Rancid Rice Bran Affects Growth Performance and Pork Quality in Finishing Pigs

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ABSTRACT : Two experiments were conducted to evaluate the feeding value of rancid rice bran in finishing pigs. In exp. 1, fresh (FRB), rancid (RRB), pelleted and extruded rice bran were used to determine stability and nutrient digestibility. The free fatty acid (FFA) values of FRB and RRB were 8.2 and 15.3%, respectively. Some of the FRB was pelleted (70°C) or extruded (110°C). In exp. 2, a total of 48 pigs (Landrace×Yorkshire×Duroc, 51.12±0.5 kg) were employed for a 56-d feeding trial with 3 treatments: Control (defatted rice bran+animal fat), 20% FRB (8.2% FFA), and 20% RRB (15.6% FFA). There was a significant difference ($p<0.05$) in FFA% between raw and pelleted, and extruded rice bran on d 10 after storage. On d 30 the extruded rice bran showed lower ($p<0.05$) FFA% than the pelleted one. Dry matter digestibility was higher ($p<0.05$) in processed rice brans (pelleted or extruded) than raw rice bran (FRB or RRB). Energy and protein digestibilities in extruded rice bran were higher ($p<0.05$) than those in raw rice brans. The digestibilities of isoleucine, leucine and phenylalanine were lower ($p<0.05$) in RRB than FRB. Pigs fed diets containing FRB grew faster ($p<0.05$) and showed better feed conversion ratio ($p<0.05$) than those fed diets containing defatted rice bran or RRB. Carcass characteristics including dressing percentage and backfat thickness were not affected ($p>0.05$) by dietary treatments. With increasing storage time, the raw pork from RRB showed higher ($p<0.05$) thiobarbituric acid reactive substance (TBARS) and peroxide value (POV) than those from FRB when stored at 1°C for 3 weeks. Cooked pork showed rapid increase in TBARS and POV as compared to raw pork regardless of rice bran rancidity. As the storage time passed, Lightness (L) was lower ($p<0.05$) in RRB than FRB. Redness (a) was higher ($p<0.05$) in control than rice bran groups when stored 2-3 weeks. However, there was no difference ($p>0.05$) in redness (a) between the two rice bran groups. In conclusion, feeding rancid rice bran gave negative effects on growth performance and pork quality in finishing pigs. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 1 : 94-101)***

Key Words : Rice Bran, Rancidity, Growth, Digestibility, Pork Quality

INTRODUCTION

Rice bran has been used as a feed ingredient in animal production. The possible inclusion level of fresh rice bran in swine diet is up to 40% (Morrison, 1959; Saunders et al., 1982). However, rice bran contains a large amount of oil and lipases, resulting in the development of rancidity at room temperature in a few days (Linfield, 1985). It also has been reported that rice bran contains protease inhibitors (Kratzer et al., 1974).

Feeding rancid rice bran reduced growth performance in chicks (Kratzer and Payne, 1977; Hussein and Kratzer, 1982), while Xu (1994) reported that there was no difference in growth performance in finishing pigs fed diets containing fresh or rancid rice brans.

Freeman (1976) and Howard (1984) reported that the FFA content of dietary fats reduced digestibility of nutrients. However, Lewis and Wiseman (1977) reported that there was no significant decrease in digestibility until the FFA reached 50%.

Rice bran can be stabilized by heat treatments such as extrusion (Randall et al., 1985; Martin et al., 1993). It was reported that chicks fed stabilized rice bran grew faster than those fed raw rice bran (Sayre et al., 1988).

In addition, oxidized oil in broiler diets induced rapid oxidation of the membrane-bound lipids and decreased their stability towards peroxide-mediated peroxidation (Lin et al., 1989). There is still limited information regarding the effects of feeding rancid rice bran on growth performance and meat stability in chicks and pigs. Therefore, this study was conducted to investigate growth performance and pork quality in finishing pigs fed different rancid degrees of rice bran. Other attempts were made to determine the effects of processing (pelleting and extrusion) on lipid stability and nutrient digestibility of rice bran in finishing pigs.

