Effects of Replacing Corn with Brown Rice or Brown Rice with Enzyme on Growth Performance and Nutrient Digestibility in Growing Pigs**

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ABSTRACT : A 4 week experiment was designed to study the effects of replacing corn with Chinese brown rice or adding different amylase in brown rice basal diet on growth performance and apparent fecal digestibilities of nutrients in growing pigs. One hundred and eight cross-bred pigs (Duroc×Landrace×Large White), weighing an average of 18.35±0.12 kg, were randomly assigned to 6 treatments with 6 replications per treatment. Diet in treatment 1 was corn-soybean meal basal diet, and in treatment 2, 3 and 4, corn was replaced by brown rice on rates of 33.3%, 66.7% and 100% respectively on the basis of treatment 1. And diets in treatment 5 and 6 were similar to treatment 4 except two kinds of amylases, glucoamylase and α-amylase, were added respectively. The brown rice used in this experiment was husked from one kind of early, long grain, non-glutinous rice (ELGNR, *indica* rice) in southern China. The results indicated that there was a slight improvement in growth performance of pigs in brown rice treatments ($p>0.05$). The blood urea nitrogen value in treatment 2 was lower than that in treatment 1 ($p<0.05$). The differences of apparent fecal digestibilities of most nutrients were significant ($p<0.05$) except CP. Digestibilities of GE, OM and DM in treatment 4 were the best and digestibility of crude fat in treatment 5 appeared best ($p<0.05$). Contrast results between treatment 1 and treatment 2 to 4 indicated that the digestibility of GE, OM and DM increased significantly with the replacing rates of brown rice ($p<0.05$). Contrast results between treatment 4 and 5 indicated that adding glucoamylase in brown rice diet increased growth performance slightly ($p>0.05$) but not for digestibilities. This experiment shows a positive effect of brown rice on growth performance, especially on nutrient digestibility. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 9 : 1334-1340)***

Key Words : Brown Rice, Corn, Amylase, Growing Pigs, Growth Performance, Digestibility

INTRODUCTION

As a feedstuff, corn is widely used in animal feed in many countries. But rice is mainly used as a foodstuff in many areas; only some of rice byproducts are used as feedstuff (Farrell and Hutton, 1990). Rice was the primary cultivated category because of the humid climate in southern China, where it is unsuitable for planting corn. If rice could replace corn as feedstuff in that region, many advantages might be brought for feed industry and animal production. Early, long grain, non-glutinous rice (ELGNR, *indica* rice) has been planted in southern China for a long time. Farmers there still cultivate it for its good adaptability and considerable yield. And the interest of using ELGNR as a feedstuff has increased in recent years.

Although the palatability of rice from ELGNR is not very good as food, the nutrition value of brown rice from ELGNR is considerable as a feedstuff for a relatively higher level of crude protein content (Tang et al., 1992; He et al., 2000). Tang et al. (1992) pointed out that the available energy of paddy rice had a strongly negative correlation to its crude fiber content. Wu et al. (1986) reported that the average daily gain (ADG) and feed conversion ratio (FCR) was parallel after feeding polished rice to growing pigs. Generally, it is uneconomical to use polished rice in animal diets not only because of the higher extra processing cost but also plenty of nutrients, such as vitamins and fat acids, were missed after it was polished (He et al., 2000). Brown rice is different from polished rice in that most of the endosperm and a layer of bran are left while paddy hull is husked. It has been documented that the performance of growing-finishing pigs were not affected when brown rice (ELGNR) was used as a feedstuff compared with corn (Gao et al., 1993; He et al., 2000). Piao et al. (2002) found that digestibility of nutrients in brown rice ration was better than that in corn ration by fecal digesting trial. The growth performance and the apparent fecal digestibility were not negative affected when 50% of corn was replaced by brown rice in weanling pig diets (Li et al., 2002).

It is well known that secretion of both amylopsin and ptyalin are insufficient for young pigs, but not for growing pigs (Li, 1996). The content of starch in brown rice is more than 80 percent (Farrell, 1994), obviously higher than that in corn. The present question is whether the endogenous amylase of growing pigs is sufficient to digest starch-rich cereal. It was reported that using a multi-enzyme product, with amylase in it, in a mixed grain diets improved growth

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performance in piglets (Partridge et al., 1998). Nevertheless, little reports have been seen on the effects of adding a single amylase to rice basal diet. Hypothesis is that it should be feasible to replace corn with brown rice and further advantage might appear when amylase is added in brown rice diet for growing pigs The objective of this experiment was to study the effects and estimate the feasibility of replacing corn with Chinese brown rice in traditional corn-soybean meal diet in growing pigs, as well as observe the effects of different amylases on brown rice diet.

