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Effects of Supplemental Fermented Agro By-products Diet on the Growth Performances, Blood Characteristics and Carcass Traits in Fattening Pigs

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ABSTRACT : Effects of a supplemental fermented agro by-products diet on growth performance, blood characteristics and carcass traits were investigated in fattening pigs. The fermented diet mainly contained 38.0% brewer's grain, 25.0% rice bran and 21.0% by-product of king oyster mushrooms. The mixed ingredients were fermented at 40°C for 7 days and fed to crossbred barrow pigs for 62 days. Ninety pigs were housed in 10 head per pen with three replicate pens per treatment. The pigs in the control group were fed with formula feed, while the pigs in T1 group were fed 20, 40, 60, 80 and 100% fermented diet substituted with formula feed on 1 week interval. Pigs in T2 group were fed 30, 60 and 100% fermented diet substituted with formula feed on 1 week interval. The fermented diet significantly ($p<0.05$) decreased body weight gain and feed efficiency of pigs. The blood characteristics differed with diet types. Carcass grade was significantly better ($p<0.05$) in the pigs fed fermented diet than in the pigs fed control diet as well as ratio of high grade was higher in the fermented diet groups. Therefore, although a dietary of fermented diet decreased growth performance and feed efficiency, it improved the carcass grade in pigs. (**Key Words :** Agro By-products, Carcass Trait, Fermented Diet, Growth Performance, Pigs)

INTRODUCTION

Recycling of by-products has increased over the last decade in pig nutrition, due to the need to decrease the use of fossil energy. The negative effects on environment and feeding costs were decreased by 10 to 17% using liquid by-products compared with dry diet in piglets (Scholten et al., 1999). Recently in Korea, a variety of by-products are produced by agricultural processing and they have the potential as piglets feed such as high crude protein (CP) and low moisture concentrations (Kim et al., 2010). Therefore, the development of feed ingredients using such by-products could decrease feeding cost in the swine industry.

A fermented diet can be obtained when a dry feed compound is mixed with water and stored for at least 8 h. Fermented diets improve gastrointestinal health such as decreased gastric pH, deceased number of enteric pathogens, decreased incidences of clinical diseases and increased concentration of gastric lactic acid compared with dry diets in pigs (Boesen et al., 2004). Fermented diets improved the daily gain of pigs (Russell et al., 1996), changed the gastrointestinal environment, reduced the growth of undesired microbes and the pH below 4.5 in weanling pigs (Jensen, 1998).

Recently, probiotics from microorganism are the most commonly used safe feed additives. Probiotics are defined as a live microbial feed additive that beneficially affects the host animal by improving the intestinal microbial balance (Kelly, 1998). Probiotics protect the constitution of enteropathogenic bacteria (Nisbet et al., 1993). The main effects of supplemental probiotics in pigs include decreased enteropathogenic bacteria due to an increase in lactic acid

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and antibiotics, increased nutrients, lactase activity, enzyme secretion and feed efficiency, and decreased diarrhea (Pollman, 1986; Collington et al., 1988). Moreover, the dietary of microorganisms as probiotics had shown good results on growth performance of pigs (Pendersen et al., 2002).

Brewer's grain is a by-product obtained from the brewing process and corresponds to around 85% of the total by-products. The chemical composition of brewer's grain varies according to barley variety, harvest time, malting and processing types (Xiros et al., 2009). Brewer's grain has the potential to decrease feedstock's cost and the production of high value products. Supplemental brewer's grain silage improved productivity in growing-fattening pigs and increased body weight (BW) and birth weight in both gestation and suck pigs (Kim et al., 1992). On the other hand, supplemental dried brewer's grain did not affect growth performance in growing-fattening pigs (Kim et al., 1993).

King oyster mushroom is a macroscopic fungus that is used as a functional food in Asian countries and contains a high quantity of proteins, carbohydrates, minerals and vitamins (Manzi et al., 1999). Song et al. (2007) reported that supplemental fermented oyster mushroom by-products changed meat quality parameters in finished Berkshire pigs.

