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Effect of fermented biogas residue on growth performance, serum biochemical parameters, and meat quality in pigs

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Objective: This study investigated the effect of fermented biogas residue (FBR) of wheat on the performance, serum biochemical parameters, and meat quality in pigs.
Methods: We selected 128 pigs (the mean initial body weight was 40.24±3.08 kg) and randomly allocated them to 4 groups (1 control group and 3 treatment groups) with 4 replicates per group and 8 pigs per pen in a randomized complete block design based on initial body weight and sex. The control group received a corn-soybean meal-based diet, the treatment group fed diets containing 5%, 10%, and 15% FBR, respectively (abbreviated as FBR5, FBR10, and FBR15, respectively). Every group received equivalent-energy and nitrogen diets. The test lasted 60 days and was divided into early and late stages. Blood and carcass samples were obtained on 60 d. Meat quality was collected from two pigs per pen.
Results: During the late stage, the average daily feed intake and average daily gain of the treatment groups was greater than that of the control group ($p<0.05$). During the entire experiment, the average daily gain of the treatment groups was higher than that of the control group ($p<0.05$). Fermented biomass residue did not significantly affect serum biochemical parameters or meat quality, but did affect amino acid profiles in pork. The contents of Asp, Arg, Tyr, Phe, Leu, Thr, Ser, Lys, Pro, Ala, essential amino acids, non-essential amino acids, and total amino acids in pork of FBR5 and FBR10 were greater than those of the control group ($p<0.05$).
Conclusion: These combined results suggest that feeding FBR could increase the average daily gain and average daily feed intake in pigs and the content of several flavor-promoting amino acids.

Keywords: Fermented Biogas Residue; Growth Performance; Meat Quality; Pigs; Serum Biochemical Parameters

INTRODUCTION

Wheat was crushed, washed, fermented, and distilled to produce alcohol. This process also yields alcohol waste liquid which is able to be centrifuged to separate the filtrate. The filtrate can be used to produce biogas, and the remaining biogas residue contains 35% crude protein on a dry matter basis [1]. These biogas residues can be used as a feed ingredient for pigs and chickens [2,3]. If the biogas residues are discarded, they will pollute the environment, waste a potential protein source, or cost too much money for drying them [4,5]. However, the protein feed resources are seriously insufficient in China, a large number of soybean meal should be imported every year to meet the needs of pig husbandry. Therefore, it is very important to develop additional protein feed resources to promote the development of animal husbandry in China. Develop the biogas into protein feed for partially replace the soybean meal for pig diet will not only achieve the economic benefits for reusing of waste, but also obtain the social benefits for reducing the environment pollution. Untreated biogas residues contain up to 80% moisture and bad peculiar smell that animals did not like which renders them unsuitable for feed ingredients. However, if they are mixed with other raw feed materials, solid aerobic fermented. At the same time, some of the water is evaporated and the odor is removed, thus it is suitable for feeding [1]. Studies showed that fermentation of feed ingredients can promote growth performance [6], digestibility of amino acids [7,8] and meat quality [9]. But the effects of feeding fermented biogas residue (FBR) on growth performance, serum biochemical parameters, and meat quality for growing and finishing pigs are not clear. So this study investigated partially replacing soybean meal with FBR for daily feeding of pigs, and evaluated the effects of them in growing and finishing pigs.

MATERIALS AND METHODS

Preparation of fermented biogas residue

The biogas residue raw material was mixed with wheat bran. The dry matter content was increased to 50%, and distiller's yeast was added to a final content of 10% based on weight. The biogas residue was aerobic fermented 48 h, then dried and crushed. The yield contained 92.01% dry materials, 21.87% crude protein, 6.35% crude fat, 7.57% crude fiber, 5.37% crude ash, 0.24% calcium, and 0.48% total phosphorous on an as-fed basis. The yield contained 0.91% Arg, 0.73% His, 0.73% Ile, 1.25% Leu, 0.89% Lys, 0.32% Met, 0.48% Cys, 0.76% Phe, 0.52% Tyr, 0.71% Thr, 0.42% Trp, 1.05% Val, 1.57% Asp, 0.8% Ser, 3.53% Glu, 1.14% Gly, 1.04% Ala, 1.12% Pro on the as-fed basis. The digestible energy of FBR is 13.84 MJ/kg on the as-fed basis [2].

