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Effect of Feeding Cyanidin 3-glucoside (C3G) High Black Rice Bran on Nutrient Digestibility, Blood Measurements, Growth Performance and Pork Quality of Pigs

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ABSTRACT : Two experiments were conducted to investigate the effect of feeding cyanidin 3-glucoside (C3G) high black rice bran on nutrient digestibility, blood measurements, growth performance and pork quality of pigs. In Exp. I, a total of fifteen pigs (19.91±1.80 kg, average initial body weight) were used in assay of nutrient digestibility and blood measurements. All pigs were allotted to 5 treatments with 3 replicates according to a completely randomized design (CRD) in an individual metabolic crate. Treatments included 1) CON: basal diet, 2) BRB-2: basal+brown rice bran 2%, 3) BRB-4: basal+brown rice bran 4%, 4) CRB-2: basal+C3G high black rice bran 2% and 5) CRB-4: basal+C3G high black rice bran 4%. The digestibility of dry matter (DM), crude protein (CP), crude fat (CF), crude ash (CA) and crude fiber (CF) was not affected by dietary treatments. Serum triglyceride (TG) and high density lipoprotein (HDL) cholesterol concentrations were not affected by addition of C3G high black rice bran. However, at the end of experiment, pigs fed rice bran showed decreased tendency in total cholesterol concentration. Especially pigs fed C3G high black rice bran showed significantly lower total cholesterol concentration compared to pigs fed brown rice bran ($p<0.03$). There was numerically lower total cholesterol concentration with increasing levels of black rice bran in the diet. In terms of serum glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT), there were no significant differences among treatments, even though pigs fed CRB-4 showed the lowest GOT concentration compared to other pigs. In Exp. II, sixteen finishing pigs (average initial body weight 89.96±0.35 kg) were divided into 4 treatments to investigate the effect of feeding C3G high black rice bran on growth performance and pork quality. There were no significant differences in average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) among the treatments. Pigs fed C3G high black rice bran showed numerical decrease in ADG and increase in FCR while not effecting feed intake. There was no significant difference in live weight, carcass weight, carcass rate, backfat thickness and carcass grade. However, pigs fed C3G high black rice bran tended to show lower backfat thickness than pigs fed basal diet. Pigs fed C3G high black rice bran showed a tendency of decreased TBA value than pigs fed basal diet, although there was no overall significant difference among treatments. In conclusion, nutrient digestibility, blood measurements, growth performance and pork quality were not significantly affected by feeding C3G high black rice bran to pigs. However, C3G high black rice bran might have an effect on lowering serum total cholesterol and decrease the TBA value in pork compared to control group and these effects might be due to high concentration of antioxidative compounds in C3G high black rice bran. (**Key Words :** Black Rice Bran, Cyanidin 3-glucoside (C3G), Pork Quality)

INTRODUCTION

In general, rice consists of approximately 20% of rice hull, 3% of rice bran and 4% of rice germ (Sharp, 1991). Rice bran, a by-product of the milling process, has been used mainly for oil production and feed ingredient. Rice bran contains 12-16% of crude protein, 20-25% of dietary fiber, 16-22% of crude fat and more than 70% of the fatty acid is in unsaturated form such as oleic acid, linoleic acid and linolenic acid. It also contains various vitamins and minerals (Fujino, 1978; Luh et al., 1991). Therefore, rice bran has been considered to be one of high energy feedstuff, with beneficial aspects in terms of cost and availability in Asian countries (Soren et al., 2003, 2004; Khalique et al., 2006).

As feed ingredient, Kratzer et al. (1974) reported that supplementation of defatted rice bran at a level of over 60% resulted in reduction of growth performance of chicks. Farrel (1994), found that possible dietary inclusion level of rice bran is up to 20% in chicks. However, Kim et al. (2003)

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Table 1. Chemical composition of experimental diet (Exp. I)