Rice bran is a by-product from rice milling, makes up approximately 10 to 15% of rough rice and generally includes germs, polish and some broken kernels (Hoffpauer, 2005). Generally, the chemical composition of rice bran is 12 to 25% crude fat (CF), 10 to 16% CP, 6 to 10% ash and 9 to 13% crude fiber (Sharma et al., 2004). Robles and Ewan (1982) reported that supplemental rice bran improved growth performance of pigs and it is possible to use the energy of supplemented feed in ruminants. Although a dietary of rice bran did not affect growth performance of pigs, it was reported to decrease the concentration of plasma low density lipoprotein (LDL) cholesterol in pigs (Qureshi et al., 2001).

Recently, by-products were studied as feed ingredients. However, to our knowledge, the supplemental fermented brewer's grain, by-product of king oyster mushroom and rice bran has not been studied in fattening pigs. The production of mushroom by-products has increased because of increasing mushroom industry in Korea and it was more than 1.90 million ton per year (Kim et al., 2007). Many researchers used brewer's grain as a roughage source in ruminants (Park et al., 2003; Choi et al., 2006). However, the brewer's grain has not been studied in pigs. This study focused on agro by-products, such as brewer's grain and mushroom by-products was able to substitute feedstuffs. However, such by-products provide in sufficient energy value, while rice bran has high energy value and low price in Korea. Therefore, the rice bran was added to increase energy value and decrease the feed cost. Experiments were conducted to study the effects of fermented agro by-products diet using the brewer's grain, king oyster mushroom and rice bran on the growth performance, blood characteristics and carcass traits in fattening pigs.

MATERALS AND METHODS

Production of fermented agro by-products diet

The fermented agro by-products diet was mainly composed of 30% brewer's grain, 25% rice bran and 21% by-products of king oyster mushroom, respectively (Table 1). The ingredients were regulated to about 60% by water and mixed in a fermenter (Bio-Rea, Tong yang, Seoul, Korea) with supplemental 0.01% probiotics at 40°C for 24 h. The probiotics approximately contained 3.0×10^7 CFU (colony forming units)/g *Lactobacillus plantarium*, 2.0×10^7 CFU/g *Enterococcus faecium* and 2.0×10^7 tfu (thallus forming units)/g *Saccharomyces cerevisae*. The mixture was transferred into 600 L plastic containers (anaerobic condition) and fermented at room temperature for 7 days. The fermented agro by-products diet was made in 3 separate plastic containers and were analysed in 3 replicates.

Analysis of fermented diet

Experimental samples were collected from fermented diet on day 0 and week 1 to determine in proximate analysis, the gross energy, pH and the number of microorganisms such as total bacteria, *Lactobacillus spp.*, yeast, *Escherichia coli* and *Salmonella spp.*.

This proximate analysis of collected samples was determined according to the methods of AOAC (2000). Dry matter (DM) was determined by drying samples at 130°C in an air-forced oven for 2 h. CP was determined by Kjeltec System (K-412/K-339; Buchi, Flawil, Switzerland), CF was determined by diethyl ether extraction method using the Extraction System (B-811; Buchi) and crude fiber was determined by filtration method using the Fiber Analyzer

Table 1. Composition of fermented agro by-products diet

Ingredients, as-fed basis	Percentage
Brewer's grain	38.0
Rice bran	25.0
By-product of king oyster mushroom	20.99
Pineapple by-product	8.0
Hulled soybean	4.0
Corn meal	4.0
Probiotics[1]	0.01

[1] Microbial contained per gram of probiotics: *Lactobacillus plantarium*, 3.0×10^7 cfu; *Enterococcus faecium*, 2.0×10^7 cfu; and *Saccharomyces cerevisae*, 2.0×10^7 tfu.

