The Nutritional Value of Brown Rice and Maize for Growing Pigs

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ABSTRACT : An experiment was designed to study the nutritional value of Chinese brown rice and maize for growing pigs. Six male grower pigs (Duroc×Landrace×Large White, 24.3±1.26 kg average initial BW) were surgically fitted with a simple T-cannula at the terminal ileum and allotted within a 2×2 Latin square design. The pigs were fed either a maize or brown rice diet in a direct method to determine their digestibility. The brown rice used in this experiment was husked from one kind of early, long grain, and non-glutinous rice (ELGNR, *indica* rice: non-waxy rice, containing amylopectin and amylose) in southern China. Chromic oxide was used as a marker. The diets were supplied at about 4.0% of body weight in dry matter/d. Total faeces and urine were collected on days 4 and 5; digesta was collected on days 6-8 in each period. The average body weight was 24.3 kg at the start of the experiment and 27.6 kg at the end. The results showed that the apparent ileal digestibilities of most amino acids of brown rice were significantly higher than those in maize ($p<0.01$), as were the apparent ileal digestibilities of crude protein (CP), digestible energy (DE), organic matter (OM) and dry matter (DM) ($p<0.05$). However, the apparent ileal starch digestibilities of the two treatments were similar ($p>0.05$). The values of the apparent faecal digestibilities derived from the two methods, marker and total faecal-collection methods, were very similar and also correlated with each other. The difference in absolute value of the apparent faecal digestibilities between brown rice and maize was smaller compared to that of the apparent ileal digestibilities. The net protein utilization was higher ($p = 0.07$) and the DE metabolizable rate was significantly higher ($p<0.01$) for brown rice than for maize. The metabolizable energy (ME) of brown rice is similar to that of maize, while the DE of brown rice was relatively lower. It can be concluded that Chinese brown rice are better than maize not only in apparent ileal digestibilities, but also in metabolizable rate of amino acids and gross energy under the present study conditions. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 6 : 892-897)***

Key Words : Brown Rice, Maize, Nutrient Digestibility, Growing Pigs

INTRODUCTION

Brown rice (BR) was husked from one kind of early, long grain, non-glutinous rice (ELGNR, *indica* rice) in southern China. Brown rice has an excellent gross energy and crude protein composition compared to maize and contains 3,801 Kcal of gross energy/kg and 8.0% crude protein (Piao et al., 2002). It has been documented that the availability of digestible energy, crude protein and dry matter for growing pigs offered by a fresh brown rice ration is better than those of a maize ration (He et al., 2000; Piao et al., 2002). There were no adverse effects on growth performance or apparent faecal digestibility of nutrients in when maize was completely replaced by brown rice diets either in weanling pigs (Li et al., 2002) or in growing pigs (Zhang et al., 2002). Therefore, the price relationship between maize and BR may provide an excellent opportunity for pork producers to use BR in order to reduce feed costs (Li et al., 2004). If ELGNR could replace maize as feedstuff, advantages might be obtained for the feed industry and animal production. However, few trials have been conducted to study the apparent ileal digestibility of amino acids of brown rice in pigs.

The main purpose of this experiment was to determine and compare the apparent ileal digestibilities of amino acids in brown rice and maize in growing pigs. At the same time, the apparent digestibilities of proximate ingredients in distal ileum and faeces were determined with a marker method; and the total faeces and urine were collected to determine the apparent faecal digestibilities, along with the biological value of crude protein and metabolizable energy.

MATERIALS AND METHODS

Procedures

Eight castrated barrows (Duroc×Landrace×Large White), with an average initial body weight of 20.0±1.09 kg, were housed individually in metabolism cages. The pigs were fitted with simple T-cannula at the distal ileum, approximately 15 cm anterior to the ileo-caecal valve after a 12-d accommodation period. Cannula preparation, surgery, pro-operative and post-operative care followed the method of Li and Sauer (1994). The experiment was conducted at China Agricultural University in July. The cages were located in an environmentally controlled metabolism room with ambient temperature maintained at 23 to 27°C and the relative humidity maintained between 60 to 75% under the control of a high-power air-conditioner. The pigs had *ad libitum* access to grower diets formulated according to NRC

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

Ingredients	Maize	Brown rice
Proximate composition		
Gross energy (kcal/kg)	3,891	3,812
Crude protein (%)	8.35	8.59
Ether extract (%)	2.80	2.44
Total starch (%)	59.6	72.4
Amylose of total starch (%)	17.2	22.8
Crude fiber (%)	2.1	1.0
Acid detergent fibre (%)	2.91	1.31
Crude ash (%)	1.22	1.05
Calcium (%)	0.02	0.03
Total phosphorus (%)	0.29	0.33
Moisture (%)	12.2	12.1
Essential amino acids (%)		
Arginine	0.36	0.77
Histidine	0.28	0.23
Leucine	1.05	0.75
Isoleucine	0.30	0.38
Lysine	0.27	0.35
Methionine	0.19	0.20
Phenylalanine	0.47	0.51
Threonine	0.30	0.32
Tryptophan	0.07	0.12
Valine	0.33	0.45
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 (%)	0.29	0.19
Sodium (%)	0.02	0.03
Magnesium (%)	0.11	0.08
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] Analysd 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.

(1998) and had free access to drinking water during the recovery period.

