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ARTICLE

Effects of Dietary Bamboo Charcoal on the Carcass Characteristics and Meat Quality of Fattening Pigs

Gyo Moon Chu[1], Jong Hyun Kim, Sung Nam Kang[1], and Young Min Song*

Department of Animal Resource Technology, Gyeongnam National University of Science and Technology, Jinju 660-758, Korea
[1]Swine Science & Technology Center, Gyeongnam National University of Science and Technology, Jinju 660-758, Korea

Abstract

The purpose of this study was to investage the effects of dietary bamboo charcoal on the carcass characteristics and meat quality of fattening pigs. Fifty four crossed pigs of 61.0±1.0 kg body weight (BW) were grouped and housed in 6 animals (3 barrows and 3 gilts) per pen and 3 replications per treatment. The basal diet (C) was supplied with 0.3% bamboo charcoal as treatment 1 (T1) and 0.6 % as treatment 2 (T2). The pigs were fed that experimental diet for 42 days, thereafter 10 *longissimus dorsi* (LD) per treatment were randomly collected at the time the pigs reached an average weight of 110.0±5.0 kg. The carcass weight, backfat thickness, and the carcass grade were better (p<0.05) in the pigs fed bamboo charcoal than in C. The crude fat concentration of LD was higher (p<0.05) in T1 than in C. While the composition of stearic acid and arachidonic acid was lower (p<0.05) in treatments than in C, the composition of oleic acid and linoleic acid of treatments was higher (p<0.05) than C. The physico-chemical characteristics, such as meat color and amino acid composition of LD were not affected (p>0.05) by the supplemented bamboo charcoal. In conclusion, dietary supplementation with bamboo charcoal improved the carcass grade and fatty acids composition of pork meat from fattening pigs, where the composition of unsaturated fatty acids was increased, but that of saturated fatty acids was decreased.

Key words: bamboo charcoal, carcass grade, meat quality, pigs

Introduction

Charcoal generally refers to the carbonaceous residues left over after heating organic matter in the absence of oxygen, such as wood, coconut shells and various industrial wastes. Charcoal is an adsorbent for many toxins, gases, drugs, fat and fat-soluble substances (Kutlu *et al*., 2001). The adsorptive power of charcoal could be increased considerably by treating it with various substances at temperatures ranging from 500 to 900ºC (Osol, 1975).

Some researchers explored charcoal as an animal's feed additives. Dietary supplemented with charcoal affected growth performance and carcass traits in fattening pigs (Hwang, 1995), and it also affected microbes reproduction in sheep (Knutson *et al*., 2006), meat quality and storage characteristics of pork (Hwang, 1995). Charcoal controls the lactic acid concentration by maintaining the pH level and microflora population in rumen animals (Hoshi *et al*., 1991). It also combines with the phenol in gastrointestinal tracks, which prevents the interference of hydro-soluble tannins with enzyme's functionality and protein digestion (Murdiati *et al*., 1991).

Bamboo charcoal is an activated charcoal made from thick stems of bamboo by dry distillation and powdered (Zhao *et al*., 2008). Bamboo charcoal powder has been used as an oral antidote to reduce swallowed poisons in the gastrointestinal tracts (Anjaneyulu *et al*., 1993). Dietary containing 0.3% bamboo charcoal was reported to increase the growth performance, feed efficiency and beneficial fecal microflora, but at the same time, decrease noxious gas emission and harmful fecal microflora in fattening pigs (Chu *et al*., 2013a). Moreover, it was reported that bamboo charcoal was able to improve swine production by enhancing the feeding environment of fattening pigs and this material can be regarded as a secure feed additive and an alternative to antibiotics in animal production. Chu *et al*. (2013b) reported that dietary of bamboo charcoal increased growth performance, feed efficiency and immunoglobulin concentration of plasma in fattening pigs. This expected that dietary of bamboo charcoal would improve swine production due to its ability to

*Corresponding author: Young Min Song, Department of Animal Resources Technology, Gyeongnam National University of Science and Technology, Jinju 660-758, Korea. Tel: 82-55-751-3588, Fax: 82-55-751-3689, E-mail: pigsong@gntech.ac.kr

improve gastrointestinal environment. Therefore, bamboo charcoal can be used as a feed additive in swine industry.