MATERIALS AND METHODS

Animals and diets

One hundred and eight cross-bred growing pigs (Duroc×Landrace×Large White), weighing an average of 18.35±0.12 kg, were randomly assigned on the basis of sex and weight to 6 treatments with 6 replications per treatment during a 4 week experiment. There were 3 pigs per pen as a replication with mixed six. The animals were housed in 2.5×4 m^2 cement floored pens, which were located in an environmentally controlled building with temperature maintained at 15-21°C. The pigs were offered diets *ad libitum* and had free access to drinking water.

Since the nutrient composition of rice is similar to that of corn (Table 1), the main difference between treatments consisted in corn and brown rice ratio. Diet in treatment 1 was corn-soybean meal basal diet, and in treatment 2, 3 and 4, corn was replaced by brown rice on rates of 33.3%, 66.7% and 100% respectively on basis of treatment 1. And diets in treatment 5 and 6 were similar to treatment 4 except two kinds of amylases, glucoamylase and α-amylase, were mixed thoroughly in either diets respectively at 0.1% level. The glucoamylase and α-amylase were fermented from *Aspergillus niger* and *Bacillus subtills* respectively, and were produced in Wuxi Enzyme Factory, Jiangsu province. The brown rice was husked from an ELGNR, named Jinyouzhe-3. The composition of brown rice and corn are shown in Table 1. Diets were formulated according to NRC (1998) (Table 2). Chromic oxide (Cr_2O_3), at a level of 0.2%, was used as indicator to measure the apparent fecal digestibility of nutrients. All diets were fed as mash form.

Procedures

At day 21, Cr_2O_3 was added to the diets and feces were collected from day 25 to day 28. Immediately after collection, the feces samples were dried at 65°C in an oven and then coarsely milled. The milled feces from each pen in 4 days were pooled together into one sample and stored at -20°C for chemical analysis.

Body weights (BW) and feed intakes were recorded from each pen to determine growth performance both at the beginning and end of the experiment. When the experiment was ended, one pig from each pen was pick out randomly before morning feeding and blood was drawn from the anterior vena cava with a 7-gauge needle and a vaccutainer tube. Blood samples were centrifuged at 3,000 rpm for 15 min. The serum was separated and stored at -20°C for analysis.

Table 1. Composition of corn and brown rice[1]

Ingredients	Corn	Brown rice
Proximate composition:		
Gross energy, MJ/kg	16.28	15.95
Dry matter, %	87.8	87.9
Total starch, %	59.6	72.4
Amylose of total starch, %	17.2	22.8
Crude protein, %	8.35	8.59
Crude ash, %	1.22	1.05
Crude fat, %	2.80	2.44
Calcium, %	0.02	0.03
Total phosphorus, %	0.29	0.33
Acid detergent fiber, %	2.91	1.31
Amino acids (%)		
Aspartic acid	0.54	0.77
Threonine	0.30	0.32
Serine	0.38	0.39
Glutamic acid	1.65	1.62
Glycine	0.35	0.42
Alanine	0.62	0.50
Valine	0.33	0.45
Isoleucine	0.30	0.38
Leucine	1.05	0.75
Tyrosine	0.36	0.40
Phenylalanine	0.47	0.51
Lysine	0.27	0.35
Histidine	0.28	0.13
Arginine	0.36	0.77
Proline	0.63	0.29
Methionine	0.19	0.20
Cysteine	0.18	0.17
Tryptophan	0.07	0.12
Fatty acids[2] (% of total)		
C16:0	38.89	53.17
C18:0	2.46	3.20
C18:1	15.61	21.47
C18:2	42.18	21.47
C18:3	0.86	0.68
Others	-	0.01
Minerals and trace elements		
Potassium, %	0.291	0.190
Sodium, %	0.022	0.027
Magnesium, %	0.106	0.082
Copper, mg/kg	1.39	1.71
Iron, mg/kg	41.73	18.84
Zinc, mg/kg	21.85	24.76
Manganese, mg/kg	4.26	20.31

[1] Analyzed value, and as-fed basis.
[2] C16:0, Palmitic acid; C18:0, Stearic acid; C18:1, Oleic acid; C18:2, Linoleic acid; C18:3, Linolenic acid.