MATERIALS AND METHODS

Design, sample preparation and animals

For stability and digestibility tests, a fresh rice bran was spoiled, pelleted or extruded. The free fatty acid (FFA) values of fresh rice bran (FRB) and rancid rice bran (RRB) were 7.6% and 16.3%, respectively. The rice bran supplied by a rice milling plant was separately stored for 10 days in a cool warehouse (below 10°C for FRB or stored outside with a cover (up to 30°C) for RRB until they were used for stability or digestibility tests.

Some of the FRB were pelleted or extruded. A pellet mill (CPM®, Model 3020, USA) was used with 4.6 mm die

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in diameter, and the operation temperature in the steam chamber was 70°C. The extrusion was done at 110°C (last barrel) with a single screw extruder (Millbank®, Model 1001S, NZ). The prepared samples were packed and kept in an oven fixed at 30°C for 20 days to determine the changes in FFA values during storage. And a digestibility study was conducted with the rice bran samples after processing.

Formula and chemical compositions of experimental diets were presented in table 1. For a digestibility trial, chromic oxide (0.3%) was added as an indigestible marker, and rice bran was the only energy and amino acid source. Four crossbred growing pigs (Landrace×Yorkshire×Duroc, 50±0.4 kg of initial body weight) were used in a Latin Square and crated in an individual cages. Treatments were 2 raw (FRB and RRB) and 2 processed (pelleted and extruded) rice brans. Limited feeds (2 kg per day) were fed two times per day (09:00 and 17:00) and water was provided *ad libitum* consumption. Feces were collected for 3 days from pigs on the 5th day after feeding the experimental diets. Feces were dried in an air-forced drying oven at 60°C for 72 h for chemical analyses.

Table 1. Formula and chemical composition of experimental diets

	Digestibility trial	Feeding trial	
		Control	Rice
Ingredients (%)			
Yellow corn	-	50.41	52.96
Defatted rice bran	-	20.00	-
Rice bran[1]	96.30	-	20.00
Soybean meal	-	18.63	19.20
Limestone	2.50	1.20	0.98
Tricalcium phosphate	-	0.54	0.95
Salt	0.30	0.30	0.30
Vit. premix[2]	0.30	0.20	0.20
Trace min. premix[3]	0.30	0.24	0.24
Animal fat	-	5.48	2.17
Molasses	-	3.00	3.00
Cr_2O_3	0.30	-	-
Total	100.00	100.00	100.00
Chemical composition (%)[4]			
ME (kcal/kg)	3,335	3,210	3,210
Crude protein	13.78	15.50	15.50
Crude fat	13.19	7.62	7.71
Lysine	0.55	0.82	0.83
Methionine + Cystine	0.51	0.61	0.60
Calcium	1.21	0.83	0.86
Phosphorus (Avail.)	0.39	0.26	0.26

[1] Rice bran, fresh or rancid, was added by weight basis.
[2] Supplied per kg diet : 8,000 IU vitamin A, 2,500 IU vitamin D_3, 30 IU vitamin E, 3 mg vitamin K, 1.5 mg thiamin, 10 mg riboflavin, 2 mg vitamin B_6, 40 μg vitamin B_{12}, 30 mg pantothenic acid, 60 mg niacine, 0.1 mg biotin, 0.5 mg folic acid.
[3] Supplied per kg diet : 200 mg Cu, 100 mg Fe, 150 mg Zn, 60 mg Mn, 1 mg I, 0.5 mg Co, 0.3 mg Se.
[4] Calculated values.

For the feeding trial, the FFA values of FRB and RRB were 8.2 and 15.6%, respectively. Treatments were: Control, FRB and RRB. Rice bran was added 20% in the diet (table 1). In the control diet, defatted rice bran (20%) was included with animal fat to meet energy level among diets. Defatted rice bran was purchased at a commercial oil plant. All diets were formulated to contain 3,210 ME kcal/kg, 15.5% crude protein and 0.82% lysine.

