Effects of Replacing Corn with Chinese Brown Rice on Growth Performance and Apparent Fecal Digestibility of Nutrients in Weanling Pigs**

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ABSTRACT : This experiment was conducted to study the effects of replacing corn with Chinese brown rice on performance and apparent fecal digestibility of nutrients in weanling pigs. Seventy-two cross-bred (Duroc×Landrace×Large White) weanling pigs, weighing an average of 7.38±0.06 kg, were randomly assigned to either a corn-soybean meal diet (treatment 1), a corn-brown rice-soybean meal diet (treatment 2) and a brown rice-soybean meal diet (treatment 3). The brown rice used in this experiment was husked from one kind of early, long grain, non-glutinous rice (ELGNR, *indica* rice). The growth performance of weanling pigs in the experiment was similar during weeks 1 and 2, but feed conversion ratio (FCR) was significantly better in treatment 2 during weeks 3 and 4. During week 2, only the digestibility of organic matter in treatments 2 and 3 was significantly higher than that in treatment 1. During week 4, the digestibility of gross energy, ether extract, organic matter and dry matter in brown rice treatment, especially in treatment 3, were significantly higher than in treatment 1. At the end of the experiment, the concentration of serum urea nitrogen of pigs in treatment 2 was lower than that in treatment 1 and 3 and no difference was found in serum glucose and phosphorus. It could be concluded from this experiment that replacing 50% of corn with brown rice in the corn-soybean meal diet caused no negative effects to weanling pig performance, and apparent fecal digestibility was unaffected. It is feasible to replace corn with brown rice in weanling pig diets in southern China. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 8 : 1191-1197)***

Key Words : Brown Rice, Corn, Weanling Pig, Performance, Digestibility

INTRODUCTION

Corn is a widely used feedstuff in animal diets in many countries while rice is mainly used as a human foodstuff in many areas of the world. Some rice byproducts are used as animal feed (Farrell and Hutton, 1990). The climate in most parts of southern China is so humid that it is unsuitable for planting corn, while rice is one of the most important cultivated crops there. If rice could replace corn as animal feed in that area, advantages might accrue to the feed industry and animal production.

Early, long grain, non-glutinous rice (ELGNR, *indica* rice) has been planted in southern China for a long time (He et al., 2000). Farmers there still cultivate it for its good adaptability and considerable yield (He et al., 2000). Although the palatability of ELGNR may be not good when being used as human food (Xiang et al., 1990), the nutritional value in it is considerable (Zheng, 2000). Interest in ELGNR as a feedstuff has increased in recent years.

Wu et al. (1986) reported that feeding polished rice (white rice) to growing pigs appeared feasible in growth performance. However, it is uneconomic to use white rice as feedstuff for animals not only because of the higher extra processing cost but also because nutrients, such as vitamins and fat acids, are missing after it is polished. Brown rice is different from paddy rice in that its hull is husked with most of the endosperm and a layer of bran left. It is in the milling that brown rice is processed to white rice. Tang et al. (1992) pointed out that the available energy in paddy rice has a highly negative correlation to crude fiber content. In order to increase the digestibility of the nutrients and the palatability of paddy rice, it is effective to husk the hull first before the diet is manufactured. It has been documented that the performance of growing-finishing pigs was not affected when brown rice (ELGNR) was used as a feedstuff compared with corn (Gao et al., 1993; He et al., 2000). However, there is little research on using brown rice in new weanling pig diets.

The objective of this experiment was to study the effects of Chinese brown rice used in newly weaned piglet diet, and to observe the feasibility of using brown rice as energy feed for weanling pigs.

** The authors wish to acknowledge the financial support from Professor In K. Han, Chairman, Han's Animal Science Foundation, Seoul, Korea.

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Received October 18, 2001; Accepted March 25, 2002

MATERIALS AND METHODS

Animals and diets

Seventy-two cross-bred weanling pigs (Duroc×Landrace×Large White), weighing an average of 7.38±0.06 kg, were randomly assigned on the basis of sex and weight to one of three treatments with 6 replications (ie, pens) per treatment during a 4 week experiment. The pigs had been weaned at 28 days old and were 31 days old at the beginning of the experiment. There were 4 pigs per pen, 2 male and 2 female. The size of the pens used in the experiment was 200 cm×175 cm with steel wire floor. The experiment was conducted in early winter in Hunan, China. One wood box was available in each pen with an overhead, infrared lamp fitted. In one side of the box there was a small gate though which pigs could go in and out freely. The pens were located in an environmentally controlled barn with appropriate temperature maintained at 18-23°C. The pigs were offered diets *ad libitum* and had free access to drinking water.