Animal, experimental design, and diet

This study adopted the randomized complete block design. We selected 128 pigs (Duroc×Landrace×Yorkshire) with a mean initial body weight of 40.24±3.08 kg and randomly assigned them into four groups on the basis of body weight and gender, including the control group, treatment group 1, treatment group 2, and treatment group 3. In the latter three groups, fed diets containing 5%, 10%, and 15% FBR respectively (abbreviated as FBR5, FBR10, and FBR15, respectively), the control group received a corn-soybean meal-based diet. We performed four replicates of each treatment with 8 pigs (4 males and 4 females). The total test period was 67 days, dietary adaptation period was 7 days, formal test period was 60 days, which was divided into the early stage (0 to 30 d) and the late stage (30 to 60 d). The dietary composition of control group was prepared according to the advised formulation of commercial premix to meet or exceed the requirement estimates of vitamins and minerals. Every group received the equivalent-energy and nitrogen diets. The ingredient and chemical compositions were shown in Table 1. Dietary nutrient values in Table 1 were formulated according to nutrient requirements by NRC

Table 1. Ingredient and chemical compositions of the experimental diets (as fed basis)

Items	0 to 30 days[1)]				30 to 60 days			
	Control group	FBR5	FBR10	FBR15	Control group	FBR5	FBR10	FBR15
Ingredient (%)								
Corn	65.35	62.20	59.02	55.9	70.05	66.93	63.77	60.59
Soybean meal[2)]	24.2	22.35	20.53	18.7	18.65	16.82	14.98	13.16
Wheat bran	4.00	4.00	4.00	4.00	5.00	5.00	5.00	5.00
Fermented biogas residue[3)]	0	5.00	10.00	15.00	0	5.00	10.00	15.00
Calcium hydrogen phosphate	0.45	0.45	0.45	0.45	0.40	0.35	0.35	0.35
Limestone	1	1	1	1	0.9	0.9	0.9	0.9
Soybean oil	1	1	1	1	1	1	1	1
Premix[4)]	4	4	4	4	4	4	4	4
Total	100	100	100	100	100	100	100	100
Nutrients[5)]								
DE (MJ/kg)	14.57	14.57	14.57	14.57	14.57	14.57	14.57	14.57
CP	17.01	17.01	17.02	17.02	15.12	15.14	15.14	15.15
Ca	0.59	0.60	0.61	0.62	0.52	0.52	0.53	0.54
Total P	0.47	0.47	0.47	0.47	0.44	0.43	0.43	0.43
Lys	0.83	0.81	0.80	0.79	0.69	0.68	0.67	0.66
Met	0.27	0.26	0.26	0.26	0.24	0.24	0.24	0.24
Met+Cys	0.56	0.57	0.57	0.58	0.52	0.52	0.53	0.53
Trp	0.19	0.20	0.21	0.22	0.16	0.17	0.18	0.19
Thr	0.62	0.61	0.61	0.60	0.54	0.54	0.53	0.53

FBR, fermented biogas residue; DE, digestible energy; CP, crude protein.

1) FBR5, the diet contained 5% FBR; FBR10, the diet contained 10% FBR; FBR15, the diet contained 15% FBR.

2) The soybean meal contained 89.00% dry materials, 44.2% CP, 1.90% crude fat, 5.90% crude fiber, 6.10% crude ash, 0.33% calcium, and 0.62% total phosphorous.

3) The fermented biogas residue contained 92.01% dry materials, 21.87% crude protein, 6.35% crude fat, 7.57% crude fiber, 5.37% crude ash, 0.24% calcium, and 0.48% total phosphorous.

4) The premix was bought from Anhui Guangtong Biotechnology Co. Ltd, China, contained the following per kg of diets: vitamin A 4,000 IU, vitamin D_3 2,000 IU, vitamin E 11.2 mg, vitamin K_3 1.2 mg, vitamin B_2 2.8 mg, vitamin B_6 1.6 mg, *D*-pantothenic acid 8 mg, choline 0.32 g, nicotinic acid 14 mg, Cu (as copper sulfate) 0.1 g, Mn (as manganese sulfate) 0.032 g, Fe (as ferrous sulfate) 0.12 g, Zn (as zinc sulfate) 0.12 g, I (as potassium) 0.28 g, Se (as sodium selenite) 0.28 g.

5) Nutrients were calculated concentration based on tables of feed composition and nutritive values in China. Chinese Feed Database.

(2012) [10]. Normal management regulations for the pig farm were conducted during the trial period. The temperature of the pig barn was controlled at 25°C. All pigs had free access to feed and water.