(Ankom A220, Mill tech, Seongnam, Korea). Ash was determined by heating at 550°C. Gross energy in fermented diet was determined by Bomb calorimeter (Parr 1266, IL, USA). Values of pH were immediately measured using a pH meter (Hanna HI 9025, Woonsocket, RI, USA) with an Orion 8163 glass electrode (Beverley, MA, USA).

Ten gram of fresh fermented diet samples were collected from each treatment at the initial and the end of fermentation period for analysis of microbial numbers. Collected samples were suspended in 90 ml distilled water then homogenized at 2,500 rpm for 1 min. The homogenized samples were diluted 10^{-3} to 10^{-8} folds. Total count of bacteria was determined using Nutrients agar (Cat. No. 213000; Difco, NJ, USA) at 37°C for 48 h in working aerobic clean bench. *Lactobacillus spp.* count was determined using Man Rogosa Sharpe (MRS) agar (Cat. No. 288210; Difco) at 35°C for 72 h in working anaerobic chamber. Yeast count was determined using Yeast Mold (YM) agar (Cat. No. 271210; Difco) at 32°C for 24 h in working aerobic clean bench. *Escherichia coli* and *Salmonella spp.* counts were determined using MacConkey agar (Cat. No. 212123; Difco) at 37°C for 24 h in an anaerobic chamber. Colony count in each plate was measured using a colony counter (Suntex-570; Sung Kwang, Seoul, Korea).

Animals and diets

Duroc×(Yorkshire×Landrace) pigs aged approximately 130 days were used in this study. At the initiation of this study, the average BW of the pigs was 78.1±2.2 kg. There were 150 pigs assigned to 3 dietary treatments based on BW and sex. The 3 dietary treatments were divided into groups of 10 pigs (5 males and 5 females) and 3 replicates. Pigs were housed individually, given pre-feeding for 3 days and had free access to water and the diets for 62 days (from day 130 to day 182). Taking care of these animals was in accordance to the Guide for the Care and Use of Laboratory Animals (Jinju National University Animal Care Committee).

Control diet was provided as a mash form formulated to meet or exceed the amounts of nutrient requirements for growing pigs, such as 3.22 Mcal/kg metabolism energy (ME), 15.5% CP, 0.87% lysine, 0.92% calcium (Ca) and 0.50% phosphorus (P). Control diet mainly contained 33.5% expanded pellet corn, 12.5% dehulled soybean meal and 30.0% wheat (Table 2). The pigs in the control group were fed control diet, while the pigs in T1 group were fed fermented diet substituted for 20, 40, 60, 80 and 100% of the control diet at 1 week intervals. Pigs in T2 group were fed fermented diet substituted for 30, 60 and 100% of the control diet at 1 week intervals. The nutritional values of experimental diet were shown in Table 2.

Table 2. Composition of basal diet

Items	Compositions
Ingredients (%)	
Corn grain	33.50
Dehulled soybean meal	12.50
Wheat	30.00
Tallow	4.20
Molasses	4.00
Wheat bran	4.00
Rapeseed meal	3.00
Cotton seed meal	3.00
Palm kernel meal	2.00
Rice bran	1.00
Limestone	1.45
Calcium phosphate, tribasis	0.60
L-lysine hydrochloric acid	0.10
DL-methionine	0.10
Vitamin premix[1]	0.20
Trace mineral premix[2]	0.20
Sodium chloride	0.30
Phytase	0.05
Chemical composition (%)	
Crude protein[3]	17.50
ME[4] (Mcal/kg)	3.35
Crude fat[3]	6.31
Crude fiber[3]	2.98
Lysine[4]	0.87
Calcium[3]	0.92
Total phosphorus[3]	0.50

[1] Supplied per kilogram of diet: 4,000 IU vitamin A, 3,800 IU vitamin D, 1,500 IU vitamin E, 320 mg vitamin K, 16 mg vitamin B_{12}, 8.0 mg thiamin, 2.0 mg riboflavin, 11.0 mg pantothenic acid, 20.0 mg niacin and 0.02 mg biotin.
[2] Supplied per kilogram of diet: 30 mg Cu, 175 mg Fe, 100 mg Zn, 90 mg Mn, 0.3 mg I, 0.5 mg Co and 0.2 mg Se.
[3] Analytical values.
[4] Calculated values were based on composition values from Rural Development Administration (2007).