The diets corresponding to treatments consisted of a corn-soybean meal diet (control, treatment 1), a corn-brown rice-soybean meal diet (treatment 2) with half of the corn in treatment 1 replaced by brown rice, and a brown rice-soybean meal diet (treatment 3). Since the nutrient composition of brown rice is similar to that of corn, the only difference between treatments was the corn and brown rice ratio; other ingredients remained unchanged.

The brown rice was husked from ELGNR, planted in Hunan province with the name Jinyouzhe-3. The nutrient composition of the brown rice and corn are shown in table 1. Diets were formulated according to the US National Research Council (NRC, 1998) (table 2). Chromic oxide (Cr_2O_3), at a level of 0.2 percent, was mixed thoroughly with more than a half of the diets 1, 2 and 3 and by this means we measured the apparent fecal digestibilities. All diets were fed as mash.

Table 1. Nutrient composition of corn and brown rice[1]

Ingredients	Corn	Brown rice
Proximate composition		
Gross energy, MJ/kg	16.284	15.950
Crude protein, %	8.35	8.59
Ether extract, %	2.80	2.44
Acid detergent fiber, %	2.91	1.31
Crude ash, %	1.22	1.05
Calcium, %	0.025	0.028
Total phosphorus, %	0.29	0.33
Moisture, %	12.2	12.1
Essential amino acids (%)		
Arginine	0.361	0.767
Histidine	0.283	0.231
Isoleucine	0.304	0.383
Leucine	1.047	0.749
Lysine	0.269	0.354
Methionine	0.187	0.200
Phenylalanine	0.467	0.507
Threonine	0.301	0.320
Tryptophan	0.070	0.120
Valine	0.333	0.450
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		
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.

Procedures

At the beginning of week 2, the Cr_2O_3 added diets were fed to all pigs in all the pens and substituted for the original diets. The multipoint collection of fresh feces was conducted from each pen at both 9:00 and 15:00 everyday for four successive days, from day 11 to day 14. Immediately after the collection, the feces samples were dried in an oven at 65°C The feces collected during this period were pooled together into one sample per pen, mixed and then coarsely milled and stored at -20°C for future analysis. A similar procedure was carried out to determine apparent fecal digestibility of nutrients from day 25 to day 28.

Body weights on day 0, 14, and 28 were recorded to determine ADG from each pen, and feed consumption was determined on day 14 and 28.

A blood sample was drawn from the anterior vena cava using a 7-guage needle and an uncoated vacutainer tube. The blood sample from a same pig in each pen was taken both at day 0 and day 28. Blood samples were centrifuged at 3,000 rpm for 15 min. The serum was separated and stored at -20°C until required for analysis.

Chemical analysis of feedstuff, diets and feces

The samples of brown rice, corn, diets and feces in the experiment were finely ground with 1 mm Wiley mill before analysis.

Proximate analyses of the composition of samples was conducted according to the methods of AOAC (1990). Amino acid composition was measured using an automatic amino acid analyzer (Hitachi L-8800, Japan). Most amino acids were determined after 24 h of acid hydrolysis in 6 N HCl. Methionine and cystine were determined using formic acid protection (9 parts of 88% formic acid plus 1 part of 30% hydrogen peroxide) before acid hydrolysis. Tryptophan was determined following lithium hydroxide (4 N LiOH) hydrolysis (20 h at 110°C) with high-performance liquid chromatography (Shimadzu LC 10, Kyoto, Japan). The fatty acid compositions of brown rice

Table 2. Ingredients of weanling pig diet and their nutrient levels[1]

Treatments	Corn and brown rice ratio		
	100:0	50:50	0:100
Ingredients (%)			
Corn	53.18	26.59	0
Brown rice	0	26.59	53.18
Wheat flour middling	8.00	8.00	8.00
Whey powder	2.50	2.50	2.50
Soybean meal	14.12	14.12	14.12
Full fat extruded soybean	13.56	13.56	13.56
Fish meal	5.00	5.00	5.00
Dicalcium phosphorus	1.17	1.17	1.17
Calcium carbonate	0.93	0.93	0.93
Salt	0.30	0.30	0.30
L-Lysine	0.12	0.12	0.12
Methionine	0.08	0.08	0.08
Threonine	0.04	0.04	0.04
Premix[2]	1.00	1.00	1.00
Chemical composition[3]			
Apparent digestible energy, MJ/kg	12.80	12.88	13.28
Crude protein, %	19.9	20.1	20.3
Calcium, %	0.91	0.89	0.90
Total phosphorus, %	0.70	0.70	0.71
Lysine, %	1.18	1.21	1.23
Methionine, %	0.42	0.43	0.44
Met+Cys, %	0.76	0.75	0.74
Threonine, %	0.83	0.82	0.81