However, to our knowledge, there are no reports on the effects of bamboo charcoal in diet on the carcass characteristics and meat quality in pigs. Hence, this study was conducted to investigate the effects of additive bamboo charcoal in diet of fattening pigs on the carcass characteristics and meat quality.

Materials and Methods

Processing of bamboo charcoal

Bamboo charcoal preparation was provided by Borim Inc. (Jinju, Korea). The detailed process of bamboo charcoal was divided into 3 steps; 1) Bamboo (*Phyllostachys pubescens*) chips of 1 cm (width) × 2 cm (length) were heated at 700°C for 6 h and cooled down to room temperature (RT) to produce ashed bamboo, 2) then ashed bamboo was transferred to a rotary furnace and heated at 900°C for 8 h and cooled to RT to form activated charcoal and 3) the activated bamboo charcoal was ground to less than 200 mesh (less than 100 μm in diameter) by jet mill.

Animals and diets

Experimental pigs were at the age of approximately 120 ±1 d and an average body weight (BW) of 61.0±1.0 kg at initiation. Fifty four crossed pigs (Landrance × Yorkshire × Duroc) were assigned to 3 dietary treatments and each treatment contained 6 pigs (3 barrows and 3 gilts) per pen and 3 replication (6 pigs × 3 diets × 3 replications). They were given pre-feeding for 3 d then fed experimental diet for 42 d (until 110.0±5.0 kg of BW) and had free access to water. The Guide for Care and Use of Laboratory Animals (Animal Care Committee of Gyeongnam National University of Science and Technology) was followed in this study.

A basal diet made of 51.80% corn, 14.59% wheat, 11.12% soybean meal, 7.00% dried distiller's grains with solubles (DDGS) and 15.49% other feedstuffs or additives. Chemically, the basal diet consisted of 14.00% crude protein, 3.125 Mcal/kg metabolizable energy (ME), 0.80% lysine and 0.40% total phosphorus. The basal diet (C) supplied with 0.3% (T1) and 0.6% (T2) bamboo charcoal.

Carcass traits and carcass grades

At the end of this experiment, the pigs were transported to a normal abattoir near the experimental station. They were electrically stunned (300 volts for 3 s) for slaughter after 12 h from the time of feed restriction. The shocked pigs were exsanguinated while being hanged, and then the carcasses were 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.

Table 1. Effects of dietary bamboo charcoal on the carcass characteristics and meat grade in fattening pigs

Item	Treatment[1]			SEM[2]
	C	T1	T2	
Carcass characteristics				
Finished body weight, kg	109.67[b]	116.83[a]	113.33[a]	1.87
Carcass weight, kg	80.94[b]	85.39[a]	83.12[a]	1.78
Dressing, %	73.80	73.09	73.34	1.02
Backfat thickness, mm	18.67[b]	22.50[a]	22.00[a]	2.07
Meat grade				
Carcass grade[3]	1.50[a]	1.00[b]	1.00[b]	0.14
Conformation terms[3]	1.67	1.50	1.67	0.39
High grade rate[4], %	50.0	81.0	83.0	-

[1]The basal diet was supplied with bamboo charcoal: C, no supplementation; T1, 0.3% and T2, 0.6%.
[2]Standard error of the means.
[3]The carcass grade and conformation terms were assessed on 4 points: 1, extremely good (1+ grade of KAPE); 2, good (1 grade of KAPE); 3, bad (2 grade of KAPE) and 4, extremely bad (3 grade of KAPE).
[4]The high grade rate was 1 (1+ grade of KAPE) plus 2 points (1 grade of KAPE) of carcass grade.
[a,b]Values in the same row with different superscripts differ at $p<0.05$.