Ingredients (%)	Control	BRB-2	BRB-4	CRB-2	CRB-4
Corn	61.14	59.73	58.51	59.73	58.42
Soybean meal	31.98	31.68	31.35	31.64	31.28
HP300	0.60	0.60	0.60	0.60	0.60
Brown rice bran	-	2.00	4.00	-	-
C3G high black rice bran	-	-	-	2.00	4.00
Soy Oil	3.85	3.60	3.20	3.60	3.30
MCP	1.20	1.10	0.95	1.15	1.05
Limestone	0.30	0.36	0.46	0.35	0.42
DL-met	0.11	0.11	0.11	0.11	0.11
Vitamin mix [a]	0.12	0.12	0.12	0.12	0.12
Mineral mix [b]	0.20	0.20	0.20	0.20	0.20
Salt	0.20	0.20	0.20	0.20	0.20
Neomycin	0.10	0.10	0.10	0.10	0.10
ZnO	0.10	0.10	0.10	0.10	0.10
Choline-Cl	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100
Chemical composition [c]					
ME (kcal/kg)	3,269	3,273	3,273	3,268	3,266
CP (%)	20.00	20.00	20.00	20.00	20.00
Lysine (%)	1.07	1.07	1.07	1.07	1.07
Methionine (%)	0.42	0.42	0.42	0.42	0.42
Ca (%)	0.70	0.70	0.70	0.70	0.70
Total P (%)	0.60	0.60	0.60	0.60	0.60

[a] Provided per kg diet: vitamin A, 16,000 IU; vitamin D_3, 3,200 IU; vitamin E, 35 IU; vitamin K_3, 5 mg; riboflavin, 6 mg; calcium pantothenic acid, 16 mg; niacin, 32 mg; d-biotin, 128 μg; vitamin B_{12}, 20 μg (0-35 d); vitamin A, 12,800 IU; vitamin D_3, 2,560 IU; vitamin E 28 IU; vitamin K_3, 4 mg; riboflavin, 5 mg; calcium pantothenic acid, 13 mg; niacin, 27 mg; d-biotin, 102 μg; vitamin B_{12}, 20 μg (35-140 d).

[b] Provided per kg diet: Cu (copper sulfate), 281 mg; Fe (ferrous sulfate), 288 mg; I (calcium iodate), 0.3 mg; Mn (manganese sulfate), 49 mg; Se (sodium selenite), 0.3 mg; Zn (zinc sulfate), 143 mg (0-35 d); Cu (copper sulfate), 187 mg; Fe (ferrous sulfate), 190 mg; I (calcium iodate), 0.2 mg; Mn (manganese sulfate), 32 mg; Se (sodium selenite), 0.2 mg; Zn (zinc sulfate), 96 mg (35-140 d).

[c] Calculated value.

observed reduction of growth and feed efficiency in chicks fed diet containing 5% defatted rice bran, while, Soren et al. (2003) reported that rice bran can be included up to 40% in pig diet with no detrimental effect on growth performance. Chae and Lee (2002) suggested that it is possible to supplement 20% raw rice bran in finishing pig diets without affecting the growth performance.

Recently, there is a growing interest in additional benefits of rice bran. Serum cholesterol concentrations have been reported to decrease with the ingestion of rice bran. This suppressed hyperlipidemia may be due to fiber-induced alterations of intestinal absorption, lipid metabolism, bile acid metabolism, or fermentation by-product and their effects on hepatic cholesterol synthesis (Fukushima et al., 1999). Moreover, it is also reported that rice bran contains various micronutrients such as phytochemicals beneficial to human and animals (Saunder, 1990; Ling et al., 2002).

Rice bran has been produced by different kinds of rice including white rice and colored rice. Among the dark purple rices, Park et al. (1998) reported that Heugjinju rice is the richest in cyanidin 3-glucoside (C3G) content. The C3G is known as a natural anthocyanin with strong antioxidative and radical scavenging activities against hydroxyl and superoxide radicals (Tsuda et al., 1996). Also, the examination of antioxidative capability of extracts from colored rice showed that Heugjinju rice with the highest C3G pigment content was the most superior (Ryu et al., 1998, 2000). Kwak et al. (1999) observed that a large amount of anthocyanin content was concentrated within black rice surface. Moreover, it is found that other phenolic acids such as protocatechuic acid, vanillic acid, quercetin and oryzafuran are contained in black rice bran which may contribute to the antioxidant properties of Heugjinju rice bran (Han et al., 2004).