[1] As-fed basis.
[2] Premix provided the following per kilogram of complete diet: vitamin A, 5512 IU; vitamin D_3, 2200 IU; vitamin E, 64 IU; vitamin K, 2.2 mg; riboflavin, 5.5 kg; D-pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline chloride, 551 mg; Cu, 250 kg; 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 values, apparent digestible energy are calculated values and amino acids are calculated from diets formulation.

were measured with the rapid method of 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 N 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 and other minerals and elements were determined on Polarized Zeeman Atomic Absorption Spectrometry (Hitachi Z5000, Japan).

Determination of serum constituents

Serum urea nitrogen, glucose and inorganic phosphorus were measured with the Technicon RA-1000 auto analyzer, 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 of SPSS 9.0 (1998) procedure. Means were separated using the Duncan's (1955) multiple range test option.

RESULT AND DISCUSSION

Most of proximate compositions were similar between brown rice and corn except for acid detergent fiber, which was distinctly higher in corn than that in brown rice (table 1). All the essential amino acids in brown rice were higher than that in corn, except histidine and leucine (figure 1). The percentage of long-chain unsaturated fatty acids, namely linoleic acid and linolenic acid, was about twice as high in corn as in brown rice.

Pig performance

This experiment demonstrated the effects of using Chinese brown rice in weanling pig diets. Replacing corn with brown rice from day 0 to day 14 did not affect the performance of the weanling pigs (p>0.05). From day 14 to 28, pigs in treatment 2 had the best result in ADG (p=0.07), ADFI and FCR (p<0.05) (table 3). Throughout the experimental period, the FCR of treatment 2 was

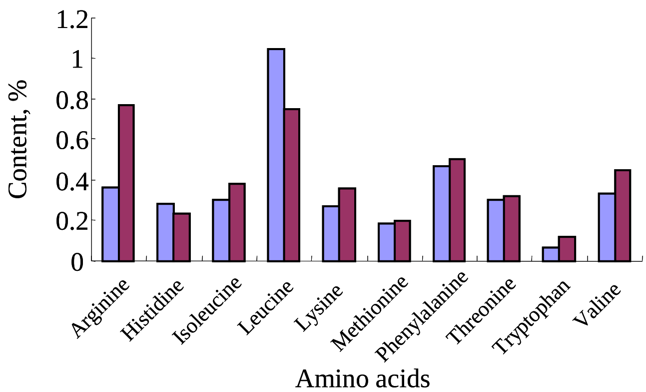

Figure 1. The essential amino acids in corn and brown rice.

Table 3. Performance of weanling pigs in different treatments[1]

Treatments	Corn and brown rice ratio			SEM[2]	P
	100:0	50:50	0:100		
	0-2 wks				
Average daily gain, kg	0.28	0.28	0.26	0.009	0.74
Average daily feed intake, kg	0.40	0.39	0.37	0.013	0.64
Feed conversion rate	1.45	1.41	1.42	0.01	0.51
	3-4 wks				
Average daily gain, kg	0.44[b]	0.53[a]	0.44[b]	0.018	0.06
Average daily feed intake, kg	0.83	0.87	0.76	0.027	0.24
Feed conversion rate	1.89[a]	1.66[b]	1.75[b]	0.03	0.005
	0-4 wks				
Average daily gain, kg	0.36	0.40	0.35	0.013	0.22
Average daily feed intake, kg	0.62	0.63	0.57	0.020	0.49
Feed conversion rate	1.72[a]	1.57[b]	1.62[b]	0.02	0.01

[1] Means within a row with different superscripts differ significantly ($p<0.05$); The initial body weight of the weanling pigs in this experiment was 7.38±0.06 kg.
[2] Standard error of mean.

significantly lower than that of treatment 1 and overall was the best result though the difference in ADG was not significant ($p>0.05$).