Growth performance index

All pigs were weighed at the beginning of the test, at the end of the early stage and late stage of the test. Feed intake and weight gains were recorded. The pigs were not fed with diets but fed water for 12 hours for fasting weight before weighing. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency were calculated on pen basis.

Serum biochemical parameters

When the test was completed at the end of 60 days, two pigs with similar weights (one male and one female) were selected randomly from each replication group and fasted for 12 h. Then, a 6 mL precaval venous blood was collected, naturally coagulated at room temperature, and centrifuged at 3,000×g for 10 min at room temperature to separate the serum. The serum was collected, assigned a serial number, packaged, and stored at –20°C until use for measurement of total protein (TP), blood urea nitrogen (BUN), aspartate transaminase (AST), and alanine aminotransferase (ALT). These biochemical parameters were measured using an automated biochemistry analyzer (full automatic 7600-020 type of analyzer from Hitachi, Tokyo, Japan).

Meat quality determination

After collecting the precaval venous blood from two pigs of each replication group, they were slaughtered, and the longissimus dorsi (the muscle that spans from the fifth rib to the dorsal region near the hip) was removed from the left side of the carcass. Then, the flesh color (lightness, L*; redness, a*; yellowness, b*), pH, tenderness, cooking loss, drip loss, hardness, elasticity, cohesion, and resilience, and concentrations of inosinic acid, fatty acid, and amino acid were determined. The following instruments were used to measure the indices: colorimeter (ADCI-WS1, CTK Instrument Technology Co., Ltd. Beijing, China) for flesh color; pH meter (Rex PHB-4, INESA Scientific Instrument Co., Ltd, Shanghai, China) for pH; digital display muscle tenderness meter (C-LM3, College of Engineering of Northeast Agricultural University, Hei Longjiang, China) for tenderness; texture analyzer (TA. XT.Plus, SMSTA Company, Vienna, UK) for hardness, elasticity, cohesion and resilience; high performance liquid chromatography (Aiglent1100, Agilent Company, Santa Clara, CA, USA) for inosinic acid; gas chromatograph-mass spectrometer (Bruker Scion SQ, American Bruker Corporation, Madison, WI, USA) for fatty acids; and automatic analyzer (Hitachi835-50, Hitachi Corporation of Japan, Tokyo, Japan) for amino acids.

Statistical analysis

Data are presented as average value, standard error, and p-value. One-way analysis of variance was computed with SPSS 17.0 software. Each pen served as the experimental unit for growth performance, and individual pig was considered as the experimental unit for other indexes. The linear and quadratic responses were assessed by the orthogonal polynomial contrast. Differences were considered significant at $p<0.05$.

RESULTS

Effect of fermented biogas residue on growth

Table 2. Effect of feeding fermented biogas residue on growth performance in pigs[1)]

Items	Control group	FBR5[2)]	FBR10	FBR15	SEM	p-value	
						Linear	Quadratic
Early stage (0 to 30 d)							
Initial body weight	40.15	40.47	40.23	40.12	0.65	0.955	0.870
ADG (kg/d)	0.84	0.80	0.83	0.85	0.01	0.842	0.200
ADFI (kg/d)	2.11	1.98	2.06	1.97	0.04	0.441	0.690
Feed efficiency	2.48	2.46	2.49	2.32	0.04	0.103	0.236
Body weight at d 30	65.35	64.47	65.13	65.62	0.65	0.804	0.606
Late stage (30 to 60 d)							
ADG (kg/d)	0.85[a]	0.95[b]	1.07[b]	1.02b	0.05	0.010	0.034
ADFI (kg/d)	2.51[a]	2.91[b]	3.11[b]	3.11b	0.14	0.008	0.149
Feed efficiency	3.00	2.94	2.92	3.06	0.05	0.711	0.320
Final body weight	90.85[a]	92.97[ab]	97.23[c]	96.22[bc]	1.47	0.002	0.244
Total stage (0 to 60 d)							
ADG (kg/d)	0.85[a]	0.91[ab]	0.95[b]	0.95[b]	0.02	0.011	0.210
ADFI (kg/d)	2.34	2.50	2.63	2.64	0.07	0.038	0.406
Feed efficiency	2.77	2.76	2.78	2.78	0.04	0.824	0.915