More recently, some researchers developed new black colored rice called C3G high black rice. Its bran has approximately seven times larger amount of C3G than general black colored rice bran such as Heugjinju rice bran. Therefore, the present study was conducted to examine the effect of C3G high black rice bran supplementation on nutrient digestibility, blood measurements, growth performance and pork quality of pigs.

MATERIALS AND METHODS

Experiment I

The study was carried out with 15 growing pigs

Table 2. Chemical composition of rice bran used in experiment

	Brown rice bran	C3G high black rice bran
Gross energy (kcal/kg)	4,643	4,389
Dry matter (%)	90.37	89.47
Crude protein (%)	12.63	13.58
Crude fat (%)	19.67	14.13
Crude ash (%)	10.06	7.49
Crude fiber (%)	13.44	10.58
NDF (%)	27.86	25.95
ADF (%)	15.34	13.66
Ca (%)	0.05	0.03
Total P (%)	1.65	1.17
Cyanidin 3-glucoside (mg/kg)	ND*	2,403.83

* ND: not detected.

(19.91±1.80 kg, average initial body weight) and housed individually in a metabolic crate for a period of 15 days. Pigs were randomly allocated to 5 treatments with 3 replicates according to a completely randomized design (CRD). Treatment included 1) CON: basal diet, 2) BRB-2: basal+brown rice bran 2%, 3) BRB-4: basal+brown rice bran 4%, 4) CRB-2: basal+C3G high black rice bran 2% and 5) CRB-4 : basal+C3G high black rice bran 4%. The basal diets were formulated to contain approximately 3,265 ME kcal/kg, 1.07% total lysine and 0.42% total methionine. All other nutrients met or exceeded the nutrient requirements recommended by NRC (1998). The ingredient and nutrient composition of the diets were presented in Table 1. Chemical composition of C3G high black rice bran was analyzed and shown in Table 2. Total amount of feeds consumed and feces were recorded daily for the first 7 days. Collected feces were pooled, sealed in plastic bag and stored at -20°C then dried in an air-forced drying oven at 60°C for 72 h. Dried fecal samples were grounded and used for chemical analyses of proximate nutrients according to the method of AOAC (1995). Blood samples were collected directly from the jugular vein at initial, 7 and 15 d. After blood sampling, all samples were quickly transferred to a centrifuge tube and then centrifuged for 15 minutes at 3,000 rpm in a cold chamber (4°C). The serum was carefully removed to plastic vials and stored at -20°C before analyzing. All samples were analyzed by blood analyzer (Ciba-Corning model, Express Plus, Ciba Corning Diagnosis Co.). Blood sample were taken from all pigs per treatment for evaluating total cholesterol, triglyceride (TG) and high density lipoprotein (HDL) cholesterol concentrations. Also, at the end of experiment (16 d), the pigs were bled in order to assay glutamate oxaloacetate transaminase (GOT) and glutamate pyruvate transaminase (GPT) activities before feeding and 8 h after the pigs were fed all feeds.

Experiment II

A total of 16 finishing pigs (average initial body weight 89.96±0.35 kg) were divided into 4 treatments to investigate the effect of feeding C3G high black rice bran on growth performance and pork quality. The experimental diets were control (basal), C3G high black rice bran 0.2% (CRB-0.2), C3G high black rice bran 0.4% (CRB-0.4) and C3G high

Table 3. Chemical composition of experimental diet (Exp. II)

Ingredients	Control	CRB-0.2	CRB-0.4	CRB-0.6
Corn	78.50	78.45	78.42	78.38
Soybean meal	12.50	12.50	12.50	12.50
Corn gluten meal	4.00	4.17	4.20	4.24
Wheat bran	3.50	3.20	3.00	0.00
C3G high black rice bran	0.00	0.20	0.40	0.60
TCP	0.40	0.35	0.38	0.38
Limestone	0.65	0.65	0.65	0.65
Vitamin mix [a]	0.10	0.10	0.10	0.10
Mineral mix [b]	0.10	0.10	0.10	0.10
Salt	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00
Chemical composition [c]				
ME (kcal/kg)	3,266	3,268	3,269	3,269
CP (%)	13.13	13.15	13.15	13.15
Lysine (%)	0.58	0.58	0.58	0.58
Methionine (%)	0.23	0.23	0.23	0.23
Ca (%)	0.45	0.45	0.45	0.45
Total P (%)	0.41	0.41	0.42	0.42

