60.9% to 64.4%) and high ratios of PUFA/SFA (2.80-3.0) in grape pomace powder.

Therefore, the objective of the current study was to evaluate the addition of FGPP on growth performance, nutrient digestibility, meat quality as well as the fatty acid composition of pork in growing-finishing pigs.

MATERIALS AND METHODS

Animal use and care

This experiment was conducted at the Experimental Unit of Dankook University, with all protocols were approved by the Animal Care and Use Committee of Dankook University.

Preparation of fermented grape pomace product

Fermented grape pomace product (FGPP) is a dried product arises from yeast (*Saccharomyces boulardii*) (2%) fermentation, based on 88% of corn-soybean meal and 10% grape pomace. Grape pomace (obtained from a winery) meal was milled to a particle size of less than 0.5 mm in a Cyclone Sample Mill (Tecator, Höganäs, Sweden). Water in an equal volume and glucose (2%) were added to the mixture together with corn-soybean powder. The mixture was subjected to sterilization in an autoclave at 121°C, for 20 min, after cooling to room temperature, the medium was inoculated with a starter yeast culture of 2% *Saccharomyces boulardii* (1.0×10^7 CFU/ml). The resultant mixture was cultured under the condition of 37°C and 160 rpm shaking for 48 h. Samples were subjected to centrifugation at 1,000 g for 40 min and filtered through 45 um sieve to obtain a supernatant, after which the supernatant was heated at 100°C, for 10 minutes, freeze-dried and crushed in the form of powder The proximate composition of FGPP is shown in Table 1, which is provided by the Korea Chemical Institution.

Table 1. Composition of fermented grape pomace

Ingredients	g/kg dry matter
Crude protein	149.9±1.20
Crude fat	51.9±0.17
Crude fiber	33.0±0.53
Crude ash	43.3±0.23
Calcium	6.0±1.90
Phosphorus	5.3±2.10
Total pholyphenols	62.1±0.12

[1] Provided by the Korea Chemical Institution.

Experimental design, animals, housing and diets

Fifty-six [(Duroc×Yorkshire)×Landrace] (weaned at day 21) pigs with an average initial BW of 19.3±0.17 kg were used in this 105-d growth trial. Pigs were allotted to 2 dietary treatments based on their initial BW using a randomized complete block design. Each dietary treatment consisted of 7 replications, with 4 pigs per pen (2 gilts and 2 barrows). The experimental dietary treatments included: i) control (CON; basal diet), ii) FGPP (CON+30 g/kg fermented grape pomace product). Pigs were fed a 3-phase diet with transition from starter (day 0-35) to grower (day 36-70), grower to finisher (day 71-105). There was 2-d acclimation time prior to the experiment. All diets used in this experiment were formulated to meet or exceed NRC (1998) recommendations for all nutrients (Table 2). Fermented grape pomace product was included in the diet by replacing the amount of soybean meal and fat. Pigs were housed in an environmentally controlled, slatted-floor facility in 14 adjacent pens (1.8×1.8 m) at the pig farm of Dankook University. All pigs were provided with *ad libitum* access to feed and water through a self-feeder and nipple drinker, respectively, throughout the experiment.

Growth performance and nutrient digestibility

Body weight and feed consumption were measured on day 35, 70 and 105 to monitor the average daily gain (ADG), average daily feed intake (ADFI) and gain/feed (G/F) ratio. Chromium oxide (Cr_2O_3) was added to the diet at a level of 2 g/kg as an indigestible marker during day 28-33, 63-68 and 98-103 to determine the digestibility coefficient. Fecal grab samples were collected at random from at least two pigs in each pen on day 33, 68 and 103. All the feed and fecal samples were freeze-dried and finely ground to be able to pass through a 1-mm screen, and stored in a refrigerator at -20°C until analysis. The DM and N concentrations were determined according to the AOAC (2000). Chromium levels were determined via UV absorption spectrophotometry (Shimadzu, UV-1201, Japan) following the method described by Williams et al. (1962). The apparent digestibility of DM and N were calculated using indirect-ratio methods using the following formula:

Coefficient of apparent total tract digestibility
= {1-[(Nf×Cd)/(Nd×Cf)]}

where Nf = nutrient concentration in feces (% DM), Nd = nutrient concentration in diet (% DM), Cf = chromium concentration in feces (% DM), and Cd = chromium concentration in feces (% DM).