SEM, standard error of the mean; FBR, fermented biogas residue; ADG, average daily gain; ADFI, average daily feed intake.
[1)] Data are the means of 4 replicates of 8 pigs per pen.
[2)] FBR5, the diet contained 5% FBR; FBR10, the diet contained 10% FBR; FBR15, the diet contained 15% FBR.
[a-c] Means in the same row with different superscripts differ ($p<0.05$).

performance and serum biochemical parameters

The effects of FBR on growth performance are shown in Table 2. There were no significant differences between the growth performances of the treatment groups and control groups during the early test stage. By contrast, during the late test stage, the ADG of three treatment groups was higher than that of the control groups ($p<0.05$), increasing by 16.47%, 25.88%, and 20.00% in FBR5, FBR10, and FBR15, respectively. The ADFI of the three treatment groups was linearly higher than that of the control group ($p<0.05$). However, there were no significant differences in the feed efficiency among the treatment and control groups. During the entire test (60 d), the ADG of treatment groups was higher than that of the control group ($p<0.05$), the ADFI of treatment groups was increased but with no significant difference. Table 3 shows that there were no significant effects of feeding FBR on biochemical parameters such as ALT, AST, TP, and BUN.

Effects of fermented biogas residue on pork quality

Feeding FBR had no significant effects on pork pH_{1h} (pH of meat after slaughter 1 hour), L*, a*, b*, drip loss, cooking loss, shearing force, intramuscular fat (Table 4), and content of fatty acid (Table 5), but affects the content of amino acids (Table 6). The contents of Asp, Arg, Tyr, Phe, Leu, Thr, Ser, Lys, Pro, Ala, essential amino acids, non-essential amino acids, and total amino acids in pork of FBR5 and FBR10 were quadraticly greater than those of the control group ($p<0.05$). The levels of Glu, Met in FBR10 were greater than that of the control group ($p<0.05$).

DISCUSSION

Effects of fermented biogas residue on growth performance of pigs

The main component of FBR is the protein that remains after the wheat is used to produce alcohol. This protein consists primarily of gliadin and glutenin, which are rich in glutamic acid and proline and are beneficial for the intestinal health of animals [11]. Previous studies have shown that fermentation of feed ingredients can increase the digestibility of amino acids [7,8], improve intestinal digestion capacity [12], promote daily gain, and increase feed intake [13,14]. Previous research showed that wheat protein can promote the growth of weaning piglets, is better than plasma protein and glutamine for improving piglet immunity, and can increase the daily gain and improve the feed efficiency in weaning piglets [15]. Feeding livestock with fermented protein feed rather than common protein feed can significantly improve the growth performance and nutrient digestibility [16].

Table 3. Effects of fermented biogas residue on serum biochemical parameters in pigs[1)]

Items	Control group	FBR5[2)]	FBR10	FBR15	SEM	p-value	
						Linear	Quadratic
ALT (U/L)	53.50	47.63	43.25	50.75	2.20	0.356	0.034
AST (U/L)	41.63	35.00	34.63	41.63	1.92	0.092	0.480
TP (g/L)	74.41	70.51	72.85	73.90	1.92	0.963	0.524
BUN (mmol/L)	6.26	6.33	6.84	7.17	0.22	0.114	0.764

SEM, standard error of the mean; FBR, fermented biogas residue; ALT, alanine aminotransferase; AST, aspartate transaminase; TP, total protein; BUN, blood urea nitrogen.
1) Data are the means of 8 replicates of 2 pigs per pen.
2) FBR5, the diet contained 5% FBR; FBR10, the diet contained 10% FBR; FBR15, the diet contained 15% FBR.

Table 4. Effects of fermented biogas residue on meat quality in pigs[1)]

Items	Control group	FBR5[2)]	FBR10	FBR15	SEM	p-value	
						Linear	Quadratic
pH_{1h}	6.62	6.69	6.65	6.64	0.04	0.942	0.589
L*	43.03	42.66	43.01	41.41	0.38	0.153	0.379
a*	8.72	8.53	7.18	8.02	0.35	0.156	0.335
b*	8.72	8.39	9.72	8.69	0.30	0.642	0.560
Drip loss (%)	2.22	2.11	2.19	2.16	0.03	0.666	0.413
Cooking loss (%)	34.73	37.76	36.11	36.26	0.62	0.527	0.174
Shear force (N)	33.79	32.98	29.55	32.85	1.22	0.456	0.161
Hardness (kg)	1.84	1.67	1.74	1.80	0.06	0.605	0.104
Elasticity (mm)	0.57	0.48	0.53	0.50	0.02	0.918	0.305
Cohesion	0.44	0.45	0.47	0.45	0.01	0.212	0.312
Resilience (N)	0.17	0.18	0.18	0.17	0.01	0.373	0.365
Intramuscular fat (%)	6.92	5.78	5.57	6.5	0.33	0.869	0.713

SEM, standard error of the mean; FBR, fermented biogas residue; pH_{1h}, meat pH after slaughter 1 hour; L*, lightness; a*, redness; b*, yellowness.
1) Data are the means of 8 replicates of 2 pigs per pen.
2) FBR5, the diet contained 5% FBR; FBR10, the diet contained 10% FBR; FBR15, the diet contained 15% FBR.