[a] Provided per kg diet: vitamin A, 16,000 IU; vitamin D_3, 3,200 IU; vitamin E, 35 IU; vitamin K_3, 5 mg; riboflavin, 6 mg; calcium pantothenic acid, 16 mg; niacin, 32 mg; d-biotin, 128 μg; vitamin B_{12}, 20 μg (0-35 d); vitamin A, 12,800 IU; vitamin D_3, 2,560 IU; vitamin E 28 IU; vitamin K_3, 4 mg; riboflavin, 5 mg; calcium pantothenic acid, 13 mg; niacin, 27 mg; d-biotin, 102 μg; vitamin B_{12}, 20 μg (35-140 d).

[b] Provided per kg diet: Cu (copper sulfate), 281 mg; Fe (ferrous sulfate), 288 mg; I (calcium iodate), 0.3 mg; Mn (manganese sulfate), 49 mg; Se (sodium selenite), 0.3 mg; Zn (zinc sulfate), 143 mg (0-35 d); Cu (copper sulfate), 187 mg; Fe (ferrous sulfate), 190 mg; I (calcium iodate), 0.2 mg; Mn (manganese sulfate), 32 mg; Se (sodium selenite), 0.2 mg; Zn (zinc sulfate), 96 mg (35-140 d).

[c] Calculated value.

Table 4. Effect of feeding C3G high black rice bran on the nutrient digestibility of pigs [a]

Items	CON	Brown rice bran (B-group)			C3G rice bran (C-group)			SEM [b]	Contrast [c]	
		BRB-2	BRB-4	Mean	CRB-2	CRB-4	Mean		CON vs. B&C	B vs. C
DM (%)	89.47	88.04	89.08	88.56	87.08	89.90	88.49	0.46	NS	NS
Protein (%)	87.71	86.88	88.43	87.66	83.94	87.51	85.73	0.70	NS	NS
Fat (%)	77.69	76.77	75.43	76.10	74.73	75.63	75.18	0.99	NS	NS
Ash (%)	54.07	48.29	49.73	49.01	50.76	55.41	53.09	1.78	NS	NS
Fiber (%)	62.64	65.83	67.97	66.90	54.82	74.12	64.47	2.95	NS	NS

[a] Fifteen pigs were fed from average initial body weight 19.91±1.80 kg to an average final body weight of 25.39±0.27 kg.
[b] Standard error of mean. [c] NS means p>0.10.

black rice bran 0.6% (CRB-0.6). Basal and experimental diets were formulated to meet or exceed the nutritional requirements by NRC (1998). Formula and chemical composition of experimental diets were presented in Table 3. Pigs were allowed *ad libitum* access to the diets and water for the 30-day experimental period. Pigs were weighed at the initiation of the study and prior to slaughter. Feed intake was recorded throughout the study. Feed conversion ratio (FCR) was calculated by dividing amount of feed consumption with corresponding the body weight. After complete feeding trial, the pigs were slaughtered at commercial slaughter plant under typical commercial procedures. Carcasses were chilled conventionally at 4°C for 24 h. At 24 h postmortem, collection of carcass data included 10th rib backfat thickness, carcass weight and carcass grade evaluated by Animal Products Grading Service (MAF, 2001). The cross-section area between 10th and 11th rib of left longissimus muscle was collected to measure pH, Hunter value and thiobarbituric acid reactive substances (TBARS) to evaluate pork quality. Collected muscle samples were immediately transported in a liquid nitrogen tank and kept under -60°C before analyzing.

Measurement of pH at 1, 6, 12, and 24 h postmortem was made with a pH meter (Model 720, Thermo Orion, USA) and Hunter L*, a*, and b* values were recorded using chromameter (Minolta, CM-508i, Japan) at the same time of pH measuring. Muscle samples at 1, 4, and 6 d postmortem were analyzed for TBARS value according to Witte et al. (1970) using homogenizer (Janke and Kunkel, T25, Germany) and spectrophotometer (Hitachi, U-1100, Japan).