Pork carcasses in Korea are graded both in quality and conformation terms. The grade system of Korea Institute for Animal Products Quality Evaluation (KAPE, 2009) grades the quality of pork carcasses as 1+, 1, 2 and 3 based on the marbling, lean color and conditions of belly streaks. However in this study, pork carcasses were graded as 1 (extremely good; 1+ grade of KAPE), 2 (good; 1 grade of KAPE), 3 (bad; 2 grade of KAPE) and 4 (extremely bad; 3 grade of KAPE). The conformation of a pork carcass is graded as A, B, C and D by assessing carcass weight, backfat thickness, balance, muscle, fat condition and so on, which was followed in this study.

The percentage of dressing was calculated as the ratio of cold carcass weight to live weight. Backfat thickness was measured using the 10th rib at three-quarters the distance along *longissimus dorsi* (LD) towards the belly.

Sampling of *longissimus dorsi* and basic analysis

The LD (6th to 13th rib) was cut off and randomly collected from 10 pigs (5 barrows and 5 gilts) in each treatment and kept at 5°C before it was transported to the laboratory to determine its chemical composition. The pH, water holding capacity (WHC), cooking loss, shear force and meat color of LD were determined about 24 h after slaughter. Additionally, to determine the thiobarbituric acid

reactive substances (TBARS) and volatile basic nitrogen (VBN), samples were vacuum-packaged, stored at 4°C and then analyzed on 7 wk of storage. The LD was frozen-stored at -60°C for approximate analysis, fatty acid composition and amino acid composition. The approximate analysis of moisture, crude protein, crude fat and ash concentration of LD were determined according to the methods of AOAC (2000).

Physicochemical characteristics

To determine the pH value, a sample of 5 g was homogenized about 24 h postmortem in 10 volumes of distilled water (DW) for 20 s at 13,500 rpm using a polytron homogenizer (T25B, IKA, Malaysia). Hanna HI 9025 pH meter (Woonsocket, USA) with an Orion 8163 glass electrode (Berverly, USA) was used to determine pH values.

Water holding capacity (WHC) was determined as described by Honikel (1998). For the cooking loss, 80 g of 1.5 cm thick LD were placed in polyethylene bags. The packages were then kept in a water bath (DS-23S, Dasol, Korea) at 75°C for 1 h and cooled at RT for 30 min. The percentage of cooking loss was determined using muscle weight that was taken before and after cooking.

Shear force was determined as described by Honikel (1998). Each LD was prepared into a cube of 4 cm × 2.5 cm × 1.5 cm (length × width × height) and then cooked and cooled. The shear force was measured using an Instron 3343 (US/MX50, A&D Co., USA) equipped with a Warner-Bratzler shearing device providing a 100 mm/min crosshead speed. The average shear force value from each treatment was calculated and expressed as kg/cm^2.

The VBN as protein degradation analysis was conducted as described by Pearson (1976) and expressed as mg VBN per 100 g of sample. Briefly, 1 g of sample and a few drops of phenolphthalein indicator were mixed with a 3.5 mL 20% sodium hydroxide solution in a distillated flask. The apparatus was tightly sealed, and steam distillate was collected in a flask containing a 20 mL of 4% boric acid and a few drops of methyl red and methylene blue. The steam distillate was continuously collected until a 250 mL distillated flask was filled. The solution obtained was then titrated using a 0.01 M hydrochloric acid and titration was stopped when the green color changed to gray. The final VBN calculation was accomplished based on a VBN value from a blank containing 6% perchloric acid steam distillation.

The TBARS analysis described by Huang and Miller (1993) was performed to determine the degree of lipid oxidation. The 3 g of each meat sample was weighed and mixed with a 57 mL phosphate buffer (pH 7.0). The mixtures were then homogenized at 12,000 *g* for 1 min (T25B, IKA, Malaysia). The homogenized samples were incubated, cooled and centrifuged at 2,000 rpm for 15 min. The supernatants were collected, read, calculated and expressed as mg malonaldehyde (MA) per kg of LD muscle tissue.