Table 5. Effects of fermented biogas residue on fatty acids in pork[1),2)]

Items (%)	Control group	FBR5[3)]	FBR10	FBR15	SEM	p-value	
						Linear	Quadratic
C20:3	4.96	4.97	4.53	4.60	0.11	0.057	0.883
C20:4	1.94	2.06	1.93	1.81	0.06	0.297	0.288
C20:1	0.50	0.51	0.51	0.50	0.01	0.837	0.679
C17:1	0.69	0.56	0.55	0.62	0.03	0.272	0.015
C18:2	3.84	3.92	3.50	4.05	0.12	0.855	0.332
C18:1	36.03	34.27	35.27	33.83	0.53	0.246	0.880
C16:1	3.48	3.62	3.06	3.49	0.12	0.526	0.427
C18:0	18.18	18.89	17.61	17.32	0.35	0.071	0.286
C20:5	0.17	0.14	0.15	0.13	0.01	0.072	0.720
C14:0	1.02	0.95	0.89	0.90	0.03	0.116	0.510
C16:0	28.56	29.46	31.48	32.25	0.86	0.020	0.958
C17:0	0.64	0.66	0.54	0.52	0.04	0.019	0.675
SFA	48.40	49.96	50.51	50.98	0.57	0.114	0.637
UFA	51.60	50.04	49.49	49.02	0.57	0.114	0.637
MUFA	40.70	38.95	39.38	38.44	0.55	0.211	0.722
PUFA	10.91	11.09	10.11	10.58	0.21	0.218	0.679

SEM, standard error of the mean; FBR, fermented biogas residue; SFA, saturated fatty acid; UFA, unsaturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, poly unsaturated fatty acid.
[1)] Data are the means of 8 replicates of 2 pigs per pen.
[2)] The fatty acid concentrations were expressed as percentages of the total identified fatty acids.
[3)] FBR5, the diet contained 5% FBR; FBR10, the diet contained 10% FBR; FBR15, the diet contained 15% FBR.

In the current study, supplement of FBR increased the ADFI in the late stage. It was reported that fermentation could produce the flavor of the product and promote palatability [17]. In the late test stage, the ADG of every treatment group fed with FBR was higher than that of the control group. This may result from the increase of ADFI of the treatment group, because there were

Table 6. Effects of fermented biogas residue on inosinic acid and amino acids in pork (dry matter mass)[1)]

Items (%)	Control group	FBR5[2)]	FBR10	FBR15	SEM	p-value	
						Linear	Quadratic
Inosinic acid (mg/g)	6.21	6.26	6.24	6.41	0.01	0.693	0.724
Asp	8.23[a]	8.52[bc]	8.63[b]	8.30[ac]	0.09	0.455	0.003
Glu	14.23[a]	14.82[ab]	15.07[b]	14.53[ab]	0.18	0.183	0.006
Ser	3.43[a]	3.60[bc]	3.67[b]	3.50[ac]	0.05	0.220	0.001
His	3.89	4.09	4.12	3.96	0.06	0.432	0.017
Gly	3.81	4.00	3.94	3.79	0.05	0.649	0.013
Thr	4.11[a]	4.29[bc]	4.35[b]	4.17[ac]	0.06	0.259	0.001
Arg	5.67[a]	5.91[b]	5.96[b]	5.74[ab]	0.07	0.523	0.006
Ala	5.23[a]	5.47[b]	5.50[b]	5.31[ab]	0.07	0.315	0.013
Tyr	2.98[a]	3.10[bc]	3.14[b]	3.02[ac]	0.04	0.435	0.003
Cys	1.05	1.10	1.16	1.07	0.02	0.224	0.023
Val	4.35	4.49	4.56	4.41	0.05	0.288	0.015
Met	2.34[a]	2.42[ab]	2.45[b]	2.36[a]	0.03	0.479	0.005
Phe	3.72[a]	3.88[b]	3.96[b]	3.83[ab]	0.05	0.076	0.009
Ile	4.37	4.52	4.57	4.44	0.05	0.250	0.013
Leu	7.85[a]	8.18[bc]	8.29[b]	7.99[ac]	0.10	0.273	0.003
Lys	7.81[a]	8.17[bc]	8.29[b]	7.88[ac]	0.12	0.507	0.001
Pro	3.25[a]	3.43[b]	3.39[b]	3.25[a]	0.05	0.833	0.003
Try	0.44	0.45	0.46	0.46	0.01	0.250	0.910
EAA	34.98[a]	36.40[bc]	36.93[b]	35.53[ac]	0.44	0.265	0.003
NEAA	51.75[a]	54.04[bc]	54.57[b]	52.468[ac]	0.66	0.369	0.002
Total amino acids	86.73[a]	90.43[bc]	91.50[b]	88.00[ac]	1.09	0.319	0.002