Table 2. Composition of experimental diets (as fed basis)[1]

Items	Starter[2]		Grower[2]		Finisher[2]	
	CON	FGP	CON	FGP	CON	FGP
Ingredient (g/kg)						
Yellow corn	626.15	594.23	644.95	614.05	687.85	656.85
Soybean meal, 48% CP	311.6	313.6	261.1	263.1	222.5	224.5
Tallow	26.0	25.2	56.5	55.4	55.0	54.0
FGPP	0	30.0	0	30.0	0	30.0
Dicalcium phosphate	16.5	16.5	18.0	18.0	14.0	14.0
Calcium carbonate	9.7	9.7	9.2	9.2	12.1	12.1
Copper sulfate	0. 5	0.5	0.7	0.7	0.5	0.5
Mineral premix[3]	1.5	1.5	1.5	1.5	1.0	1.0
Vitamin premix[4]	1.5	1.5	1.5	1.5	1.25	1.25
Antibiotic[5]	1.25	1.25	1.25	1.25	0.5	0.5
Ethoxyquin	0.3	0.3	0.3	0.3	0.3	0.3
Salt	5.0	5.0	5.0	5.0	5.0	5.0
Calculated composition (g/kg)						
DE, kcal/kg	3,513	3,513	3,548	3,548	3,563	3,563
Crude protein	198.8	198.8	176.2	176.2	160.9	160.9
Lysine	11.0	11.0	9.6	9.6	8.5	8.5
Threonine	7.8	7.8	6.9	6.9	6.3	6.3
Tryptophan	2.7	2.7	2.3	2.3	2.1	2.1
Methionine+cystine	6.5	6.5	5.9	5.9	5.5	5.5
Calcium	8.0	8.0	8.0	8.0	7.0	7.0
Phosphorus	6.9	6.9	6.9	6.9	6.0	6.0
Analyzed composition (g/kg)						
GE, kcal/kg	4,283	4,280	4,325	4,327	4,343	4,345
CP	198.4	198.5	175.9	176.2	160.7	160.5
Calcium	7.9	8.0	8.0	7.9	7.0	6.9
Phosphorus	6.9	6.9	6.8	6.9	5.9	6.0

[1] Pigs were fed the starter diet from 23 to 36 kg of BW, the grower diet from 36 to 64 kg of BW, and the finisher diet from 64 kg of BW to market weight.

[2] Supplied 84 mg of Ca as calcium carbonate, 165 mg of Fe as ferrous sulfate, 165 mg of Zn as zinc sulfate, 39 mg of Mn as manganese sulfate, 16.5 mg of Cu as copper sulfate, 0.30 mg of I as calcium iodate, and 0.30 mg of Se as sodium selenite per kilogram of complete feed during the starter and grower phases, and 70 mg of Ca as calcium carbonate, 137.5 mg of Fe as ferrous sulfate, 137.5 mg of Zn as zinc sulfate, 32.5 mg of Mn as manganese sulfate, 13.75 mg of Cu as copper sulfate, 0.25 mg of I as calcium iodate, and 0.25 mg of Se as sodium selenite per kilogram of complete feed during the finisher phase.