A total of 48 crossbred pigs (Landrace× Yorkshire×Duroc, 51.12±0.5 kg) were used in a 56-d feeding trial with 4 pigs (2 barrows and 2 gilts)/pen and 4 replicates/treatment. All pigs were alloted on the basis of sex and weight in a randomized completely block design. The pigs were housed in 2.0 m×2.5 m pens with half slotted floors. Feed and water were provided *ad libitum* consumption.

After termination of feeding trial, pigs were fed the experimental diets 1 week more to reach body weight over 105 kg. In each treatment, three gilts with similar body weight were sacrificed to evaluate carcass and pork quality. The average live weight of the pigs was 107.9±1.2 kg. Pork samples (*M. trapezius cevicalis*) from the carcasses were also taken, ground and sealed with polyethylene film and stored in a refrigerator at 1±1°C for the determination of lipid stability and colors. A part of the pork samples was heated to an internal temperature 80°C in the water bath, chopped, sealed and stored under the same condition of raw pork.

Chemical and statistical analyses

Proximate and free fatty acid of the feeds or feces were analyzed according to the methods of AOAC (1990) and gross energy was measured with an adiabetic bomb calorimeter (Model 1241, Parr Instrument Co., Molin, IL). Chromium was measured with a spectrophotometer (Contron 942, Italy). Amino acids and fatty acids were analyzed with HPLC (Waters, Model 486, USA) and a gas chromatography (Hewlett Packart Co., Model 5890, USA), respectively.

Pork color was measured with a color difference meter (Yasuda Seiko Co., CR 310, Minolta, Japan). Oxidative changes in ground pork was determined by measuring thiobarbituric acid reactive substances (TBARS: Sinnhuber and Yu, 1977). Meat samples (0.3-0.4 g) were mixed with 3 mL of TBA solution (1% TBA in 0.075 N NaOH), 17 mL of trichloroacetic acid (5%)-NCl (0.04 N) solution and three drops of antioxidant solution (0.3% BHA, 0.3% BHT, 54% propylene glycol and 40% Tween 20). Samples were flushed with nitrogen, placed in a boiling water bath for 30 min, and cooled to room temperature in tap water. Chloroform (2 mL) was mixed with 5 mL of the colored solution to remove emulsified fat. The aqueous phase and chloroform were separated by centrifugation at 2,000 g for

15 min. Absorbance of the aqueous phase was measured at 532 nm. The TBARS concentrations were expressed as mg malonaldehyde/kg meat, as determined from a following equation.

TBARS (mg malonaldehyde/kg meat) =

$$\frac{(As\text{-}Ab)\times 46}{Sample\ (g)\times 5}$$

As: Absorbance of the sample
Ab: Absorbance of the blank

Lipid peroxides were determined using a modified thiocyanate method. Lipid was extracted by homogenizing 0.4 g muscle with 5 mL chloroform:methanol (2:1) for 20s using a homogenizer (Heidolph, Diax 600, Germany) at a setting of red color (No load 13,500 rpm). The homogenizer was rinsed by homogenizing in 2 mL chloroform:methanol for 8s (power setting of 8) followed by an additional rinsing with 3 mL chloroform:methanol. The chloroform:methanol fractions were combined and filtered through Whatman No. 1 filter paper. The resulting filter paper was rinsed with additional chloroform:methanol until the filtrate volume was 10 mL. 2 mL of water was added to the filtrate and the mixture was vortexed and centrifuged (2,000×g for 3 min). Then 3 mL of the clear lower solvent phase was mixed with 1.9 mL chloroform:methanol (2:1), 25 μL 3.94 M ammonium thiocyanate and 25 μL 18 mM ferrous chloride and measured absorbance at 500 nm after exact 20 min. The peroxide concentrations were determined according to the Shantha and Decker (1994).