Table 2. Ingredients and chemical composition (% of air dried) of the experiment diets

Ingredients	C100[1]	C67:R33[1]	C33:R67[1]	R100[1]	R100[1]	
					Glucoamylase	α-amylase
Corn	52.26	34.84	17.42	0	0	0
Brown rice	0	17.42	34.84	52.26	52.26	52.26
Wheat flour middling	22.0	22.0	22.0	22.0	21.9	21.9
Soybean meal	18.0	18.0	18.0	18.0	18.0	18.0
Cotton meal	2.0	2.0	2.0	2.0	2.0	2.0
Rapeseed meal	2.0	2.0	2.0	2.0	2.0	2.0
Dicalcium phosphorus	1.08	1.08	1.08	1.08	1.08	1.08
Limestone	1.16	1.16	1.16	1.16	1.16	1.16
Salt	0.40	0.40	0.40	0.40	0.40	0.40
Mycosis inhibitor	0.1	0.1	0.1	0.1	0.1	0.1
Premix[2]	1.0	1.0	1.0	1.0	1.0	1.0
Enzyme	-	-	-	-	0.1	0.1
Total	100	100	100	100	100	100
Chemical composition[3]						
Digestible Energy, MJ/kg	13.19	13.20	13.21	13.22	13.22	13.22
Crude protein, %	16.98	17.06	17.12	17.21	17.21	17.22
Calcium, %	0.91	0.90	0.90	0.91	0.90	0.91
Total phosphorus, %	0.57	0.58	0.59	0.60	0.61	0.60
Lysine, %	0.85	0.86	0.88	0.89	0.89	0.89
Methionine+Cysteine, %	0.58	0.58	0.58	0.58	0.58	0.58
Threonine, %	0.62	0.62	0.63	0.63	0.63	0.63

[1] C100: treatment 1, corn-soybean meal basal diet, no brown rice; C67:R33: corn to brown rice is 67:33, namely treatment 2; C33:R67: corn to brown rice is 33:67, namely treatment 3; R100: treatment 4, no corn. Followed by treatment 5 and 6 with glucoamylase and α-amylase, respectively.

[2] Premix provided the following, per kg complete diet: vitamin A, 5512 IU; vitamin D_3, 551 IU; vitamin E, 66.1 IU; vitamin K, 2.2 mg; vitamin B12, 27.6μg; riboflavin, 5.5 mg; D-pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline chloride, 551 mg; Cu, 250 mg; Mn, 100 mg; Zn, 100 mg; Fe, 100 mg; I, 0.3 mg; Co, 1mg; Se, 0.3 mg.

[3] Crude protein, calcium, total phosphorus are determined value, others are calculated. As-fed basis.

Chemical analysis of feedstuff, diets and feces

Brown rice and corn compositions were determined before the experiment was carried out. Diet samples were collected right after formulation. Both diet and feces samples were finely ground before analysis.

Proximate analysis of feedstuff, diets and excreta was conducted according to the methods of AOAC (1990). Amino acid composition was measured according to methods of GB/T18246-2000 (2000) using an automatic amino acid analyzer (Hitachi L-8800, Japan) with ninhydrin reaction of post column derivatization, a visible light detector and Ion-exchange resin column. Fifteen of amino acids were determined after 24 hours of acid hydrolysis at 110°C in 6 mol/L HCl. Methionine and cystine were determined from 24 h acid hydrolysates following formic acid oxidation of the samples. Tryptophan was determined following lithium hydroxide hydrolysis (24 h at 110°C). The fatty acid compositions were measured through rapid method applied by Sukhija and Palmquist (1988) with one-step extraction-transesterification procedure, using gas chromatography (HP 6890, Hewlett-Packard Co., USA). Crude protein was analyzed using the Kjeldahl method (Tecator, Kjeltac system 1002), and gross energy was measured by bomb calorimeter (Parr Instrument Co., Model 1281, USA). Calcium was determined by method of titration with 0.1 mol/L EDTA. Total phosphorus was determined colorimetrically using a molybodovanadate reagent with a UV-visible spectrophotometer (Model 752C, Shanghai, China). ADF was determined with Fibertec system 1010 heat Extract (Foss Co.). Chromium, other minerals and elements were determined on Polarized Zeeman Atomic Absorption Spectrometry (Hitachi Z5000, Japan). Starch and amylose contents were determined according to the methods in AACC (2000).