[3] Supplied 238.5 mg of Ca as calcium carbonate, 6,613.8 IU of vitamin A, 992.1 IU of vitamin D_3, 26.46 IU of vitamin E, 0.0265 mg of vitamin B_{12}, 2.65 mg of vitamin K (menadione), 5.95 mg of riboflavin, 19.84 mg of pantothenic acid, and 33.07 mg of niacin per kilogram of complete feed during the starter and grower phases, and 159 mg of Ca as calcium carbonate, 4,409.2 IU of vitamin A, 661.4 IU of vitamin D_3, 17.64 IU of vitamin E, 0.0176 mg of vitamin B_{12}, 1.76 mg of vitamin K (menadione), 3.97 mg of riboflavin, 13.23 mg of pantothenic acid, and 22.05 mg of niacin per kilogram of complete feed during the finisher phase.

[4] Provided 0.11 g of tylosin per kilogram of feed during the starter and grower phases, and 0.04 g of tylosin per kilogram of feed during the finisher phase.

Meat quality

At the end of the experiment, all the pigs were slaughtered at a local commercial slaughterhouse. A 2.5-cm-thick section of longissimus muscle was removed from the center (in the region of the 10th rib) of a boneless pork loin. After chilling at 2°C for at least 24 h, the meat samples were thawed at ambient temperature prior to evaluation. Sensory evaluation (color, marbling and firmness scores) was conducted according to the National Pork Producers Council Standards (NPPC, 1991). Immediately after the subjective tests were conducted, the lightness (L*), redness (a*) and yellowness (b*) values were measured at 3 locations on the surface of each sample using a Model CR-410 Chroma meter (Konica Minolta Sensing, Inc., Osaka, Japan). At the same time, duplicate pH measurements of each sample were taken directly using a pH meter (Pittsburgh, PA, USA). The longissimus muscle (LM) area was measured by tracing the surface of the longissimus muscle (LM) at the 10th rib, which was also conducted using a digitizing area-line sensor (MT-10S; M.T. Precision

Co. Ltd., Tokyo, Japan). The 2-Thiobarbituric acid reactive substances (TBARS) were measured using the method described by Witte et al. (1970). The TBARS values were expressed in terms of milligrams of malonaldehyde per kilogram of muscle. Trichloroacetic acid solution (TCA, 20% wt/vol) was utilized for the extraction. UV absorption spectrophotometry (UV-1201, Shimadzu, Japan) was employed for the spectrohoptometric analyses.

Fatty acid composition of longissimus muscle and subcutaneous fat

A 2.5-cm-thick section of longissimus muscle was removed from the center (in the region of the 10th rib) of a boneless pork loin. The sample was trimmed free of all subcutaneous fat and epimysial connective tissue. Meanwhile, a 5×5 cm section of backfat was removed from the left side between the 4th and 8th thoracic vertebra, after which the samples were placed in sample bags identified with the identification number. All the samples were immediately frozen at -20°C until analysis for fatty acid.

Approximately 25 g longissimus muscle and 5 g subcutaneous fat were weighed and placed in 30-ml beakers, which were then placed into vacuum flasks attached to the manifold of a Labconco freeze-dryer (Model 4.5, Labconco Corp., Kansas City, MO) with a temperature setting of -50°C and a vacuum of less than 10 mmHg. Samples were freeze-dried for 60 h and then pulverized in liquid nitrogen before duplicate 30-mg freeze-dried samples were subjected to direct transesterification by incubating in 2.0 ml of 0.2 *M* methanolic potassium hydroxide in 16×125-mm screw-capped tubes at 50°C for 30 min, with vortex-mixing 2 to 3 times/min until tissues were dissolved (Murrieta et al., 2003). Tubes were allowed to cool to room temperature, and 1 ml of saturated sodium chloride was added to each tube. A 1-ml quantity of a hexane solution containing an internal standard (glyceryl tridecanoic acid (13:0)) was then added to each tube, and the hexane was evaporated before tubes were vortexed and subsequently centrifuged for 5 min at 1,100×*g* and 20°C to separate phases. A portion of the hexane layer containing the fatty acid methyl esters was transferred to GLC vials that contained a 1.0-mm bed of anhydrous sodium sulfate. Separation of fatty acid methyl esters was achieved by GLC (Model HP 5890 Series II GC, with an HP-7673 automatic injector and HP-3365 software; Hewlett- Packard, Avondale, PA) equipped with a 100-m capillary column (0.25-mm i.d.; Model 2560 fused-silica capillary column, Supelco Inc., Bellefonte, PA) and helium as the carrier gas at 0.5 ml/min (1:50 split ratio). Oven temperature was maintained at 175°C for 35 min, increased at 5°C/min to 215°C, and then increased at 10°C/min to 235°C, whereas injector and detector temperatures were maintained at 250°C. Identification of peaks was accomplished by using purified standards obtained from Nu-Chek Prep (Elysian, MN), Matreya (Pleasant Gap, PA), and Supelco.