Peroxide value (milliequivalents of peroxide/kg meat) =

$$\frac{(As\text{-}Ab)\times m\times V2}{55.84\times m0\times 2\times V1}$$

As: Absorbance of the sample
Ab: Absorbance of the blank
m: slope of the calibration curve
m0: grams of the sample
55.84: atomic weight of iron
V1: volume used in measurement (mL)
V2: total volume of extract (mL)

Data were analyzed using the General Linear Model (GLM) Procedure of SAS (1985). The statistical model was that appropriate for a randomized complete block design.

RESULTS

Stability and nutrient digestibility

Proximate analysis and free fatty acid (FFA) contents of the rice bran used in the stability and nutrient digestibility were presented in table 2. Crude protein and crude fat contents of the rice bran were 14.16 and 16.95%, respectively.

As the storage period was increased, the FFA% in rice bran was linearly ($p<0.05$) increased regardless of processing methods (table 3). There was a significant difference ($p<0.05$) in FFA% between raw and pelleted, and extruded rice bran on d 30 after storage. On d 30 raw rice bran showed the highest ($p<0.05$) FFA% among rice bran products. The extruded rice bran showed lower ($p<0.05$) FFA% than the pelleted one. Also, unsaturated fatty acid (USFA) levels in raw, pelleted or extruded rice brans were slightly reduced when they were stored for 30 days, while saturated fatty acids (SFA) levels were increased.

Table 2. Chemical compositions of rice bran used in digestibility and feeding trials

Contents (%)	Rice bran[1]		Defatted rice bran
	FRB	RRB	
Moisture	12.82	13.14	11.95
Crude protein	14.16	14.17	15.41
Crude fat	16.95	17.00	1.25
Crude ash	8.75	9.50	13.18
Calcium	0.32	0.40	0.36
Phosphorus	1.47	1.44	1.73
Free fatty acid[2]			
Digestibility	7.60	16.30	-
Feeding trial	8.20	15.60	-

[1] FRB: Fresh rice bran, RRB: Rancid rice bran.
[2] The rancidity of rice bran was different in digestibility and feeding trial.

Table 3. Changes in free fatty acids and fatty acids[1] in rice bran products during storage

	Rice bran			SE
	Raw	Pelleted	Extruded	
Free fatty acid[2]				
D 0	7.60	7.60	7.60	0.24
D 10	11.42^{ab}	13.57^{a}	10.37^{b}	1.63
D 20	15.55^{a}	16.57^{a}	12.83^{b}	2.01
D 30	20.50^{a}	19.50^{b}	15.24^{c}	2.43
SFA				
D 0	21.67	21.67	21.68	0.41
D 15	21.47	21.58	21.79	0.25
D 30	22.18	22.58	22.43	0.39
USFA				
D 0	78.33	78.33	78.32	0.41
D 15	78.53	78.42	78.21	1.70
D 30	77.82	77.42	77.57	2.31

[1] SFA: Saturated fatty acids (C12:0, C14:0, C16:0, C18:0), USFA: Unsaturated fatty acids (C16:1, C18:1, C18:2, C18:3).
[2] Storage effect (linear, $p<0.05$).
[a,b,c] Values with different superscripts in the same row differ ($p<0.05$).

Table 4. The effect of raw and processed rice brans on the nutrient digestibility in pigs

	Raw[1]		Processed		SE
	FRB	RRB	Pelleted	Extruded	
Dry matter	62.25[b]	62.93[b]	72.28[a]	74.41[a]	6.86
Gross energy	65.81[c]	69.36[bc]	74.76[ab]	78.31[a]	6.12
Crude protein	65.07[b]	62.11[b]	67.38[a]	76.14[a]	5.55
Crude fat	81.33	80.88	83.09	85.22	3.14
EAA[2]					
Valine	67.58	68.54	74.83	78.17	8.30
Isoleucine	70.52[a]	48.52[b]	63.90[a]	66.54[a]	8.75
Leucine	74.63[a]	49.24[c]	61.23[b]	66.87[ab]	11.54
Phenylalanine	70.40[a]	42.64[b]	59.53[ab]	57.41[ab]	14.43
Lysine	69.24	54.28	57.57	66.69	14.65
Histidine	63.24[b]	64.69[b]	73.72[ab]	82.02[a]	10.63
Arginine	59.68	58.50	66.59	73.62	13.52
Threonine	65.83[b]	67.85[b]	70.22[ab]	78.87[a]	7.66
Average	68.08[a]	56.26[b]	65.14[a]	68.91[a]	5.79

[1] FRB: Fresh rice bran, RRB: Rancid rice bran.
[2] Methionine and tryptophan were not determined.
[a,b,c] Values with different superscripts in the same row differ ($p<0.05$).