Meat surface color

Meat color of LD was evaluated on freshly cut surface (3 cm thick slice) using a Chroma Meter CR-300 (Minolta, Japan) after 20 min at room temperature. Three color measurements were carried out across individual sample surfaces and the average of five replicates was expressed as CIE L*, CIE a*, CIE b*, chroma and hue angel. The CIE is defined international commission on illumination (usually abbreviated CIE for its French name as commission international de l' éclairage). The Chroma Meter CR-300 was calibrated against a white tile (L*=89.20, a*=0.921 and b*=0.783). The aperture was 8 mm, illuminant D65 and 10° Standard Observer. Chroma (saturation) was calculated as $(a^{*2} + b^{*2})^{1/2}$, and hue angle was calculated as arctan b*/a* (Wyszcecki and Stiles, 1982).

Fatty acid composition

To determine fatty acids composition, the total lipid was extracted as described by Ways and Hanahan (1964), and then saponification and esterification was conducted using a 0.5 N potassium hydroxide in methanol and 14% boron trifluoride methanol solution. At the end, the fatty acids methyl esters (FAME) in the hexane were injected to a gas chromatography (Agilent 6890+, Agilent HP, USA) fitted with a capillary column (HP-5MS capillary GLC column, 30 m × 0.32 mm i.d. 0.25 mm film thickness, Agilent HP, USA) and a mass spectrometry detector (G1530A, Agilent HP, USA).

The mass spectrometry interface and injector temperature were fixed at 270°C and 260°C, respectively. The oven temperature was instituted to 160°C for 2.5 min, 160 to 260°C at 4°C per min and then 260°C for 5 min. Each fatty acid was identified by comparing its retention time with that of FAME standard (FAME Mix C8-C24, Supelco, USA) and expressed as a percentage of the standard.

Amino acid composition

A 100 mg sample of each LD was added to 3 mL of 6 N hydrochloric acid then packed in nitrogen gas. The packed samples were hydrolyzed at 110°C for 24 h and then removed from the hydrochloric acid. The enriched samples

were added to 5 mL of 1 M sodium citrate buffer (pH 2.2) and filtered through 0.2 μm membranes. The amino acid composition was measured with an amino acid auto analyzer (Biochrom 20, Olympus, Japan).

Texture profile analysis

Texture profile analysis (TPA) of ten samples of 2.00 cm × 2.00 cm × 2.00 cm (length × width × height) from each treatment and then cooked and cooled. The cooked sample was assessed using an Instron 3343(US/MX50, A&D Co., USA) equipped with a cylindrically shaped plunger (5-mm diameter) and a 500 N load cell (Bourne, 1978; Szczceniak, 1963). To determine texture parameters including hardness, cohesiveness, springiness, gumminess, chewiness and adhesiveness, each sample cube was equilibrated to a room temperature and compressed twice to 50% of its original thickness at a constant speed of 60 mm/min.

Texture profile parameters were calculated from the force deformation curves as follows: hardness (kg f; force necessary to attain a given deformation, maximum force), cohesiveness (dimensionless, ratio; ratio of the positive force area during the second compression to that during the first compression excluding the areas under the decompression portion of each cycle), springiness (ratio; ratio of distances that the sample recover after the first compression), gumminess (kg f; simulated energy required to disintegrate a semisolid food to a steady state, hardness × cohesiveness) and chewiness (kg f; hardness × cohesiveness × springiness).

Statistical analyses

The collected data was analyzed with one-way ANOVA. The General Linear Model (GLM) procedure of SAS (1999) was applied to conduct all analyses and significant differences among the means were determined using the Duncan's Multiple Range Test method (Duncan, 1955) and significant difference between means was examined at 5% threshold.