At the beginning of the experiment, replacing corn with brown rice slightly reduced ADFI of weanling pigs, especially when corn was totally replaced. This might be due to the relatively poorer palatability of rice compared to corn, in particular for weanling pigs, which was mentioned by He et al. (1994). This situation changed during weeks 3 and 4, when the ADFI of pigs in treatment 2 was the highest. The ADFI of pigs in treatment 3 was less than that in treatment 1, but the difference was not significant.

ADG and FCR had the best result when 50% of the corn was replaced with brown rice (treatment 2) in this 4 week experiment, particularly in weeks 3 and 4. It could be deduced that partially replacing corn with brown rice in diets may improve growth performance of weanling pigs.

Different levels of brown rice used in growing pigs have been studied. Gao et al. (1993) reported that the growth performance of pigs feed brown rice was significantly higher than that of the control treatment when brown rice either partially or completely replaced corn, and the complete replacing took on a little better result than partially replacing with though insignificant difference. 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 100% of corn was replaced ($p>0.05$). Few reports were found on newly weaned piglets; the best performance of weanling pigs in this experiment occurred when corn was partially replaced in the diets, which is different from above.

He et al. (2000) reported that the balance of amino acids in brown rice was better than that in corn. After analyzing 18 samples, he concluded that lysine, threonine and isoleucine were the first three limiting amino acids in brown rice for non-ruminant animals. We found that the balance between isoleucine and leucine is better in brown rice than that in corn (table 1), which was also mentioned by He et al. (1994). Sometimes isoleucine may play an important role in low isoleucine diets and can affect performance of weanling pigs (Zheng et al., 2001). A higher level of isoleucine might contribute to the fact that better performance was found in brown rice treatments.

Serum constituents

There was no significant difference in levels of serum urea nitrogen, glucose and phosphorus at the beginning of the experiment. At the end, the serum urea nitrogen was the lowest in pigs fed the corn-brown rice-soybean meal diet ($p<0.05$). The serum glucose concentration of pigs in treatment 2 and 3 was a bit lower than in treatment 1, but the difference was not significant ($p>0.05$). Serum phosphorus did not differ between treatments ($p>0.05$) (table 4).

The serum urea nitrogen concentration has been suggested to be a useful response criterion to determine amino acid requirements (Brown and Cline, 1974) for there was an inverse relationship between serum urea nitrogen and dietary amino acid balance It was shown in this experiment that replacing 50% corn with brown rice brought about a decrease in serum urea nitrogen, revealing that there might be a concurrently compensatory relationship between digestible essential amino acids in corn and brown rice. The serum glucose concentration of pigs in brown rice treatments was a bit lower than in treatment 1, which may mean that more energy was engrossed in achieving the higher ADG and FCR in brown rice treatments.

Table 4. Contents of serum constituents in pigs in the experiment[1]

Treatments	Corn and brown rice ratio			SEM[2]	P
	100:0	50:50	0:100		
	day 0				
Serum urea nitrogen, mg/dl	16.8	17.2	16.8	0.83	0.98
Glucose, mg/dl	120.7	119.9	118.2	3.19	0.96
Phosphorus, mg/dl	5.98	6.35	6.43	0.15	0.46
	day 28				
Serum urea nitrogen, mg/dl	20.3[a]	13.5[b]	19.2[ab]	1.3	0.05
Glucose, mg/dl	127.8	122.1	116.7	4.6	0.64
Phosphorus, mg/dl	9.23	9.03	9.27	0.24	0.92

[1] Means within a row with different superscripts differ significantly (p<0.05).

[2] Standard error of mean.

Fecal digestibility of nutrients

In week 2, the apparent digestibility of crude protein, crude ash and total phosphorus was the highest in treatment 2 (p>0.05). The apparent digestibility of organic matter was significantly higher in treatment 2 and 3 than that in treatment 1 (p<0.05) and there was also a tendency of better digestibility of gross energy, crude protein, ether extract and dry matter in brown rice treatments (p>0.05). Linear trends were found in apparent digestibility of some ingredients from treatments 1 to 3, except that of crude protein, calcium and phosphorus (table 5).