Statistical analyses

All of data were carried out by comparing means according to least significant difference (LSD) multiple range test, using the General Linear Model (GLM) procedure of SAS (1985) package program. Individual pig data served as the experimental unit in this study.

RESULTS AND DISCUSSION

Experiment I

The effect of feeding C3G high black rice bran on the nutrient digestibility was presented in Table 4. The digestibility of dry matter (DM), crude protein (CP), crude fat (CF), crude ash (CA) and crude fiber (CF) was not significantly different among treatments. For nutrient digestibility of rice bran, it has been reported to depend on animal, nutritive value and processing method. Warren and Farrel (1990) reported that digestibility of DM in pigs fed defatted rice bran was relative low because of its high fiber content and digestibility of GE was also lower than that of basal diet, but higher than the value for digestibility of DM. It is also reported that DM digestibility was higher in processed rice bran than raw rice bran and the digestibility of energy and protein in extruded rice bran was also higher than those in raw rice bran (Chae and Lee, 2002). In the present study, there is no significant difference in nutrient digestibility between brown rice bran and black rice bran. One possible reason is that both brown rice bran and black rice bran had similar proximate nutrient values and remained unprocessed.

There was no significant difference in serum total cholesterol, TG and HDL cholesterol concentrations among the treatments (Table 5). However, towards the end of experiment, pigs fed rice bran showed decreasing tendency in total cholesterol concentration except for pigs fed BRB-4. Especially, pigs fed C3G high black rice bran showed significantly lower total cholesterol concentration compared to pigs fed brown rice bran (p = 0.03). Also, there was numerically lower total cholesterol concentration with increasing levels of black rice bran in the diet. While, there was no observable effect in TG and HDL cholesterol concentrations among treatments.

Rice bran is high in soluble fiber and in oil which is rich in monounsaturated fatty acids and low in saturated fatty acids (Babcock, 1987). Water soluble fiber included in rice bran would be expected to lower plasma cholesterol (Mattson and Grundy, 1985). It is reported that this mechanism is mediated by reduction of bile salt absorption (Arjmandi et al., 1992). Although whole rice bran has anti-cholesterol properties, it is the oil which most likely offers the most significant benefits. Several studies of rice bran in humans failed to show lipid reduction using defatted rice bran (Miyoshi et al., 1986; Kestin et al., 1990; Sanders and Reddy, 1992), but rice bran oil produced an effect

Table 5. Effect of feeding C3G high black rice bran on serum total cholesterol, TG and HDL cholesterol concentrations of pigs

Items	CON	Brown rice bran (B-group)			C3G rice bran (C-group)			SEM [a]	Contrast [b]	
		BRB-2	BRB-4	Mean	CRB-2	CRB-4	Mean		CON vs. B&C	B vs. C
Total cholesterol (mg/dl)										
Initial	74.33	71.67	77.00	74.34	76.00	74.33	75.17	2.30		
7 day	80.33	80.00	92.00	86.00	86.33	78.33	82.33	2.24	NS	NS
15 day	88.67	80.33	90.33	85.33	82.67	77.67	80.17	1.97	NS	0.03
TG (mg/dl)										
Initial	30.33	39.00	42.33	40.67	37.33	29.00	33.17	2.92	NS	NS
7 day	33.67	32.33	38.67	35.50	39.33	24.67	32.00	2.54	NS	NS
15 day	38.67	39.67	50.33	45.00	43.33	31.33	37.33	2.84	NS	NS
HDL cholesterol (mg/dl)										
Initial	22.00	21.33	21.00	21.17	22.67	22.33	22.50	0.54	NS	NS
7 day	27.33	26.67	28.33	27.50	29.33	26.00	27.67	0.57	NS	NS
15 day	27.67	26.67	27.00	26.83	26.33	25.00	25.67	0.70	NS	NS

[a] Standard error of mean. [b] NS means p>0.10.