Table 3. Effects of grape pomace product supplementation on growth performance in grower-finisher pigs[1]

Items	CON[1]	FGP[1]	SE[2]
Initial BW (kg)	19.35	19.28	0.712
Day 35 BW (kg)	46.65	46.27	1.021
Day 70 BW (kg)	73.92	75.36	1.562
Final BW (kg)	103.35	105.69	2.254
Day 0-35			
ADG (kg)	0.780	0.771	0.0229
ADFI (kg)	2.433	2.349	0.1203
Gain/feed	0.320	0.328	0.0132
Day 36-70			
ADG (kg)	0.779[a]	0.831[b]	0.0234
ADFI (kg)	2.126	2.380	0.1804
Gain/feed	0.351	0.349	0.0123
Day 71-105			
ADG (kg)	0.840	0.866	0.0442
ADFI (kg)	2.798	2.803	0.0941
Gain/feed	0.300	0.309	0.0111
Overall			
ADG (kg)	0.800	0.823	0.0363
ADFI (kg)	2.452	2.511	0.1213
Gain/feed	0.326	0.328	0.0095

[1] Each mean represents 7 pens with 4 pigs (28 pigs) in each per treatment. Dietary treatments were as follows: CON = Basal diet; FGP = CON+ 3.0% grape pomace product.
[2] Pooled standard error.
[a,b] Means in the same row with different superscripts differ ($p<0.05$).

Statistical analyses

In this experiment, pen was considered as the experimental unit. Data were analyzed using the GLM procedure of SAS (1996). Variability of all the data was expressed as standard error (SE) and a probability level of $p<0.05$ was considered as statistically significant.

RESULTS

Growth performance and coefficient of apparent total tract digestibility (CATTD) of DM and N

In the starter phase, there was no significant difference on growth performance or CATTD of DM and N (Tables 3 and 4). Dietary FGPP increased the ADG ($p<0.05$) and the DM and N digestibility ($p<0.05$) during grower phase. In the finisher phase, pig fed the FGPP supplemented diet had a higher ($p<0.05$) N digestibility compared with the CON group.

Meat quality

Pig fed the FGPP diet led to a improved marbling scores

Table 4. Effect of grape pomace product supplementation on nutrient digestibility in grower-finisher pigs[1]

Items	CON[1]	FGP[1]	SE[2]
Dry matter			
5 weeks	0.810	0.827	0.0123
11 weeks	0.717[b]	0.795[a]	0.0253
16 weeks	0.766	0.784	0.0121
Nitrogen			
5 weeks	0.808	0.815	0.0181
11 weeks	0.739[b]	0.825[a]	0.0234
16 weeks	0.705[b]	0.745[a]	0.0178

[1] Each mean represents 7 pens with 2 pigs (14 pigs) in each per treatment. Dietary treatments were as follows: CON = Basal diet; FGP = CON+ 3.0% grape pomace product.
[2] Pooled standard error.
[a,b] Means in the same row with different superscripts differ (p< 0.05).

(p<0.05, Table 5) in compared with CON group. The redness (a*) and yellowness (b*) values were higher (p< 0.05) in pigs fed FGPP supplemented diets. The inclusion of FGPP had a lower TBARS (p<0.05) compared with CON group (p<0.05).