In week 4, the pigs in treatment 3 had the highest apparent digestibility of gross energy, crude protein, ether extract, organic matter and dry matter (p=0.008, p=0.10, p=0.01, p=0.001, and p=0.004 respectively), which corresponded with the study of Piao et al. (2002). The digestibility of crude protein in treatment 2 was lower than that in treatment 1, while digestibility of gross energy, organic matter and dry matter was equal. Digestibility of calcium, phosphorus and crude ash didn't differ remarkably (table 6). The energy digestibility was higher, but the

Table 5. Digestibility of nutrients in different treatments from day 11 to 14[1], %

Treatments	Corn and brown rice ratio			SEM[2]	P
	100:0	50:50	0:100		
Gross energy	76.1[b]	77.4[ab]	79.6[a]	0.64	0.07
Crude protein	66.9	69.2	68.8	0.72	0.39
Crude fat	55.5[b]	60.0[ab]	63.7[a]	1.48	0.07
Crude ash	46.8	48.1	45.5	1.45	0.78
Calcium	47.8	45.6	51.1	2.30	0.65
Total phosphorus	42.4	44.7	42.8	2.19	0.91
Organic matter	79.9[b]	81.2[ab]	83.4[a]	0.57	0.03
Dry matter	77.7[b]	79.1[ab]	81.0[a]	0.60	0.08

[1] Means within a row with different superscripts differ significantly (p<0.05).

[2] Standard error of mean.

Table 6. Digestibility of nutrients in different treatments from day 25 to 28[1], %

Treatments	Corn and brown rice ratio			SEM[2]	P
	100:0	50:50	0:100		
Gross energy	77.9[b]	78.4[b]	82.4[a]	0.72	0.008
Crude protein	72.2[ab]	70.77[b]	74.1[a]	0.65	0.10
Crude fat	53.6[b]	57.4[b]	65.4[a]	1.77	0.01
Crude ash	46.2	47.1	45.9	1.27	0.93
Calcium	55.3	51.2	52.8	2.27	0.78
Total phosphorus	41.3	43.2	42.6	2.19	0.95
Organic matter	81.2[b]	81.5[b]	85.3[a]	0.57	0.001
Dry matter	79.0[b]	79.3[b]	82.8[a]	0.58	0.004

[1] Means within a column with different superscripts differ significantly (p<0.05).

[2] Standard error of mean.

digestibility of crude protein was lower in treatment 2 than that in treatment 1. The cause may be either the higher feed intake compared to the control diet, or the slightly higher of crude protein content.

The pigs in treatment 3 had the highest apparent digestibility of gross energy both in week 2 and in week 4, which caused the actually calculated apparent digestible energy in treatment 3 to be the highest (table 2). Further research is needed to find whether it is correlated with the lowest feed intake of pigs in treatment 3 or not.

Zhang et al. (1999) studied the nutritive value of brown rice in 35 kg growing pigs. The results showed that the apparent digestibility of dry matter, organic matter, nitrogen-free extract and gross energy were significantly higher in brown rice than in corn. He et al. (1994) pointed out that diminished content of crude fiber in brown rice might be benefit to its utilization. He found that the digestibilities of lysine, threonine and isoleucine in brown rice were higher than in corn, and the apparent digestibilities of dry matter, ether extract and nitrogen-free extracts of brown rice were significantly higher than in corn, which is similar to the present results.

Little research is available on the digestibility of minerals and no reports were found on trace elements or vitamins in brown rice. There was no linear trend on the digestibility of calcium and phosphorus in this trial. A bit higher digestibility of phosphorus was found in treatment 2 both in week 2 and 4, but it was bit lower for calcium.

From week 2 to week 4, the improvement of digestibility of gross energy, crude protein, organic matter and dry matter indicated that the digestive ability in weanling pigs improved with age. The digestibility of calcium increased while digestibility of phosphorus declined slightly, but it did not differ in digestibility of crude ash. The digestibility of ether extract increased only in weanling pigs in treatment 3 which might suggest that the fatty acids in brown rice are more beneficial for growing pigs.

It should be pointed out that the apparent fecal digestibility could only reflect the true amino acids utilization in some extent but not accurately represent it. Ileal digestibility method needs to be used for further studying in the amino acids availability in brown rice.

IMPLICATIONS

Partially replacing corn with Chinese brown rice can enhance growth performance of weanling pigs without any negative effects. Since the cost of Chinese brown rice is similar to that of corn in recent years, it is feasible to use brown rice in the weanling pig diets and it would be an effective feeding strategy in practical pig production especially in southern China. Further research is needed to study the detailed mechanism in the better result of partial replacement.

ACKNOWLEDGEMENT

We appreciate Tangrenshen Group (Hunan, China) very much for their generous supports in brown rice, weanling pigs and facilities in this experiment. Thanks should be given to Ajinomoto Animal Nutrition (Tokyo, Japan) who provided the crystalline amino acids.

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