Determination of serum constituents

Blood urea nitrogen (BUN), blood glucose and alkaline phosphatase (ALP) were measured using a Technicon RA-1000 auto analyzer (Germany), with commercially available kits supplied by the Zhongsheng High-Tech Bioengineering Company (Beijing, China).

Statistical methods

The data obtained from the study were analyzed by analysis of variance, in a one-way classification using the General Linear Model procedure of SAS (1985) package program. Means were compared using the Duncan's (1955) multiple rang test option when the differences among treatments were significant.

RESULTS AND DISCUSSION

Growth performance

It can be seen from Table 3 that after replacing 33.3%

Table 3. Effects of brown rice on growth performance of growing pigs

Treatment	Initial BW, kg	Finial BW, kg	ADG, kg	ADFI, kg	FCR
1	18.35	30.63	0.44	1.24	2.83
2	18.36	32.01	0.49	1.31	2.68
3	18.34	31.72	0.48	1.30	2.73
4	18.31	31.46	0.47	1.26	2.69
5	18.36	32.29	0.50	1.32	2.65
6	18.37	31.63	0.47	1.29	2.72
PSE [1]	0.124	0.321	0.010	0.011	0.044
P Value	1.00	0.55	0.66	0.30	0.91
			Contrast		
1 vs 2 to 4	0.9780	0.1112	0.1755	0.0964	0.3855
1 vs 4	0.9404	0.2821	0.3873	0.5245	0.4672
4 vs 5	0.9149	0.4668	0.4297	0.1623	0.8211
4 vs 6	0.9008	0.8810	0.9129	0.5185	0.9836

[1] Pooled standard error.

corn with brown rice, the ADG and ADFI of pigs appeared best among treatment 1 to 4 (p>0.05). The ADG and ADFI of pigs in treatment 4 were lower than that of partially replaced treatments, namely treatment 2 and 3, but FCR in treatment 4 is similar to that in treatment 2. And all growth performances in treatment 2, 3 and 4 were higher than that in treatment 1 (p>0.05). Adding glucoamylase in treatment 5 enhancing growth performance slightly (p>0.05), which was best in all 6 treatments. FCR value in treatment 1 was higher than any other treatments (p>0.05).

Contrast results between treatment 1 and treatment 2 to 4 indicated that partially replacing corn with brown rice slightly increased ADG and ADFI in growing pigs (p>0.05). It was said that the palatability of *indica* brown rice was not very good as foodstuff for human beings compared to that of corn, which mentioned by Xiang et al. (1990). Up to now some farmers always take on granted that *indica* rice is not palatable for livestock, and hesitate to use it in swine diets. But we may argue that the palatability of brown rice should not be an adverse factor in growing pigs because there were not negative effects at all on growth performance when using brown rice in growing pig diets.

This experiment demonstrated that some improvement in growth performance was found after replacing corn with brown rice in this experiment. Different level of brown rice used in growing pigs has been studied. Gao et al. (1993) reported that the growth performance in pigs fed brown rice diets was significantly higher than the control, and the completely replacing took on slightly better result in performance than partially replacing. He et al. (2000) found that there was no significant difference in ADG and FCR when replacing corn with brown rice and a slightly better FCR was found when corn was totally replaced. The result of our experiment did not accord with these two reports since partial replacing with brown rice took on better results in growth performance here.

Li et al. (2002) found that partially replacing corn with Chinese brown rice enhanced growth performance of weanling piglets without any negative effects, which sponsored the result of our experiment. He et al. (2000) reported that the balance of amino acids in brown rice were better than in corn. After analyzing 18 samples, he concluded that lysine, threonine and isoleucine were the first three limited essential amino acids in brown rice for non-ruminant animals. As for the balance of branch-chain amino acids, especially isoleucine and leucine, it is better in brown rice than that in corn by comparison (Table 1), which was in agreement with He et al. (1994). These above might contribute to the fact that better performance was found in brown rice treatments.

Serum constituents

Blood urea nitrogen (BUN) of pigs in treatment 2 was the lowest among all treatment and it is lower than treatment 1 significantly by multiple range text (p<0.05) (Table 4). Blood glucose (BGLU) was the lowest in treatment 1 and it was the highest in treatment 5, but the difference was insignificant among all the 6 treatments. The alkaline phosphatase (ALP) value in treatment 1 was lower than that in treatment 2, 3 and 4 (p>0.05) and the ALP values in treatment 5 and 6 were higher than that in treatment 4 (p>0.05), but these differences were insignificant.