As presented in table 4, dry matter digestibility was higher ($p<0.05$) in processed rice brans (pelleted or extruded) than raw rice bran (FRB or RRB). Energy and protein digestibilities in extruded rice bran were higher ($p<0.05$) than those in raw rice bran. The digestibilities of DM, energy and protein were not affected ($p<0.05$) by degrees of rancidity and processing methods (pelleting vs extruding). However, the digestibilities of isoleucine, leucine and phenylalanine were lower ($p<0.05$) in RRB than FRB. Histidine and threonine digestibilities were higher ($p<0.05$) in the extruded rice bran than the two raw rice brans. The average essential amino acid digestibility was lower ($p<0.05$) in RRB than others.

Growth performance and pork quality

As data can be seen in table 5, pigs fed diets containing FRB grew faster ($p<0.05$) and showed better feed conversion ratio ($p<0.05$) than those fed diets containing defatted rice bran or RRB. Feed intake was also higher in FRB than others, but it was not significant ($p>0.05$).

Carcass characteristics including dressing percentage and backfat thickness were not affected ($p>0.05$) by dietary treatments.

Changes in lipid stability and pork color during storage

With increasing storage time, the raw pork from RRB showed higher ($p<0.05$) TBARS and POV than those from FRB when stored at 1°C for 3 weeks (table 6). However, when stored at 1°C for 3 weeks, there were no differences in TBARS and POV between RRB and control groups. Similar trends were found in TBARS and POV in cooked pork. However, cooked pork showed rapid increase in TBARS and POV as compared to raw pork regardless of rice bran rancidity.

Table 5. Effects of feeding rice bran on the growth performance and carcass traits in growing-finishing pigs

	Control	Rice bran[1]		SE
		FRB	RRB	
Growth performance				
ADG (g)	674[b]	781[a]	692[b]	34.58
ADFI (g)	2.080	2,181	2,087	197.81
Feed conversion ratio	3.08[b]	2.79[a]	3.02[b]	0.16
Carcass traits				
Dressing percentage	73.85	74.03	72.52	1.46
Backfat thickness (last lib, mm)	15.16	13.98	15.08	1.55

[1] FRB: Fresh rice bran, RRB: Rancid rice bran.
[a,b] Values with different superscripts in the same row differ ($p<0.05$).

Fatty acid compositions in pork were shown in table 7. The concentration of saturated fatty acids (C12:0, C14:0, C16:0, C18:0) in pork was higher ($p<0.05$) in RRB than in FRB group. However, the concentration of unsaturated fatty acids (C16:1, C18:1, C18:2, C18:3) in pork had opposite results.

Pork colors as affected by feeding rancid rice bran were presented in table 8. Lightness (L) was lower ($p<0.05$) in RRB than control group. As the storage time passed, lightness (L) was lower ($p<0.05$) in RRB than FRB. Redness (a) was higher ($p<0.05$) in control (defatted rice bran and animal fat) than rice bran groups when pork was stored for 2-3 weeks. However, there was no difference

Table 6. Lipid stability of raw or cooked porks from pigs fed fresh or rancid rice bran[1]