Results and Discussion

Carcass characteristics and meat grade

Effect of dietary supplemented with bamboo charcoal on the carcass characteristics and meat grade is shown in Table 1. Although dietary of bamboo charcoal showed no effect ($p>0.05$) on dressing, it significantly increased ($p<0.05$) the final BW, carcass weight and backfat thickness of LD.

Carcass grade was significantly improved ($p<0.05$) in pigs fed bamboo charcoal diet compared with those fed C diet alone, and the conformation was not affected ($p>0.05$). The ratio of high grade (1+ and 1 grades of KAPE) was higher in pigs fed bamboo charcoal diet and the highest grade was in T2 group with 0.6 % bamboo charcoal.

Chu *et al*. (2013b) reported that dietary of bamboo charcoal increased the average daily gain and feed efficiency in fattening pigs due to increased villus size (Lauronen *et al*., 1998). Moreover, the lower nutritional value of the experimental diet decreased carcass weight and backfat thickness (Chu *et al*., 2011). These studies support the findings of the present study where bamboo charcoal increased the final BW and carcass weight due to an increased average daily gain and feed efficiency, which was a result of improved nutrient utilization due to increased microscopic parameters, such as protuberated cells by increased villi size and epithelial cells in fattening pigs (Kutlu *et al*., 2001).

Bamboo charcoal improved the carcass and ratio of high carcass grade in the present experiment. In Korea, carcasses are graded in a standard based on many factors such as, carcass weight, backfat thickness, balance, muscle, fat condition and etc (KAPE, 2009). The best carcass grade of pork is when the weight ranges between 84 to 94 kg with 18 to 25 mm backfat thickness of LD (KAPE, 2009). The LD of fattening pigs fed supplemental bamboo charcoal showed optimal ranges of carcass weight and backfat thickness in this experiment.

Proximate analysis and physico-chemical characteristics

The proximate analysis and physico-chemical characteristics of LD from fattening pigs fed bamboo charcoal are shown in Table 2. The experimental dietary of bamboo charcoal showed no effect ($p>0.05$) on the concentration of moisture, crude protein and ash, but significantly affected ($p<0.05$) the crude fat concentration, which was significantly higher ($p<0.05$) in T1 than in C.

Typically, the consumption of diet with high energy and fat was found to increase backfat thickness (Pettigrew and Moser 1991) and crude fat concentration of LD (Kang *et al*., 2010). Song *et al*. (2011) reported that the low concentration of crude fat and diet with low total calorie decreased the crude fat concentration of LD in fattening pigs. The dietary of 0.3 and 0.6% bamboo charcoal increased 1.54 and 0.74% of crude fat concentration of LD in present experiment. Therefore, diet with bamboo charcoal may have increased the crude fat concentration of LD as a result of improved nutrient utilization in fattening pigs,

Table 2. Effects of dietary bamboo charcoal on proximate analysis and phsico-chemical characteristics of *longissimus dorsi* in fattening pigs

Items	Treatment[1]			SEM[2]
	C	T1	T2	
Proximate analysis, %				
Moisture	70.60	69.55	69.98	0.26
Crude protein	22.77	22.22	22.40	0.23
Crude fat	7.83[b]	9.37[a]	8.57[ab]	0.34
Ash	1.04	0.95	1.21	0.03
Physico-chemical characteristics				
pH	5.250	5.332	5.228	0.061
Water holding capacity, %	22.20	26.04	22.82	3.26
Cooking loss, %	38.96	37.46	36.23	1.17
Shear fore, kg/cm^2	3.03	3.18	3.94	0.31
Drip loss, %	3.05	2.98	5.79	1.26
Volatile basic nitrogen, mg/100g	5.731	5.936	6.972	0.889
TBARS[3], mg malonaldehyde/kg	0.398	0.357	0.369	0.021

[1]The basal diet was supplied with bamboo charcoal: C, no supplementation; T1, 0.3%; and T2, 0.6%.
[2]Standard error of the means.
[3]Thiobarbituric acid reactive substances.
[a,b]Values in the same row with different superscripts differ at $p<0.05$.

which increased the backfat thickness.