BUN concentration has been suggested to be a useful response criterion to determine amino acid requirements (Brown and Cline, 1974) in that there is an inverse relationship between blood urea nitrogen and dietary amino acid balance It was shown in this experiment that replacing 33.3% corn with brown rice brought about a decrease in BUN. This revealed that there might be concurrently compensatory relationship between digestible essential amino acids of corn and brown rice.

The BGLU concentration in pigs of brown rice treatment was higher than that of treatment 1 more or less, which might mean that more energy was absorbed into the vein to maintain higher level of performance. But this result

Table 4. Effects of brown rice on serum constituents of growing pigs

Treatment	BUN[1], mg/dl	BGLU[1], mg/dl	ALP[1], μ/L
1	13.3[ab]	107	178
2	8.0[c]	122	214
3	9.7[bc]	109	215
4	11.0[abc]	127	209
5	10.3[abc]	137	222
6	13.7[a]	129	237
PSE[2]	0.58	4.26	6.68
P Value	0.02	0.19	0.13
		Contrast	
1 vs 2 to 4	0.0130	0.2426	0.0517
1 vs 4	0.1932	0.1403	0.1571
4 vs 5	0.7064	0.4670	0.7969
4 vs 6	0.1328	0.7315	0.1244

[1] BUN: Blood urea nitrogen; BGLU: Serum glucose; ALP: Alkaline phosphatase.
[2] Pooled standard error.
[a,b,c] Values within columns with no common superscripts differ significantly (p<0.05).

was opposite to the trial of Li et al. (2002), who found that the newly weaned pigs in brown rice treatments had a slightly lower lever of BGLU. The difference might due to that growing pig digests brown rice more effectively than piglet does, which need be further researched.

In addition to liver, bile duct, or gallbladder dysfunction, an elevated serum ALP may be due to rapid growth of bone since bone-forming cells called osteoblasts produce it. So the activity of ALP increases when bones grow fast for healthy animals. But it has been reported that the level of serum ALP was lowest when phosphorus supplied at proper rate in the diets (Jiang et al., 1999). The ALP in treatment 1 was the lowest, which might indicate that the supply of phosphorus just met the requirement of pigs in that condition. Growth performance was found better in the brown rice treatments with higher level of ALP values. The reason to this result need be further studied.

Digestibility of nutrients

The digestibilities of GE, OM and DM appeared exactly similar among all of the treatments, replacing 100% corn with brown rice made highest value and the lowest one was treatment 1 (Table 5). The differences of each criterion mentioned above among treatments were extra significant ($p<0.01$). The digestibility of crude fat (CFat) in glucoamylase treatment was the highest.

There was little difference on the digestibility of CP among treatments ($p>0.05$). The digestibility of phosphorus (P) in treatment 6 was significantly lower than those in others except treatment 3 by multiple range text ($p<0.01$). And also the digestibility of ash in treatment 6 turned out a lower level than those of the other treatments significantly ($p<0.01$).

Contrast results between treatment 1 and treatment 2 to 4 indicated that the digestibility of GE, OM and DM increased linearly with the replacing rates of brown rice and the difference was highly significant ($p<0.01$). For CP, CFat, ash and P, the highest digestibility also occurred in treatment 4, but the trend did not linearly increase with replacing rates of brown rice.

Zhang et al. (1999) reported that the apparent digestibilities of DM, OM, nitrogen-free extract (NFE), GE and the metabolic rate of crude protein were significantly higher in brown rice than that in corn in growing pigs. He et al. (1994) concluded that the apparent digestibilities of DM, Cfat, NFE were significantly higher ($p<0.01$) and most amino acids, especially lysine, threonine and isoleucine were higher in brown rice than that in corn. These two reports were comparable to the present paper.