Sampling and chemical analyses

BW was measured at the beginning and end of the experimental period. Consumption amounts of diet were recorded at one-week interval. Feed efficiency was calculated as an average daily gain (ADG) divided by feed intake. Blood samples were collected from jugular vein 3 h late after the last feeding.

The blood corpuscles, such as leukocytes, erythrocytes, hemoglobin, hematocrit and platelets were determined using an automatic hematological analyzer (VET abc, Montpellier, France) within 2 h after blood sampling. Plasma was obtained by centrifugation at 2,500 g for 30 min at 4°C and stored at -20°C for analyses. The chemical

Table 3. The effects of frementation priod on the chemical composition of fermented agro by-products diet[1]

Items	Fermentation period[2]		SEM[3]
	Initial	End	
pH	6.45	4.49*	0.004
Dry matter, as fed basis	51.19	49.99	4.49
Chemical compositon, % of DM basis			
Crude protein	15.43	19.48*	1.57
Crude fat	8.57	8.61	0.81
Crude fiber	17.75	17.80	1.10
Ash	4.87	4.67	0.38
Total calorie (Mcal/kg)	4.46	4.80*	0.32

[1] Mean of three diets individually analysed at the initial and end of fermentation days.
[2] Fermented diet of the initial (0 day) and end (7 day) days were analysed in 3 replicates.
[3] Standard error of the means.
* Significantly different from the initial fermentation period at p<0.05.

composition of plasma such as total cholesterol, high-density lipoprotein (HDL) cholesterol, LDL-cholesterol, total protein, triglycerides and blood urea nitrogen (BUN) were determined using Blood Analyzer (Express Plus, Bayer, MA, USA).

Carcass traits, carcass grades and analyses

The pigs averagely 182 days of age were transported to a normal abattoir near the experimental station. They were slaughtered after 12 h from the time of feed restriction and electrically stunned (300 volts for 3 seconds). The shocked pigs were exsanguinated while being hanged. Carcasses were then placed in a dehairer at 62°C for 5 min and remaining hair was removed using a knife and flame. Carcasses were eviscerated and split before being placed in a chiller set at 5°C for 12 h.

Carcass grade in Korea is explained in the web site of Korea Institute for Animal Products Quality Evaluation (KAPE; www.ekpe.or.kr). All pork carcasses in Korea are graded both in quality and conformation terms. The quality of pork carcasses is graded 1+, 1, 2 and 3 based on the marbling, lean color and conditions of belly streaks. The conformation terms of pork carcasses is graded A, B, C and D by assessing carcass weight, backfat thickness, balance, muscle, fat condition, etc. Carcass grades in this study were expressed as 1 (extremely good), 2 (good), 3 (bad) and 4 (extremely bad) in A, B, C and D grade of conformation terms. The percentage of dressing was calculated as the ratio of cold carcass weight to live weight. Backfat thickness was measured using the 10th rib as three-quarters the distance along *longissimus dorsi* toward the belly. The *longissimus dorsi* (6th to 13th rib) was cut off and kept at 5°C before it was transported to the laboratory for the determination of chemical composition. The concentrations of moisture, CP, CF and ash of *longissimus dorsi* were determined according to the methods of AOAC (2000) about 24 h after slaughter.

Statistical analyses

The data were analyzed using the General Linear Model (GLM) procedures of SAS (1999) and the significance of differences among the means was determined using the Duncan's Multiple Range Test method at p<0.05 (Duncan, 1955).