Pork	Storage (week)[1]	TBARS[2]			SE	POV[2]			SE
		Control	FRB	RRB		Control	FRB	RRB	
Raw	0	1.54	1.68	1.66	0.26	0.03	0.03	0.04	0.01
	1	1.70^{b}	1.94^{ab}	2.41^{a}	0.27	0.05^{b}	0.04^{c}	0.06^{a}	0.01
	2	3.01^{b}	2.72^{c}	3.74^{a}	0.27	0.07^{b}	0.06^{c}	0.09^{a}	0.01
	3	3.83^{a}	2.80^{b}	3.89^{a}	0.40	0.08^{a}	0.06^{b}	0.08^{a}	0.01
Cooked	0	3.69	3.21	4.58	0.37	0.10	0.07	0.09	0.02
	1	7.08^{b}	6.43^{b}	8.81^{a}	0.50	0.36^{c}	0.42^{b}	0.51^{a}	0.03
	2	9.92^{a}	8.55^{b}	9.92^{a}	0.47	0.55^{ab}	0.54^{b}	0.67^{a}	0.05
	3	11.94^{a}	11.01^{b}	12.35^{a}	0.70	0.66^{b}	0.84^{a}	0.86^{a}	0.04

[1] Ground pork was stored in loose packaging at 1°C for 3 weeks.
[2] Control: defatted rice bran, FRB: Fresh rice bran, RRB: Rancid rice bran.
[a,b,c] Means within row with different superscripts are significantly different ($p<0.05$).

Table 7. Fatty acid compositions of porks from pigs fed fresh or rancid rice bran

Fatty acid[1]	Rice bran[2]			SE
	Control	FRB	RRB	
	---------- % ----------			
C12:0	0.41^{b}	1.07^{a}	1.04^{a}	0.33
C14:0	1.44^{c}	1.66^{b}	2.11^{a}	0.30
C16:0	25.31^{c}	28.25^{b}	32.78^{a}	3.26
C16:1	2.38^{b}	1.63^{c}	2.67^{a}	0.47
C18:0	13.45^{b}	15.33^{a}	14.90^{a}	0.89
C18:1	37.97^{a}	26.24^{b}	26.15^{b}	5.89
C18:2	15.23^{c}	16.03^{a}	9.89^{c}	2.90
C18:3	3.80^{ab}	9.79^{b}	10.46^{ab}	3.18
SFA	40.62^{c}	46.31^{b}	50.83^{a}	4.45
USFA	59.38^{a}	53.69^{b}	49.17^{c}	4.45

[1] SFA: Saturated fatty acids (C12:0, C14:0, C16:0, C18:0), USFA: Unsaturated fatty acids (C16:1, C18:1, C18:2, C18:3).
[2] FRB: Fresh rice bran, RRB: Rancid rice bran.
[a,b,c] Values with different superscripts in the same row differ ($p<0.05$).

($p>0.05$) in redness (a) between the two rice bran groups. Yellowness (b) of pork was higher ($p<0.05$) in control than rice bran groups, but it was also higher ($p<0.05$) in FRB than RRB when pork was stored more than 2 weeks.

DISCUSSION

As expected, extruded rice bran was slowly oxidized as compared to raw or pelleted rice brans. This result is in agreement with previous reports (Sayre et al., 1988; Martin et al., 1993). The FFA content of rice bran was 2.5% when purchased from a rice milling plant. During storage the FFA % of fresh rice bran was increased up to 2 times. Even though we stored fresh rice bran in a cool warehouse, lipid oxidation was progressed due to high fat content in the rice bran as stated by Linfield (1985).

Extrusion cooking was effective processing for improving stability of rice bran in this study. It has already become the most widely used method to stabilize rice bran for human foods (Martin et al., 1993). They also suggested that extrusion temperatures above 120°C would provide adequate protection against the development of hydrolytic rancidity. In our study, the extrusion temperature was 110°C, which was slightly lower than their temperature. Shin et al. (1997), however, recommended that when stabilizing rice bran by extrusion the lowest possible temperature should be used, preferably below 120°C because high temperature resulted in greater destruction of endogenous antioxdants. Rice bran contains 0.1-0.14% vitamin E vitamers (Kato et al., 1981) and 0.9-2.9% oryzanol (Okada and Yamaguchi, 1983).

In this study, it also would appear that pelleting of rice bran would be inadequate method for protection from hydrolytic rancidity due to low processing temperature, 70°C.