Few researches are available on the digestibility of minerals in brown rice and no reports found on trace elements and vitamins. There was no linear trend on the digestibility of phosphorus with the replacing rate of the brown rice in the present experiment. A lower digestibility of phosphorus was found in treatment 6, and the exact

Table 5. Effects of brown rice on apparent fecal digestibilities of nutrients in growing pigs (%)

Treatment	GE[1], %	CP[1], %	CFat[1], %	Ash, %	P[1], %	OM[1], %	DM[1], %
1	78.8[e]	74.5	68.9[c]	42.7[b]	33.6[a]	81.9[e]	79.4[e]
2	80.2[d]	76.3	70.8[bc]	46.2[a]	34.8[a]	83.1[d]	80.8[d]
3	82.1[c]	75.5	65.5[d]	43.6[b]	32.6[ab]	85.2[c]	82.7[c]
4	84.0[a]	76.5	71.9[ab]	43.1[b]	34.7[a]	87.0[a]	84.4[a]
5	83.2[b]	76.2	73.9[a]	43.4[b]	32.7[a]	86.1[b]	83.5[b]
6	82.1[c]	76.7	70.5[bc]	38.4[c]	30.1[b]	85.2[c]	82.4[c]
PSE[2]	0.31	0.29	0.53	0.49	0.42	0.31	0.3
P Value	0.0001	0.241	0.0001	0.0001	0.006	0.0001	0.0001
				Contrast			
1 vs 2 to 4	0.0001	0.0492	0.6001	0.1019	0.6954	0.0001	0.0001
1 vs 4	0.0001	0.0485	0.0112	0.7856	0.3685	0.0001	0.0001
4 vs 5	0.0302	0.7598	0.0701	0.7625	0.1045	0.0130	0.0168
4 vs 6	0.0001	0.8120	0.2314	0.0002	0.0006	0.0001	0.0001

[1] GE: General energy; CP: Crude protein; Cfat: Crude fat; P: Phosphorus; OM: Organism matter; DM: Dry matter.
[2] Pooled standard error.
[a,b,c,d,e] Values within columns with no common superscripts differ significantly (p<0.05).

reason is to be further studied.

Contrast results between treatment 1 and treatment 2 to 4 indicated the highest digestibilities of GE, CP, OM and DM were in treatment 4 and the differences were significant ($p<0.05$), which were corresponded with the study of Piao et al. (2002) and Li et al. (2002) who both found that digestibilities of most nutrients were higher in high level replacing with brown rice.

Contrast results between treatment 4 and 5 indicated that adding glucoamylase in treatment 5 increased ADFI to a certain extent, and there was an improving trend on ADG and FCR. But for digestibilities the trend was opposite to that of performance above. The alterations of digestibilities in different treatments were not corresponded with that of performance in this experiment. This disagreement between performance and digestibility might due to the variance of voluntary feed intake of animals in different treatments (Table 3).

Amylase function

Starch is abundant in cereal feedstuff where it serves as primary energy source for animals. The two basic compositions of this glucose polymer are amylose and amylopectin. Glucoamylase breaks single glucose molecules off the ends of the chain, while α-amylase breaks glucose-glucose bonds at random points within the starch chain (Hu and Zhu, 1984). The α-1, 6-glucosidic bonds of amylopectin can block the hydrolytic action of α-amylase, preventing the active site of the enzymes from coming in contact with the glucose-glucose bonds thus inhibiting hydrolysis. Glucoamylase hydrolyzes the α-1,6-glucosidic bond, freeing the chain for continued hydrolysis of the α-1,4-bonds. Glucoamylase can also assure the breakdown of maltose into glucose molecules, allowing greater absorption of this energy-giving sugar. Starch digestion may be improved with the combination of both of them.

It was pointed out that both of amylopsin and ptyalin in human or in mammalian were endoenzymes, and they could only hydrolyze the α-1, 4-bonds within the starch molecule (Mei, 1990). The glucose can only be a very small part of starch hydrolysate without help of other carbohydrase (Hu and Zhu, 1984). There was more starch in brown rice than that in corn (72.4%:59.6%, as-fed basis) and also there was a higher percent unit of amylose in brown rice (22.8:17.2) (Table 1). Recently, evidences showed that starch is able to escape from being digested in small intestine and then ferment in large intestine in pigs (Bird et al., 2000; Wang, 2000). Exogenous glucoamylase in the diet of treatment 5 might have reacted on starch digestibility in small intestine of pigs, which could bring out better performance by contrast between treatment 4 and 5. At the same time, adding α-amylase in treatment 6 was ineffective, which might mean that the secretion of this kind of endoenzyme is enough in growing pigs. The exact mechanisms of amylase function would also merit further study.

IMPLICATIONS

Partially replacing corn with Chinese brown rice could enhance the performance of growing pigs without any negative effects. Since the cost of Chinese brown rice is similar to that of corn in recent years, it is feasible and an effective feeding strategy to use brown rice in the growing pig diets. Further study needs be conducted on hydrolysis mechanism of starch in swine digestive tract.

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