Fatty acids composition

The effect of GPP on the fatty acid composition of subcutaneous fat is shown in Table 6. Dietary FGPP supplementation lead to lower palmitic acid (C:16:0), stearic acid (C:18:0) and arachidic acid (C:20:0) levels (p<0.05) than those in CON group, which may have resulted in the decrease (p<0.05) in total SFA. Moreover, a higher (p<0.05) linoleic acid (C18:2n6), total PUFA and PUFA/SFA ratio were also observed in FGPP group compared with CON group.

In terms of fatty acid composition of the longissimus muscle (Table 7), significant difference was only observed on the arachidic acid (C:20:0) level, which was decreased (p<0.05) by FGPP diet compared with the CON group. No difference was observed in total SFA, MUFA, PUFA and PUFA/SFA ratio in the longissimus muscle.

Table 5. Effects of grape pomace product supplementation on *Longissimus* muscle quality in grower-finisher pigs[1]

Item	CON[1]	FGP[1]	SE[2]
Longissimus muscle area (cm^2)	43.97	44.53	2.872
pH	5.83	6.12	0.410
TBARS (mg MA/kg)	0.049[a]	0.026[b]	0.009
Meat color	2.74	2.84	0.131
Meat marbling	2.79	2.89	0.212
Meat firmness	2.43	2.51	0.141
Meat color			
L (lightness)	47.96	48.77	0.688
a* (redness)	6.57[b]	8.25[a]	0.544
b* (yellowness)	1.74[b]	2.54[a]	0.213

[1] Each mean represents 7 pens with 4 pigs (28 pigs) in each per treatment. Dietary treatments were as follows: CON = Basal diet; FGP = CON+3.0% grape pomace product.
[2] Pooled standard error.
L* = Measure of lightness to darkness (larger number indicates a lighter color); a* = Measure of redness (larger number indicates a more intense red color); and b* = Measure of yellowness (larger number indicates more yellow color).
[a,b] Means in the same row with different superscripts differ (p<0.05).

DISCUSSION

Growth performance and coefficient of apparent total tract digestibility (CATTD) of DM and N

Previously, it is well suggested that grape pomace (GP) could depress the growth performance in livestock because

Table 6. Effects of grape pomace product supplementation on the fatty acid composition of the subcutaneous fat [1]

Fatty acid	CON[1]	FGP[1]	SE[2]
SFA[3]			
C:14:0	1.53	1.45	0.052
C:16:0	25.06[a]	23.80[b]	0.241
C:18:0	12.92[a]	12.19[b]	0.142
C:20:0	0.69[a]	0.59[b]	0.042
C:22:0	0.04	0.02	0.024
MUFA[3]			
C:14:1n6	0.08	0.16	0.043
C:16:1n7	2.72	2.84	0.062
C18:1n9	39.26	39.68	0.264
C20:1n9	0.47	0.51	0.052
C22:1n9	0.26	0.29	0.032
C24:1n9	0.03	0.03	0.012
PUFA[3]			
C18:2n6	9.76[b]	11.21[a]	0.394
C20:2n6	0.08	0.13	0.033
C20:4n6	1.00	1.18	0.122
C18:2n2	0.16	0.16	0.020
C20:3n3	-	-	-
C22:6n3	0.03	0.03	0.021
Total SFA	40.24[a]	38.05[b]	0.431
Total MUFA	42.82	43.51	0.421
Total PUFA	11.03[b]	12.71[a]	0.523
Total PUFA/SFA	0.27	0.34	0.042

[1] Each mean represents 7 pens with 4 pigs (28 pigs) in each per treatment. Dietary treatments were as follows: CON = Basal diet; FGP, CON+3.0% grape pomace product.
[2] Pooled standard error.
[3] SFA = Saturated fatty acid, MUFA = Monounsaturated fatty acid, PUFA = Polyunsaturated fatty acid.
[a,b] Means in the same row with different superscripts differ (p<0.05).