RESULTS

Changes of fermented diet and experiment diets

The effects of fermentation period on the chemical composition of fermented agro by-products diet are shown in Table 3. Fermentation period did not affect the concentrations of DM, CF, crude fiber and ash. However, the CP concentration and total calorie in agro by-products diet was changed by fermentation period. The CP concentration was significantly increased (p<0.05) as well as the total calories at the end of fermentation period (day 7) compared with the initial fermentation day (day 0). The microbial population was affected in agro by-products diet during the fermentation period (Table 4). *Escherichia coli* and *Salmonella spp.* were not detected at the initial or at the end of fermentation days, while aerobic total bacteria, anaerobic *Lactobacillus spp.* and anaerobic yeast populations were significantly increased (p<0.05) at the end of fermentation period compared with the initial fermentation day. The nutritional values of DM, CP, CF and ash were decreased, while ME values and crude fiber concentration were increased by increasing supplemental fermented mushroom by-products diet (Table 5).

Growth performance

The dietaries of fermented agro by-products diet affected the growth performance and feed efficiency in the

Table 4. The effects of frementation priod on the pH and microbial population in a fermented agro by-products diet[1]

Microbial population[2]	Fermentation period[3]		SEM[4]
	Initial	End	
Total bacteria (log_{10} cfu[5]/g)	5.383	7.822*	0.260
Lactobacillus sp. (log_{10} cfu[5]/g)	4.519	8.282*	0.297
Escherichia coli (log_{10} cfu[5]/g)	ND[7]	ND	
Salmonella sp. (log_{10} cfu[5]/g)	ND	ND	
Yeast, (log_{10} tfu[6]/g)	3.084	8.098*	0.904

[1] Mean of three diet samples individually analysed at initial and end of fermentation days.
[2] The microbial populations was determined using agar: i) total bacteria, Nutrients, ii) *Lactobacillus sp.*, Man Rogosa Sharpe (MRS), iii) *Escherichia coli* and *Salmonella sp.*, MacConkey, iv) yeast, Yeast Mold (YM).
[3] The fermented diet of initial (0 day) and end (7 day) days were analysed in 3 replicates.
[4] Standard error of the means. [5] Colony forming units. [6] Thallus forming units. [7] Not detected.
* Significantly different from the initial fermentation period at p<0.05.

Table 5. Chemical composition of supplemental fermented agro by-product diets

Items	Fermented diet (%)					
	20	30	40	60	80	100
Chemical compositon[1] (% of as-fed basis)						
Dry matter	79.60	75.90	72.20	64.79	57.39	49.00
Crude protein	15.95	15.17	14.40	12.84	11.29	9.74
Crude fat	5.91	5.71	5.51	5.11	4.71	4.30
Crude fiber	4.16	4.76	5.35	6.53	7.71	8.90
Ash	4.44	4.18	3.92	3.39	2.86	2.33
ME[2] (Mcal/kg)	3.16	3.06	2.97	2.78	2.59	2.40

[1] Analytical values. [2] Based on composition values from Agriculture, Rural Development Administration (2007).

Table 6. The effects of supplemental fermented agro by-products diet on the growth performance and feed efficiency in fattening pigs[1]

Items	Treatments[2]			SEM[3]
	C	T1	T2	
Growth performance				
Initial body weight (kg)	78.50	77.67	79.65	1.91
Finished body weight (kg)	119.69^a	110.33^b	110.22^b	2.01
Average daily gain (kg/d)	0.73^a	0.53^b	0.50^b	0.031
Feed intake				
Average daily feed intake (kg)	2.58^c	2.77^b	2.85^a	0.02
Feed efficiency (g/g)	0.270^c	0.190^b	0.173^a	0.031

[1] Mean of 30 pigs individually housed in pens.
[2] The basal diet substituted the fermented diet at 1 week intervals: i) C, no substitution, ii) T1, 20, 40, 60, 80 and 100%, iii) T2, 30, 60 and 100%.
[3] Standard error of the means. [a,b,c] Values in the same row with different superscripts differ at p<0.05.

fattening pigs (Table 6). The end BW, ADG and feed efficiency were significantly lower (p<0.05) in the pigs fed fermented diet and feed efficiency was lowest in the T2 group. The average daily feed intake was significantly higher (p<0.05) in the pigs fed fermented diet.