Table 6. Effect of feeding C3G high black rice bran on serum GOT and GPT concentrations of pigs

Items	CON	Brown rice bran (B-group)			C3G rice bran (C-group)			SEM [a]	Contrast [b]	
		BRB-2	BRB-4	Mean	CRB-2	CRB-4	Mean		CON vs. B&C	B vs. C
GOT (U/L)										
0 h	51.2	43.9	53.2	48.6	42.6	44.3	43.5	3.28	NS	NS
8 h	55.2	51.3	48.3	49.8	65.3	46.5	55.9	4.84	NS	NS
GPT(U/L)										
0 h	30.5	36.0	31.9	34.0	33.4	34.5	34.0	1.35	NS	NS
8 h	24.9	28.1	27.8	26.9	31.4	25.5	28.5	1.51	NS	NS

[a] Standard error of mean. [b] NS means p>0.10.

(Raghuram et al., 1989; Lichtenstein et al., 1994). Rice bran oil has an unusually unsaponificable matter concentration (Saunders, 1985). This fraction includes tocotrienols, r-oryzanol, β-sitosterol and unsaturated fatty acids, all of which may contribute to cholesterol reduction (Gerhadt and Gallo, 1998). In the present study, full-fat brown and black rice bran were used, therefore, the effect on reducing total cholesterol concentration might be caused by low level of oil in black rice bran.

Furthermore, it was observed that C3G high rice bran had an effect on more reduction of cholesterol concentration than brown rice bran. Ling et al. (2001) reported that supplementation of black rice, compared to with white rice significantly reduced atherosclerotic plaque formation induced by hyper cholesterolemia in rabbits, and the mechanism of this action was related to improvement of antioxidant status. Black rice bran used in this study contained high level of C3G which had strong antioxidative and radical-scavenging activity, and other phenolic acids such as oryzafuran, quercetin, vanillic acid etc., thus it is considered that more reducing effect on cholesterol concentration might be resulted from those antioxidative components included in black rice bran.

Similar results were found in another experiment (not published). Four pigs were fed basal diet or C3G high black rice bran 6%, through out 2-month feeding trial. Pigs fed at 6% C3G high black rice bran showed 11.64% (105.25 vs. 93.00 mg/dl) , 26.24% (47.00 vs. 34.67 mg/dl), and 33.05% (53.48 vs. 35.80 mg/dl) reductions of total cholesterol, TG and HDL cholesterol, respectively compared to pigs fed basal diet. This could be due to the inclusion of higher level of C3G high black rice bran and long-term feeding. Therefore, it is expected that increasing the dosage level and feeding period could have an effect on total cholesterol, TG, and HDL cholesterol.

There was no significant difference in serum GOT and GPT concentrations (Table 6). However, pigs fed CRB-4 showed the lowest GOT concentration compared to other pigs. It is generally known that serum GOT and GPT reflects a stability of hepatocytes. The elevated serum GOT and GPT values may have affected to cellular damage, because these cytosolic enzymes are released into the circulatory fluid when cell membrane integrity is damaged (Kim and Mahan, 2001). This symptom could be induced by feeding diets that are high in lipid, including some toxins or deficient of antioxidant and alleviated by addition of antioxidant (Tandon et al., 1992; Othman et al., 1999). Achuthan et al. (2003) reported that oral administration of fresh juice of *Rosa damascena* having strong antioxidant components, significantly reduced serum GOT and GPT concentrations and the result was attributed to its free radical scavenging activity. In addition, Harish and Shivanandappa (2005) found that feeding *P. niruri* containing high phenolic compounds reduced CCl_4^- induced

Table 7. Effect of feeding C3G high black rice bran on growth performance of pigs

Items	CON	C3G high black rice bran			
		CRB-0.2	CRB-0.4	CRB-0.6	Mean
Body weight (kg)					
Initial	90.25	90.00	89.50	89.50	89.67
Final	115.75	115.00	108.25	107.88	110.38
Average daily gain, ADG (kg)	0.85	0.83	0.63	0.61	0.69
Average daily feed intake, ADFI (kg)	2.71	2.71	2.96	2.70	2.79
Feed conversion ration (FCR)	3.19	3.26	4.75	4.45	4.15

* Significance was not observed among treatments.