For nutrient digestibility, even though digestibilities of DM, energy and protein were not affected ($p>0.05$), some amino acid digestibilities such as isoleucine, leucine and phenylalanine were reduced by increased rancidity. Limited data are available to compare the difference in nutrient digestibility between fresh and rancid rice bran. It was reported that the FFA content of dietary fats influenced digestibility (Howard, 1984). Freeman (1976) also suggested a fall of about 15% in digestibility from 0 to 100% free fatty acid. However, similar digestibilities of DM, energy and protein between fresh and rancid rice brans in the present study supported the report of Lewis and Wiseman (1977), who demonstrated that there was no significant reduction in nutrient digestibility until the FFA reached 50%. In this study the FFA value of RRB was 15.6%.

In general, pelleting or extrusion of rice bran improved

Table 8. Pork color as affected by feeding fresh or rancid rice bran during storage

Color	Storage (week)[1]	Treatment[2]			SE
		Control	FRB	RRB	
L	0	49.9[a]	48.8[ab]	48.2[b]	0.67
	1	49.9[a]	49.2[a]	47.8[b]	0.60
	2	51.1[a]	49.0[b]	47.8[c]	0.50
	3	51.7[a]	49.6[b]	48.8[c]	0.87
a	0	15.9	15.6	16.9	0.57
	1	15.1	14.6	15.2	1.03
	2	17.6[a]	14.5[b]	14.9[b]	0.70
	3	19.5[a]	17.9[b]	18.7[ab]	0.83
b	0	7.9[a]	6.9[b]	6.3[c]	0.27
	1	8.3[a]	6.8[b]	6.6[b]	0.50
	2	8.3[a]	6.8[b]	5.6[c]	0.27
	3	8.3[a]	7.6[b]	6.5[c]	0.43

[1] Ground pork was stored in loose packaging at 1°C for 3 weeks.
[2] Control: Defatted rice bran, FRB: Fresh rice bran, RRB: Rancid rice bran.
[a,b,c] Means within row with different superscripts are significantly different ($p<0.05$).

DM, energy and crude protein digestibilities. Several researchers reported that heat treatments by means of pelleting or extrusion cooking improved nutrient digestibility (Stoch et al., 1983; Hancock, 1992; Chae et al., 1997a,b). But high temperature reduces digestibility of nutrients, especially lysine and methionine, which are very sensitive to heat (Chae et al., 1997b). In terms of nutrient digestibility, there was no adverse effects by pelleting or extrusion cooking of rice bran in the present study (table 4).

On the other hand, growth performance of pigs fed diets containing RRB was reduced as compared to those fed diets containing FRB. This result was in agreement with the previous studies with chicks (Kratzer and Payne, 1977; Hussein and Kratzer, 1982). Kratzer and Payne (1977) suggested that the stability of fat influenced the growth of chicks. It is also stated that feeding RRB can be a cause of reduced palatability (Hussein and Kratzer, 1982) and digestive disorders (Yokochi, 1972). In the present study, there was a trend towards reduced feed intake when RRB was fed, even though it was not significant.

However, Xu (1994) reported that there was no difference in growth performance in growing-finishing pigs fed diets containing FRB or RRB. Limited studies were conducted to evaluate the feeding values of rancid rice bran in pigs. In addition, feed intake was reduced in the control group (defatted rice bran) compared to the FRB group, thus reducing weight gain.

The possible inclusion level of fresh rice bran in swine diet is up to 40% (Morrison, 1959; Saunders et al., 1982). In our study, the inclusion level of rice bran was 20%, and pigs fed diets containing FRB grew faster ($p<0.05$) than those fed diets containing defatted rice bran (control diet). In terms of growth performance, it seems that it is possible to include 20% rice bran in finishing pig diets as far as it is fresh.