Blood characteristics

The effects of supplemental fermented agro by-products diet on the blood corpuscle and plasma chemical composition are shown in Table 7. In blood corpuscle, the concentrations of leukocytes, erythrocytes and hemoglobin were not affected by diet type. The concentrations of hematocrit and platelets were significantly lower (p<0.05) in the pigs fed fermented diet. In chemical composition of plasma, the diet type did not affect the concentrations of total protein and triglyceride. Concentrations of HDL-cholesterol and LDL-cholesterol were significantly lower (p<0.05) in the pigs fed fermented diet and the BUN concentration was significantly higher (p<0.05) in the pigs fed fermented diet. The total cholesterol concentration was

Table 7. The effects of supplemental fermented agro by-products diet on the blood corpuscle and plasma chemical composition in fattening pigs[1]

Items	Treatments[2]			SEM[3]
	C	T1	T2	
Blood corpuscle				
Leukocytes (10^3/mm^3)	17.74	17.57	17.41	0.26
Erythrocytes (10^6/mm^3)	7.13	7.11	7.09	0.11
Hemoglobin (g/dl)	9.47	10.94	10.96	0.21
Hematocrit (%)	40.29[a]	36.65[b]	36.88[b]	0.30
Platelets (10^3/mm^3)	251.6[a]	212.2[b]	220.8[b]	1.69
Chemical composition of plasma				
Total cholesterol (mg/dl)	106.5	104.1	103.3	0.38
HDL cholesterol[4] (mg/d)	44.03[b]	35.56[a]	35.60[a]	1.21
LDL cholesterol[5] (mg/d)	81.41[a]	67.80[b]	67.82[b]	2.20
Total protein (g/dl)	5.53	5.40	5.50	0.19
Triglyceride (g/dl)	57.61	57.91	57.98	0.58
BUN[6] (mg/dl)	14.39[b]	16.65[a]	16.52[a]	0.18

[1] Mean of 30 pigs individually housed in pens.
[2] The basal diet substituted the fermented diet at 1 week intervals: i) C, no substitution, ii) T1, 20, 40, 60, 80 and 100%, iii) T2, 30, 60 and 100%.
[3] Standard error of the means. [4] High density lipoprotein cholesterol. [5] Low density lipoprotein cholesterol. [6] Blood urea nitrogen.
[a,b] Values in the same row with different superscripts differ at $p<0.05$.

less ($p = 0.08$) in the T2 group than in the C group.

Carcass traits and chemical composition

The carcass characteristics and chemical compositions of *longissimus dorsi* of pigs fed fermented agro by-products diet are shown in Table 8. The carcass weight, dressing and backfat thickness were significantly lower ($p<0.05$) in the pigs fed fermented diets than in the pigs fed control diet. The carcass grade was also significantly ($p<0.05$) improved and it was most improved in T2 group. The ratio of high grade (A and B grades) was higher and the highest grade was T2 group. Moreover, fermented agro by-products diet decreased the feed cost by 27 to 33% and increased the income of animal farmers by 24.7 to 45.3% (data not shown).