Table 8. Effect of feeding C3G high black rice bran on carcass characteristics of pigs

Items	CON	C3G high black rice bran				SEM [a]
		CRB-0.2	CRB-0.4	CRB-0.6	Mean	
Live weight (kg)	113.00	111.00	113.00	106.33	110.11	-
Carcass weight (kg)	88.67	86.00	89.33	79.67	85.00	1.10
Carcass rate (%)	78.55	77.47	79.00	74.92	77.13	0.54
Backfat thickness (cm)	0.27	0.25	0.23	0.17	0.22	0.01
Carcass grade [b]	3.67	3.00	3.00	3.33	3.11	-

[a] Standard error of mean.
[b] Carcass grade was scored as A = 4, B = 3, C = 2, and D = 1 and presented as the mean value.
* Significance was not observed among treatments.

changes in GOT and GPT.

Experiment II

There was no significant difference in average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) among the treatments as shown in Table 7. However, pigs fed C3G high black rice bran showed numerical decrease in ADG with no effect on feed intake, resulting in an increase in FCR. Similar results were reported by Borin et al. (1990) that mean daily gain and feed efficiency decreased with increasing level of defatted rice bran in the diet of growing-finishing pigs. However, Soren et al. (2003) reported that rice bran can be included up to 40% in pig diet with no detrimental effect on growth performance. Chae and Lee (2002) suggested that it is possible to supplement 20% raw rice bran in finishing pig diets without affecting the growth performance. Also, Warren and Farrell (1990) found that mixed diets containing defatted rice bran at up to 300 g/kg supported an acceptable growth rate in growing pigs when digestible energy intake was constant. However, in the present experiment, although relatively small amount of black rice bran was supplemented to pigs' diet compared to other previous experiments, grow rate was slightly reduced without change of feed intake. The reason might be supported by Saunders et al. (1982) who explained that rice bran contained some antinutritional factors which can reduce the growth performance of poultry.

Carcass characteristics and pork quality are summarized in Table 8 and 9. There was no significant difference in live weight, carcass weight, carcass rate, backfat thickness and carcass grade among treatments. However, pigs fed C3G high black rice bran tended to have the lower backfat thickness than pigs fed basal diet. This result was in agreement with Brook and Lumanta (1975) who reported that feeding rice bran reduced backfat thickness of pigs, while another study showed that carcass characteristics including backfat thickness were not affected by feeding rice bran (Chae and Lee, 2002).

Carcass grade was assessed by carcass weight, backfat thickness and sex. However, although backfat thickness was decreased in pigs fed C3G high rice bran as the level of rice bran increased, pigs fed basal diet showed better grade than pigs fed C3G high rice bran. No clear explanation for this result is evident because few experiments with feeding rice bran have been available to compare the difference in carcass grade.

Feeding C3G high black rice bran had no effect on pH and Hunter L*, a*, and b* values when measured at 1, 6, 12 and 24 h after slaughter. Ultimate pH has been suggested to be an indicator of meat quality, with a low pH being indicative of inferior quality pork (Bendall and Swatland, 1998). There were some experiments studying pork quality by feeding antioxidants such as vitamin E and C. Lauridsen et al. (1999) observed that increased ultimate pH in pigs fed 200mg of DL-α-tocopheryl acetate/kg compared to pigs supplemented with 0 or 100 mg of DL-α-tocopheryl acetate/kg in feed. In contrast, Cannon et al. (1996) and Hasty et al. (2002) found no improvement in pH due to vitamin E supplementation. Also, Pion et al. (2004) reported vitamin C supplementation did not affect initial and ultimate pH of pork. Until now, dietary antioxidants have

Table 9. Effect of feeding C3G high black rice bran on pH and Hunter L*, a* and b* value of pork

Items	CON	C3G high black rice bran				SEM [a]
		CRB-0.2	CRB-0.4	CRB-0.6	Mean	
pH						
1 h	6.18	6.13	6.03	6.06	6.24	0.06
6 h	5.72	5.88	5.90	5.87	5.88	0.04
12 h	5.78	5.80	5.86	5.78	5.81	0.02
24 h	5.84	5.77	5.88	5.73	5.79	0.03
L* value						
1 h	37.01	36.94	36.10	34.77	35.94	0.46
6 h	36.56	36.09	36.95	36.65	36.56	0.59
12 h	39.59	38.93	39.64	41.19	39.92	0.53
24 h	41.00	41.64	42.12	42.33	42.03	0.54
a* value						
1 h	1.10	0.39	1.39	0.06	0.61	0.24
6 h	0.80	0.82	1.80	0.74	1.12	0.20
12 h	1.86	1.21	1.86	1.13	1.40	0.21
24 h	2.31	0.89	2.23	1.14	1.42	0.19
b* value						
1 h	6.38	6.08	6.21	5.19	5.83	0.18
6 h	5.60	5.85	6.64	5.73	6.07	0.18
12 h	7.02	6.44	7.10	6.92	6.82	0.12
24 h	7.99	6.54	8.11	7.26	7.30	0.18

[a] Standard error of mean. * Significance was not observed among treatments.