The experimental dietary of bamboo charcoal did not affect ($p>0.05$) the physic-chemical characteristics, such as pH, WHC, cooking loss, shear force, VBN and TBARS of LD from fattening pigs.

The pH of meat is changed by nutrient (Rosenvold *et al*., 2003) and energy values of diet, which affect the concentration of macro-glycogen in muscles and change the glycolysis and cooling rate of meat (McDonagh *et al*., 1999; Rosenvold *et al*., 2001). In the current study, the concentration of glycogen was not measured, but it is well known that an increased pH is a result of a decreased glycogen concentration in meat (Rosenvold *et al*., 2001). In this report, the bamboo charcoal in diet showed no effect on the pH of meat, because the energy values of diet were not different between treatments.

The WHC is an important factor in the quality of fresh pork and affected by many factors after slaughter (Kwon *et al*., 1995). Cooking loss of meat is affected by soluble creatine and soluble fat (Carlin *et al*., 1965). Up to now, the effects of charcoal or activated charcoal on the WHC, cooking loss or shear force are not well understood (Hwang, 1995).

The VBN such as protein degradation is an important index for estimation of meat freshness, because it is increased by the levels of microbial contamination. Meat protein is degraded into amino acids by protease and enzymes from microorganisms and amino acids in turn are degraded into inorganic nitrogen compounds when the levels of microorganism contamination are increased (Lee *et al*., 2006). The protein degradation of breast meat from broilers is not affected by activated charcoal (Kim and Park, 2001) or in pork of fattening pigs (Hwang, 1995). These reports agree with results of the present experiment as bamboo charcoal expressed no effect on protein degradation of LD in fattening pigs.

The TBARS such as lipid oxidation is affected by various factors including storage period and temperature, fatty acids composition, active oxygen and antioxidants (Chen and Wailmaleongoraek, 1981). Usually, a dietary with high contents of poly-UFA is more prone to oxidation and a dietary of high antioxidant contents, such as vitamins, carotenoids and flavonoids, protects the meat against lipid oxidation (Paiva-Martins *et al*., 2009). However, bamboo charcoal did not affect lipid oxidation of pork in this study.

Meat color

The effect of dietary bamboo charcoal on the meat color and backfat color is shown in Table 3. Dietary with bamboo charcoal did not show significant effects ($p>0.05$) on CIE a* (redness), CIE L* (lightness), CIE b* (yellowness), chroma and hue angel of LD from fattening pigs. Moreover, the dietary of bamboo charcoal did not significantly ($p>0.05$) affect the surface color (lightness, redness and yellowness) of the backfat.

Meat color is an important factor of pork quality and the most important factor that appeals to consumers who prefer high redness of pork. Meat color is mainly affected by pH and temperature of meat during the slaughter process (Lindahl *et al*., 2006). In this study, dietary of bamboo charcoal did not change the lightness, redness and yellowness of pork, which was suggested by Hwang (1995) who reported that a dietary supplemented with charcoal did not affect the meat color of pork from fattening pigs.

Fatty acid composition

The composition of the oleic acid and linoleic acid from the LD of fattening pigs was significantly increased ($p<0.05$) by the dietary of bamboo charcoal, but the composition of myristic acid, palmitoleic acid and linolenic acid was not significantly affected ($p>0.05$) and the stearic acid and arachidonic acid composition was significantly decreased ($p<0.05$). The oleic acid composition was highly significant ($p<0.05$) in T1 compared with other treatments. The composition of saturated fatty acid (SFA) was significantly lower ($p<0.05$) in treatments than in C and it was

Table 3. Effects of dietary bamboo charcoal on meat color[1] and backfat color[1] of *longissimus dorsi* in fattening pigs