Table 7. Effect of grape pomace product supplementation on the fatty acid composition of the longissimus muscle [1]

Fatty acid (%)	CON[1]	FGP[1]	SE[2]
SFA[3]			
C:14:0	1.42	1.45	0.042
C:16:0	23.39	23.16	0.322
C:18:0	12.25	12.24	0.021
C:20:0	0.84[a]	0.76[b]	0.033
C:22:0	-	-	-
MUFA[3]			
C:14:1n6	0.02	0.01	0.012
C:16:1n7	2.06	2.10	0.091
C18:1n9	38.76	38.62	0.245
C20:1n9	0.75	0.81	0.048
C22:1n9	0.11	0.10	0.021
C24:1n9	-	-	-
PUFA[3]			
C18:2n6	12.70	12.93	0.251
C20:2n6	0.21	0.21	0.021
C20:4n6	0.24	0.24	0.022
C18:2n2	0.16	0.15	0.031
C20:3n3	0.02	0.02	0.012
C22:6n3	-	-	-
Total SFA	37.90	37.62	0.423
Total MUFA	41.70	41.64	0.330
Total PUFA	13.33	13.55	0.332
Total PUFA/SFA	0.35	0.36	0.029

[1] Each mean represents 7 pens with 4 pigs (28 pigs) in each per treatment. Dietary treatments were as follows: CON = Basal diet; FGP = CON+3.0% grape pomace product.
[2] Pooled standard error.
[3] SFA = Saturated fatty acid, MUFA = Monounsaturated fatty acid, PUFA = Polyunsaturated fatty acid.
[a,b] Means in the same row with different superscripts differ ($p< 0.05$).

of the large amount of polyphenols such as tannins, phenolic acids, anthocyanins and proanthocyanidins, which could bind with digestive enzymes and proteins located at the luminal side of the intestinal tract (Jansman et al., 1989). Hughes et al. (2005) confirmed the growth depression in chickens fed diets containing grape seed extract (902 g/kg total phenolics) at the level of 30 g/kg. However, recent studies suggested there were no growth depression in broilers when GP (48.6 g/kg total phenolics) was added up to 30 g/kg (Goñi et al., 2007; Brenes et al., 2008). In our experiment, the FGPP was supplemented at the level of 30 g/kg diet, where the total phenolic in FGPP was only 62.1 g/mg (Table 1), therefore, the levels supplemented in this study may have been too low to produce a growth expression effect. However interestingly, the growth performance was increased during d 36-70 in the present study, which may be attributed to the increased digestibility during this period. Goñi et al. (2005) had previously reported that intestinal bacteria showed a high ability to degrade extracted polyphenols in rats. Saura-Calixto et al. (2000) suggested that the indigestible fraction of grape pomace in the small intestine could reach the colon and provide a substrate for some of the fermentative microflora. Various studies also documented that phenolic grape extracts and red wine polyphenols could decrease the number of *Propionibacteria*, *Bacteroides*, and *Clostridia* and increase *Lactobacilli* and *Bifidobacteria* numbers (Dolara et al., 2005; Papadopoulou et al., 2005). Therefore, the polyphenols in FGPP could play an additional mechanism to stimulate the intestinal fermentation and subsequently influence the production of particular microbial metabolites. Furthermore, Shen et al. (2009) demonstrated that the yeast culture supplementation can positively affect the growth performance by improving gut health and nutrients digestibility in nursery pigs. Huang et al. (2003) also demonstrated that fermentation of material distiller's grains could improve the growth performance in pigs. Therefore, it is convincible that the fermentation process could be responsible for the growth performance in this study. However, it should be noted that the nitrogen digestibility was increased by the FGPP supplementation at the finisher phase, whereas the growth performance was not affect by the administration of the FGPP in this period. The reason is likely to be the non-significant effect of the DM digestibility in this period, since the N digestibility could just only reflect the protein utilization of the pigs, which may not be manifested on the growth performance.