The moisture concentration of *longissimus dorsi* was

Table 8. The effects of supplemental fermented agro by-products diet on the carcass traits and chemical compisition of *longissimus dorsi* in fattening pigs[1]

Items	Treatments[2]			SEM[3]
	C	T1	T2	
Carcass trait				
Carcass weight (kg)	94.63[a]	82.44[b]	83.89[b]	2.23
Dressing (%)	80.96[a]	74.73[b]	76.12[b]	2.02
Backfat thickness (mm)	26.63[a]	18.56[b]	19.11[b]	2.58
Meat grade				
Carcass grade[4]	3.61[a]	2.60[b]	1.83[c]	0.134
High grade rate[5] (%)	13.0	31.0	91.0	
Chemical composition of *longissimus dorsi* (%)				
Moisture	73.12[a]	72.86[a]	72.18[b]	0.67
Crude protein	22.37	22.19	21.89	0.49
Crude fat	3.20[b]	3.62[ab]	3.91[a]	0.43
Ash	1.21[a]	1.09[b]	1.07[b]	0.08
Cholesterol (mg/100 g)	39.43[a]	26.74[b]	29.55[ab]	5.06

[1] Mean of 30 pigs individually housed in pens.
[2] The basal diet substituted the fermented diet at 1 week intervals: i) C, no substitution, ii) T1, 20, 40, 60, 80 and 100%, iii) T2, 30, 60 and 100%.
[3] Standard error of the means.
[4] The carcass grades were assessed on 4 points base as: i) 1, A (extremely good), ii) 2, B (good), iii) 3, C (bad), iv) 4, D (extremely bad).
[5] The percentage of high grade rate was A plus B grades of carcass grade.
[a,b,c] Values in the same row with different superscripts differ at $p<0.05$.

significantly higher ($p<0.05$) in the C and T1 groups than in T2 group. Diet types did not affect the CP concentration of *longissimus dorsi*. The CF concentration of *longissimus dorsi* was significantly higher ($p<0.05$) in T2 group than in C group. The ash and cholesterol concentrations of *longissimus dorsi* was significantly lower ($p<0.05$) fermented diet groups than control group.

DISCUSSION

Fermented diets improve gastrointestinal health and prevent clinical diseases by decreasing gastric pH and a number of enteric pathogens and increasing gastric lactic acid concentration in pigs (Boesen et al., 2004). Anaerobic fermentation using the lactic acid bacteria improves storability, palatability and nutrient values of feedstuffs (Gao et al., 2008). Moreover, yeast helps lactic acid bacteria to use substrates, such as lactic acid and organic acids (Yang et al., 2006). The fermentation by lactic acid bacteria and yeast decreased the pH and increased lactic acid concentration due to increaseed populations of lactic acid bacteria and yeast (Kwak et al., 2009). Therefore, the fermentation by lactic acid bacteria and yeast improves storability and nutrient values.

The CP concentration and total calorie were increased at the end of fermentation days compared with the initial fermentation day in this experiment. Kim et al. (2006b) reported that fermentation period changed the concentrations of CP, ash and total calorie in fermented persimmon shell diet. The protein proportion of DM silages increased during storage period can be explained by the utilization of carbohydrates during the fermentation process (Dapkevicius et al., 1998). The increase of CP concentration may be due to the increase microbial population as aerobic total bacteria, anaerobic *Lactobacullus spp.* and anaerobic yeast. The pH was decreased during the storage days and it was related to the rate and increase of lactic acid production (Davies et al., 1998). Results of this study show that changes in chemical composition and pH due to fermentation of diet were in consistence with previous studies.

Total bacteria (aerobic condition), *Lactobacillus spp.* (anaerobic condition) and yeast (aerobic condition) populations were increased 7.822, 8.282 and 8.098 $\log_{10}$ cfu/g at the end of fermentation days in this experiment. Mikkelsen and Jensen (1998) reported that the fermented diet had a number of 9.6 $\log_{10}$ cfu/g lactic acid bacteria and 6.0 $\log_{10}$ cfu/g yeast and it was similar to this study. Edwards et al. (1986) reported that the amount of lactic acid bacteria and yeast ranged from 7.0 to 8.4 $\log_{10}$ cfu/g and 3.7 to 6.7 $\log_{10}$ cfu/g in the fermented potato steam peel. Carbohydrates fermented by lactic acid bacteria and yeast changed to lactic acid, organic acids, alcohol and CO_2 (Prescott et al., 1996). Therefore, agro by-products diet has shown good fermentation ability by lactic acid bacteria and yeast in this experiment.