Item	Treatment[2]			SEM[3]
	C	T1	T2	
Meat color				
CIE L*	56.81	55.78	55.38	0.98
CIE a*	2.04	2.37	2.76	0.37
CIE b*	4.00	3.87	4.18	0.28
Chroma	4.53	4.61	5.04	0.36
Hue angle	63.60	60.49	47.37	5.62
Backfat color				
CIE L*	80.83	80.92	80.62	0.46
CIE a*	-0.58	-0.90	-1.27	0.27
CIE b*	7.63	7.02	7.04	0.18
Chroma	7.67	7.18	7.17	0.16
Hue angle	94.47	97.62	100.21	2.31

[1]CIE L*, black (0) to white (100) color scale; CIE a*, red (+) to green (-) color scale; CIE b*, yellow (+) to blue (-) color scale; Chroma, $(a^{*2}+b^{*2})^{1/2}$ and hue angle, b*/a*.
[2]The basal diet was supplied with bamboo charcoal: C, no supplementation; T1, 0.3%; and T2, 0.6%.
[3]Standard error of the means.

Table 4. Effects of dietary bamboo charcoal on fatty acid composition of *longissimus dorsi* in fattening pigs

Items	Treatment[1]			SEM[2]
	C	T1	T2	
Fatty acid composition, %				
Myristic acid	1.01	1.24	1.25	0.10
Palmitic acid	21.38^{b}	22.36^{ab}	23.08^{a}	0.41
Palmitoleic acid	3.10	2.52	2.99	0.21
Stearic acid	18.82^{a}	13.38^{b}	14.71^{b}	0.65
Oleic acid	41.25^{c}	46.08^{a}	43.53^{b}	0.48
Linoleic acid	9.68^{b}	11.23^{a}	11.04^{a}	0.34
Linolenic acid	0.83	0.86	0.85	0.09
Arachidonic acid	3.95^{a}	2.33^{b}	2.44^{b}	0.29
Saturated fatty acid (SFA)	41.63^{a}	37.44^{c}	39.42^{b}	0.49
Unsaturated fatty acid (USFA)	58.37^{b}	62.56^{a}	60.58^{ab}	0.49
Essential fatty acid	11.51	12.90	12.89	0.27
USFA/SFA	1.40^{b}	1.67^{a}	1.54^{a}	0.03

[1]The basal diet was supplied with bamboo charcoal: C, no supplementation; T1, 0.3%; and T2, 0.6%.
[2]Standard error of the means.
[a,b,c]Values in the same row with different superscripts differ at $p<0.05$.

lowest ($p<0.05$) in T1, while the ratio of unsaturated fatty acid (USFA) to SFA (USFA/SFA) was significantly higher ($p<0.05$) in treatments than in C. The USFA composition was significantly higher ($p<0.05$) in T1 than in C, though the dietary of bamboo charcoal had no effect ($p>0.05$) on the composition of essential fatty acids (EFA) and the ratio of SFA to USFA of LD (Table 4).

The fatty acids composition of LD is changed by diet in monogastric animals (Pascual *et al*., 2007). In this study, the nutrient values of diet were not different between C and treatments, but the diet of treatment might have increased nutrient utilization (Kutlu *et al*., 2001). A high level of USFA and low level of SFA in LD is more beneficial to human health, such as prevention of arteriosclerosis and hypertension (Decker and Shantha, 1994; Engler *et al*., 1991). Therefore, based on the results of this study, a dietary supplemented with bamboo charcoal improved the fatty acid composition of LD from fattening pigs in away that might be beneficial to human health. The benefits might come from the ability of the diet to increase USFA and decrease SFA composition of LD in fattening pigs.

Amino acid composition

Dietary of bamboo charcoal did not affect ($p>0.05$) the composition of essential amino acids including arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threnonine and valine. Additionally, the dietary did not affect the composition of unessential amino acids including alanine, aspartic acid, cysteine, glutamic acid, glycine, proline, serine and tyrosine in the LD of fattening pigs (Table 5).