SEM, standard error of the mean; FBR, fermented biogas residue; EAA, essential amino acids; NEAA, nonessential amino acids.
[1)] Data are the means of 8 replicates of 2 pigs per pen.
[2)] FBR5, the diet contained 5% FBR; FBR10, the diet contained 10% FBR; FBR15, the diet contained 15% FBR.
[a-c] Means in the same row with different superscripts differ ($p < 0.05$).

no significant differences in the feed efficiency between the treatment group and control group. Further research is needed to test the effects of higher percentages of FBR on the growth performance of pigs.

Effects of fermented biogas residue on serum biochemical parameters of pigs

Serum biochemical parameters reflect comprehensive functions of body organs and nutritional metabolism [18]. The ALT and AST activities in serum are important indices that reflect the functions of liver and heart [19]. The ALT primarily exists in liver cytosol; however, alanine amino transferase content in blood increases when the liver cell membrane is damaged [20]. The AST primarily exists in heart muscle and liver mitochondria, and AST content in blood significantly increases when the liver mitochondrial membrane is damaged [21]. Our results showed that there were no significant effects of feeding FBR on ALT and AST, which indicates that the tested levels of FBR do not significantly affect transamination reactions and liver function. The TP content primarily reflects the relationship between protein absorption *in vivo* and humoral immunity [22]. The BUN content reflects protein metabolism and renal function [23]. When the amino acid profiles are well balanced, the BUN content decrease [23]. There were no significant differences in serum TP and BUN contents among the control and treatment groups in our study, which indicates that the addition of ≤15% FBR did not significantly affect protein metabolism in pigs.

Effects of fermented biogas residue on pork quality

The pH value, meat color, tenderness, drip loss, and cooking loss of pork are commonly used indices for evaluating meat quality, eating quality, and palatability of pork [24]. After the pig is slaughtered, lactic acid is produced by muscle glycolysis, which reduces pH. The meat pH value measured within 45 to 60 min after the pig was slaughtered is an important index for evaluating the meat quality. If the pH decreases too rapidly, it can cause meat whitening, dehydration, and protein denaturation, and reduce nutritional value [25,26]. The intramuscular fat content is also an important index for evaluating meat quality, and is important for tenderness, succulence, and flavor [27,28].

The amino acid profile in pork is important to evaluate quality. For example, Ala, Gly, Glu, Asp, and Ser may affect the delicate flavor of pork [29]. These are precursor amino acids required for generating the delicate flavor of meat, especially Glu, which is the primary flavor molecule and functions in meat freshness and buffering salty and sour tastes [27]. In the current study, feed FBR can increase the content of Asp, Arg, Tyr, Phe, Leu, Thr, Ser, Lys, Pro, Ala, essential amino acids, non-essential amino acids, and total amino acids in meat. This may be due to the fact that utilization efficiency of amino acid in FBR was higher than that in soybean [2].These results indicate that the flavor of pork could be improved by the addition of 5% to 10% FBR to the diet, which results from an increase in the content of several flavor-promoting amino acids [29]. Further research is needed to test the effects of dietary FBR on flavor of pork.

CONCLUSION

This study has shown that the FBRs can be used as raw materials for feeding growing and finishing pigs, and the addition of ≤15% FBR to diet of growing-finishing pigs can increase the feed intake, weight gain, and concentration of essential amino acids, flavor-promoting amino acids in the pork, but has no significant effects on serum biochemical indices.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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