This study was conducted to test the addition of 20, 40, 60, 80 and 100% fermented agro by-products as T1 and 30, 60 and 100% as T2. As mentioned earlier, the nutritional values of CP concentration and ME value were decreased, while crude fiber concentration was increased by increasing fermented agro by-products diet. Because the brewer's grain and mushroom by-products contain high level of crude fiber. Generally, the ratio of CP concentration and ME values affected the meat quality (Kang et al., 2010) as a result of diet with high level crude fiber that decreased the growth performance (Song et al., 2007), while improved brood parameters (Turley et al., 1991). Therefore, the experimental diet affected the carcass composition, meat composition and blood parameters instead of diet with low energy level that increased fat accumulation due to increased growth performance in fattening pigs.

The supplementation of fermented agro by-products diet decreased ADG and feed efficiency in this experiment, which is in contrast with previous studies (Kim et al., 2006b; Song et al., 2007). The fermented diets used in these studies substituted less than 10% of formula feed. In this experiment, the fermented agro by-products diet was substituted by 100% of formula feed. Moreover, supplemental high fiber diet was found to decrease ADG and feed efficiency (Ndindana et al., 2002) as well as reduced ileal digestibility of nutrients (Ehle et al., 1982). Therefore, the ADG might be affected by digestibility of nutrients or diet ingredients.

The supplemental fermented agro by-products diet decreased the concentrations of hematocrit, platelets and LDL-cholesterol and increased HDL-cholesterol concentration in this experiment. This is in contrast with previous studies. Kim et al. (2006b) reported that an addition of fermented persimmon to the feed decreased hematocrit and platelet concentrations and increased HDL-cholesterol concentration in Berkshire pigs. Kitawaki et al. (2009) reported that *Lactobacillus spp.* fermented soymilk and soy yogurt decreased the concentration of plasma cholesterol because of the hydrophobic high molecular weight fraction produced by the enzymatic hydrolysis in rats. Xiao et al. (2003) reported that a dietary of milk products fermented by *Bifidobacterium longum* decreased the concentrations of total cholesterol and LDL-cholesterol in humans. Moreover, lactic acid bacteria have the capacity to assimilate and bind cholesterol (Hosono and Tonooka, 1995) which reduced serum total cholesterol due to inhibited absorption of bile acids in the intestine.

The supplementation of fermented agro by-products diet decreased carcass weight, dressing and backfat thickness, and improved carcass grade in this study. Moreover, the economic efficiency was calculated as diet cost or carcass grade in fattening pigs (data not shown). Fermented agro by-products diet decreased the feed cost in T1 by 27% and 33% in T2. Hence, fermented agro by-products diet increased the income in T1 by 24.7% and 45.3% in T2. Pork quality was affected by the ratio of carbohydrate and fat in fermented diet (Kang et al., 2010). Sasaki et al. (2007) reported that supplemental fermented food co-products affected pork quality. Therefore, the effects on carcass grade in this experiment may be to due the nutritional value of the diet as CP, CF concentrations and ME value. Lee et al. (2009) reported that supplemental fermented apple diet decreased backfat thickness and affected moisture, CP and ash concentrations of *longissimus dorsi* in pigs. Song et al. (2007) reported that a supplemental fermented oyster mushroom by-product decreased carcass weight and dressing, and changed the CP and CF concentrations of *longissimus dorsi* in Berkshire pigs. Kim et al. (2006a) also reported that supplemental fermented persimmon shell affected the moisture and CF concentrations of *longissimus dorsi* in Berkshire pigs.

In conclusion, although the fermented agro by-products diet decreased ADG and feed efficiency, it is expected to increase economical benefit through decreased feed cost and increased ratios of high grade in fattening pigs. Moreover, carcass traits of *longissimus dorsi* were changed by the dietary of fermented agro by-products diet in fattening pigs.

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