Meat quality

In our study, the inclusion of FGPP decreased TBARS value of the pork, indicating the supplementation of FGPP could increase the antioxidant value of the pork. Grape pomace could reduce the TBARS values of raw breast chicken patties and pork chops (Goñi et al., 2007; Sáyago-Ayerdi et al., 2009) because of the one-electron reduction potential of polyphenols (quercetin, (-)-epicatechin and (+)-catechin) in grape pomace (Frank, 2005). Puiggross et al. (2005) demonstrated that grape seed procyanidins could affect the gene expression of antioxidant enzymes by interacting with element promoter in DNA. Therefore, our study confirmed the antioxidant effect of grape pomace. Moreover, dietary FGPP led to a higher redness (a*) and yellowness (b*) values in the present study. It is well accepted that dietary vitamin E supplementation led to higher a* in pork chops (Monahan et al., 1994); Goñi et al. (2007) also suggested the GP could be considered as a good alternative to α-tocopheryl acetate, which would protect the molecule reducing systems from free radical attack in the cured products (Morrissey et al., 1998). Therefore, although

we did not investigate the vitamin E level in the tissue in this study, we hypothesized this effect may be due to the sparing effect of GP on vitamin E in the intestine, and subsequently enhanced the vitamin E status in tissue (Frank, 2005). Furthermore, it has been demonstrated that the b* value is primarily affected by the type of myoglobin in the muscle (Mancini and Hunt, 2005). Mitsumote et al. (1993) also suggested that increased antioxidant can prevent the oxidation of myoglobin and oxymyoglobin to metmyoglobin. Therefore, we suggest the supplemental FGPP may have enhanced the antioxidant activity via mechanisms similar to those associated with vitamin E and explained the higher marbling score and b* values observed in this study.

Fatty acid composition

Previously, experiments conducted on the utilization of GP mainly emphasized on the its anti-oxidative ability (Brenes et al., 2008; Sáyago-Ayerdi et al., 2009), Experiment regarding the effect of GP on the fatty acid composition of pork is limited, Yi et al. (2009) had reported there are larger proportions of PUFA (60.9% to 64.4%) in grape pomace powder. Pascual et al. (2007) also proved that the increasing PUFA (mainly linoleic acid) intake had a positive effect on linoleic acid content, but a negative effect on the levels of palmitic and stearic acid levels of several tissues. Therefore, we hypothesized that the inclusion of FGPP could increase the PUFA and decrease the SFA concentration in meat. In the current study, dietary FGPP supplementation significantly decreased SFA (palmitic acid (C:16:0), stearic acid (C:18:0), arachidic acid (C:20:0) and increased PUFA (mainly linoleic acid (C18:2 n6)) concentrations in meat, which confirmed our hypothesis. The reason for this effect is likely to be the higher PUFA levels in the FGPP. However, as we did not measure the fatty acid composition of the diets used in our experiment, we can only suggest, based on the results of Yi et al. (2009), who reported larger proportions of PUFA (60.9% to 64.4%) in grape pomace powder. Moreover, it is well accepted that the inclusion of a probiotic including *saccharomyces* can increase the linolenic acid and the unsaturated fatty acid/saturated fatty acid ratio in pectoral meat of broiler, and was explained by its positive effect on the intestinal flora (Endo et al., 1999). Collectively, we suggested the FGPP supplementation could have altered the fatty acid composition, and subsequently improved the meat quality form a health perspective. However, since only the concentration of arachidic acid was increased in the longissimus muscle with FGPP supplementation, these effects seem to be tissue dependent. To the best of our knowledge, no other studies are available to compare with herein study. Therefore, further study is still warranted to investigate the effect of FGPP supplementation on the meat fatty acid composition.

CONCLUSION

In conclusion, dietary FGPP supplementation at the level of 30 g/kg improved the growth performance, nutrients digestibility, and altered the fatty acid pattern in the subcutaneous fat as well as some attributes of pork meat.

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