Dietary of bamboo charcoal was not observed on the amino acid composition of LD and the reason is unknown. Therefore, further study is still warrant to make a conclusion about the effects of bamboo charcoal on the amino acid composition of LD. However, no difference was observed with fermented diet in pigs. In contrast, a fermented diet did not affect the amino acid composition of LD in pigs (Chu *et al*., 2011) as well as a high-carbohydrate-low-fat diet (Kang *et al*., 2010) in agreement with the results of the present study.

Texture profile analysis

The dietary of bamboo charcoal did not affect ($p>0.05$) the texture profile analysis that includes hardness, cohesiveness, springiness, gumminess, chewiness and adhesiveness of LD in fattening pigs (Table 6).

Tenderness of meat is the most important factor for evaluation of pork meat and animal products, though appearance, meat color, flavor, taste and juiciness are also important factors to consumers (Bailey, 1972). It was not reported that dietary of charcoal, activated charcoal or bamboo charcoal had any effect on TPA of LD from pigs. However, TPA of LD was greatly affected by fatty acids composition, while tenderness and juiciness of meat were correlated with the concentration of crude fat, WHC and cooking loss (Wood *et al*., 2008). In this study, the dietary

Table 5. Effects of dietary bamboo charcoal on amino acid composition of *longissimus dorsi* in fattening pigs

Items	Treatment[1]			SEM[2]
	C	T1	T2	
Essential amino acid, %	8.644	8.867	8.563	0.330
Arginine	1.100	1.137	1.107	0.046
Histidine	1.658	1.735	1.631	0.067
Isoleucine	0.806	0.828	0.812	0.030
Leucine	1.427	1.483	1.407	0.059
Lysine	0.759	0.759	0.758	0.023
Methionine	0.463	0.434	0.455	0.029
Phenylalanine	0.746	0.749	0.717	0.032
Threonine	0.833	0.864	0.816	0.031
Valine	0.853	0.879	0.859	0.028
Unessential amino acid, %	8.107	8.402	7.981	0.296
Alanine	0.990	1.034	0.981	0.038
Aspartic acid	1.642	1.719	1.623	0.061
Cystine	0.127	0.119	0.127	0.007
Glutamic acid	2.591	2.706	2.562	0.088
Glysine	0.733	0.825	0.747	0.030
Proline	0.702	0.703	0.673	0.033
Serine	0.723	0.756	0.712	0.026
Tyrosine	0.600	0.539	0.554	0.035
Total amino acid, %	16.751	17.269	16.543	0.623

[1]The basal diet was supplied with bamboo charcoal: C, no supplementation; T1, 0.3%; and T2, 0.6%.
[2]Standard error of the means.

Table 6. Effects of dietary with bamboo charcoal on texture profile analysis[1] of *longissimus dorsi* in fattening pigs

Items	Treatment[2]			SEM[3]
	C	T1	T2	
Hardness, kg f	1.79	1.34	1.49	0.19
Cohesiveness, ratio	0.46	0.51	0.44	0.05
Springiness, ratio	1.07	1.22	1.05	0.07
Gumminess, kg f	0.85	0.68	0.67	0.13
Chewiness, kg f	0.92	0.88	0.72	0.20
Adhesiveness, kg f	0.44	0.28	0.34	0.07

[1]Texture profile analysis were scored on point scale based on - (extremely soft) to + (extremely hard).
[2]The basal diet supplied with bamboo charcoal: C, no supplementation; T1, 0.3%; and T2, 0.6%.
[3]Standard error of the means.

of bamboo charcoal did not affect the TPA of LD from fattening pigs. The experimental dietary of bamboo charcoal tested in this study might be used to produce pork from fattening pigs with appealing sensory features to consumers.

Conclusion

The results of this study indicated that the test dietary supplemented with bamboo charcoal increased the carcass weight and backfat thickness. The dietary also improved the carcass grade and ratio of high carcass grade in fattening pigs. Moreover, the experimental dietary of bamboo charcoal affected the crude fat concentration. Therefore, dietary of bamboo charcoal was expected to improve swine farms income due to increased carcass prices and improved fatty acids composition (increased USFA composition and decreased SFA composition) of LD from fattening pigs.

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