Carcass characteristics such as dressing percentage and back fat thickness in pigs were not affected by degrees of rancidity in rice bran, which is supported by the result of Xu (1994). However, oxidative stability in terms of TBARS and POV was significantly decreased in porks from pigs fed RRB as compared to FRB. It might be influenced by the reduced antioxidant agents (α-tocopherol, oryzanol, etc.) in rice bran during storage. Xu (1994) reported that non-rancid rice bran treatment led to a higher level of total vitamin E vitamers and α-tocopherol in pig tissues than rancid rice bran treatment. The content of vitamin E vitamers in rice bran is decreased during storage. Of seven kinds of vitamin E vitamers that exist in rice bran, α-tocopherol was oxidized more quickly than other vitamers (Godber et al., 1993). In addition, the lipid stability in control group was similar with that of RRB group, because the animal fat used in this experiment had high FFA value (18.2%).

Our results support the reports of Asghar et al. (1989), Lin et al. (1989), and Buckley et al. (1989), who found that rates of lipid peroxidation in pig and broiler muscles fed oxidized oil were much higher than those from control animals. α-tocopherol content in the diet is very important to improve lipid stability (Monahan et al., 1992; Jensen et al., 1997; Rey et al., 2001).

Fatty acid profiles in pork also affect lipid stability during storage (Rhee et al., 1990; Maraschiello et al., 1998). They reported differences in oxiditive stability in porks with different degrees of fatty acid saturation. In the present study, unsaturated fatty acids (C16:1, C18:1, C18:2, C18:3) in porks from pigs fed diets containing FRB were higher than those from pigs fed diets containing RRB (table 7). Even though the USFA content was higher in FRB than in RRB, lipid stability was better in porks from FRB than

those from RRB. It might be attributed to differences in antioxidants between the two rice bran groups, as described by Xu (1994).

In addition, there might be some changes in fatty acid profiles in rancid rice bran during storage, thus showing difference in fatty acid profiles in porks. It would appear that USFA content would be reduced in RRB due to the high rancidity as compared to FRB. It is reported that USFAs are more susceptible to oxidation than SFAs, and the changes in the type and amount of fat in the diet will be reflected in the composition of adipose tissue fatty acids (Enser, 1984; Morgan et al., 1992). However, it is impossible to compare the fatty acid profiles between control and rice bran groups because the animal fat used in this study was blended with tallow and lard.

Cooked pork was more unstable than raw pork during storage. It might be originated from reduced antioxidants during cooking. Xu (1994) reported that α-tocopherol and γ-tocopherol concentrations decreased more rapidly in cooked than raw porks during storage, thus the TBA values increased much faster in cooked than in raw pork chops.

In addition to the lipid stability, pork color is related to vitamin E content in the pork (Buckley et al., 1989). In the present study, pork color was lightier and more yellowish in FRB than in RRB group, but it was not significant ($p>0.05$). This result is in agreement with the report of Xu (1994). He observed no differences in pork color between pigs fed different degrees of rancidity in rice bran. α-tocopherol content was slightly higher in the diet containing FRB than RRB, but α-tocopherol content in muscle was not affected by dietary treatments.

It was reported that lipid oxidation and pigment oxidation in fresh meat are closely related; delaying lipid oxidation results in a similar delay of meat discoloration (Akamittath et al., 1990; Asghar et al., 1991). Asghar et al. (1991) observed that L and b values of pork chops decreased with length of storage without showing any relation to the vitamin E levels in the diet of pigs, but a value changes were relatively slow when dietary vitamin E level was high. However, Cannon et al. (1996) reported that vitamin E supplementation of the growing-finishing diet of hogs reduced lipid oxidation in fresh pork but did not influence pork color. Resurrection and Reynolds (1990) also reported that there was no difference in pork color values when dietary vitamin E level was different. In the present study, there was no trend in color changes in each group during the 3 weeks of storage period. More studies are necessary to conclude the impact of feeding rancid rice bran on pork color stability.

IMPLICATION

Extrusion cooking would be a way to improve the stability of rice bran. Feeding rancid rice bran gives negative effects on growth performance and pork quality in growing-finishing pigs. Therefore, it is very important to use rice bran as a feed ingredient when it is fresh or stabilized.

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