Table 10. Effect of feeding C3G high black rice bran on TBA value of pork.

Items	CON	C3G high black rice bran			SEM [a]
		CRB-0.2	CRB-0.4	CRB-0.6	
TBA value [b]					
1 day	0.25	0.15	0.14	0.18	0.02
4 day	0.23	0.19	0.18	0.20	0.01
6 day	0.24	0.20	0.22	0.21	0.01

[a] Standard error of mean.
[b] TBA value was expressed as mg of malondialdehyde (MDA)/kg.
* Significance was not observed among treatments.

not been reported to have a direct effect on glycolytic potential or postmortem glycolysis.

Antioxidants have been proposed to stabilize muscle membranes, which could improve meat color (Buckley et al., 1995). Hasty et al. (2002) reported higher b* value (yellowness) in pigs fed vitamin E and Asghar et al. (1991) found increased a* value (redness) of fresh pork when vitamin E was added at 200 IU/kg. While there was a report that vitamin C supplementation had a negative effect on meat color (Pion et al., 2004). However, in the present study, there was no significant effect of feeding C3G high black rice bran on Hunter L*, a*, and b* values of pork.

As expected, TBA value (Table 10), pigs fed C3G high black rice bran showed a tendency of lower TBA value than pigs fed basal diet even though there was no overall significant difference among treatments. Sinnhuber and Yu (1958) suggested that TBA value could be used for measuring oxidation of fat in pork. Supplementation of antioxidants could lead to improvement in the oxidation stability of muscle (Cannon et al., 1996; Jensen et al., 1997; Lauridsen et al., 1999), although inconsistent results have been reported (Tsai et al., 1978; Pion et al., 2004). While it is generally reported that full-fat rice bran has higher free fatty acid and unsaturated fatty acids and these fatty acids could compromise the lipid stability of meat (Jakobsen, 1995a). However, Chae and Lee (2002) reported that pigs fed full-fat rice bran showed better lipid stability of pork than those fed rancid rice bran, although the unsaturated fatty acid content was higher in full-fat rice bran than in rancid rice bran. They explained the reason was related to differences in antioxidant concentration. Those reports were in agreement with our finding. Therefore, C3G high black rice bran might have a beneficial effect on stability of lipid in pork.

However, there is still some uncertainty in the literature, regarding antioxidant properties for meat quality. Most of antioxidant included in black rice bran is water-soluble, so that it has a property of relatively fast breakdown and it is also difficult to be deposited in living tissue and muscle as the same manner as vitamin C. While most studies, reported observable effects on meat quality by feeding antioxidants and explained that improved pork quality was related to accumulation of antioxidants in muscle tissue (Buckley et al., 1995; Lauridsen et al., 1999). Therefore, a subsequent trial will be conducted to determine the impact of dietary antioxidants on meat quality.

IMPLICATION

Nutrient digestibility and blood measurements in pigs were not significantly affected by feeding C3G high black rice bran. However, C3G high black rice bran might have an effect on lowering serum total cholesterol. Pigs fed C3G high black rice bran showed slightly lower growth rate. Backfat thickness tended to be decreased by supplementation of C3G high black rice bran although other carcass characteristics were not different among treatments. In addition, the pH and Hunter L*, a* and b* values were not changed by feeding C3G high black rice bran. However, the TBA value was reduced in pork from pigs fed C3G high black rice bran. These results suggested that C3G high black rice bran might have an effect on serum cholesterol concentration and lipid stability of pork. It is supposed that these effects might be due to high concentration of antioxidative compounds, C3G in black rice bran, further research is needed to explore the full potential of utilizing C3G in swine diet.

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