When the experiment began, six post-operative male pigs in good condition were selected and offered two kinds of experimental diets (Table 2) according to a 2×2 repeated Latin square design. Each experimental period was 8 d. The amount fed daily to each pig was about 90% of the total amount consumed daily during the adjustment period, which was about 4.0% of the average body weight (BW). At the start of period 1 and 2, the average BW of the pigs was 24.5±1.26 kg and 25.9±1.51 kg, respectively and 27.6±2.07 kg at the end of period 2. The total daily allowance was offered as two meals of equal amounts at 0800 and 1700, respectively. Water was mixed with each meal to produce a moist mash. Additional water was provided *ad libitum* in feed troughs after each feeding. All pigs usually consumed their own meal allowance within an hour though the maize diet was eaten up a bit slowly at the end of each experimental period.

Table 2. Ingredients of the experimental diets[1]

Item (%)	Diet 1	Diet 2
Maize	96.6	-
Brown rice (BR)	-	96.6
Limestone	1.0	1.0
Dicalcium phosphate	0.8	0.8
Salt	0.35	0.35
Vit. min. premix[2]	1.0	1.0
Chromic oxide	0.25	0.25
Total	100.0	100.0

[1] As-fed basis.
[2] Premix provided the following, per kg complete diet: vitamin A, 5,512 IU; vitamin D_3, 551 IU; vitamin E, 66.1 IU; vitamin K, 2.2 mg; vitamin B_{12}, 27.6 μg; 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.

The brown rice was husked from an ELGNR, named Jinyouzhe-3. The composition of brown rice and maize is shown in Table 1. Since the nutrient composition of brown rice is similar to that of maize, the experimental diet consisted of either brown rice or maize alone. The particle size of brown rice or maize alone was similar. Minerals, vitamins and trace elements were supplemented according to NRC (1998) requirement, with no added amino acids (Table 2). Chromic oxide was used as a marker at a level of 0.25% of the diet to determine digestibility. The diets were fed in mash form.

Total faeces were collected from day 4 of each experimental period and continued for 48 consecutive hours, and total volume of urine from each experimental pig was collected at the same time into a barrel containing 10% H_2SO_4 solution. Digesta were collected from 0800 to 2000 every 12 h on day 6, 7 and 8. The procedures for collection of faeces and digesta were according to Li and Sauer (1994). Immediately after collection, faeces samples were dried at 65°C in an oven and then coarsely milled. The collected digesta from each day were firstly frozen at -20°C, then pooled and freeze-dried. The urine samples were stored at -20°C before chemical analysis. Each kind of sample from each pig during either period was pooled to give one sample.

The determination of the apparent ileal digestibility of amino acids and the apparent digestibilities of proximate ingredients at the distal ileum and faeces were determined with the marker method. Total faeces and urine were collected to determine the apparent faecal digestibilities, along with biological value of crude protein and the metabolizable energy.

This experiment was conducted under protocols approved by the China Agricultural University Animal Care and Use Committee.

Table 3. Apparent ileal digestibilities of approximate ingredients and amino acids

Item (%)	Maize	Brown rice	SEM[1]	p value
Gross energy	75.3	82.2	1.31	0.001
Crude protein	60.8	72.5	3.65	0.011
Dry matter	75.7	80.9	1.65	0.003
Organic matter	78.1	84.4	1.21	0.001
True starch	97.7	96.6	0.77	0.22
Apparent starch	94.4	95.0	1.36	0.68
Essential amino acids				
Threonine	53.1	72.3	3.17	0.000
Valine	50.5	70.7	3.14	0.000
Isoleucine	66.3	80.3	2.13	0.000
Leucine	76.1	82.5	1.87	0.007
Phenylalanine	76.2	86.2	1.60	0.000
Lysine	63.2	82.3	2.28	0.000
Histidine	74.3	87.5	2.27	0.001
Arginine	73.1	84.8	2.29	0.001
Methionine	81.0	87.5	2.01	0.030
Tryptophan	61.9	77.5	2.01	0.000
Nonessential amino acids				
Aspartic acid	66.1	80.4	1.99	0.000
Serine	63.8	77.3	2.26	0.000
Glutamic acid	72.7	81.1	2.05	0.003
Glycine	32.8	57.5	7.44	0.020
Alanine	69.0	78.6	2.72	0.006
Tyrosine	74.0	85.1	1.26	0.000
Proline	62.2	56.9	9.64	0.600
Cysteine	47.9	64.2	4.88	0.02
Total AA	66.2	76.1	3.31	0.015

[1] Standard error of mean (n = 6).

Chemical analysis of diets and faeces

The chemical composition of brown rice and maize was determined before the experiment. Diet samples were collected immediately after formulation. All samples of diets, digesta and faeces were finely ground through a 1.00-mm mesh screen for analysis. 2 ml urine freshly thawed from freezing at -20°C was absorbed onto a pre-weighted filter paper pellet previously standardized for calorific purposes. The pellet containing the urine sample was then naturally dried overnight in a fume-cupboard prior to combustion and gross energy of the sample was determined by subtraction.

Proximate analysis of the samples was made according to the methods of AOAC (1990). Amino acid profiles were measured using an automatic amino acid analyser (Hitachi L-8800, Japan). Most amino acids were determined after 24 h of acid hydrolysis at 110°C in 6 N HCl. Methionine and cystine were determined from 24-h acid hydrolysates following formic acid oxidation of the samples. 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 composition was measured by a 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 analysed 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 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 the Fibertec system 1010 heat Extract (Foss Co.). Chromic oxide content of the samples was determined after digestion in nitric and perchloric acid (Kimura and Miller, 1957). Chromium, other minerals and elements were determined on a Polarized Zeeman Atomic Absorption Spectrometer (Hitachi Z5000, Japan). Starch content was determined by an enzyme hydrolyzing method according to AACC (2000).

Statistical methods

The data obtained from the study were statistically analyzed by independent samples T test procedure for equality of means using the SPSS 9.0 (1998) package program.

RESULTS AND DISCUSSION

As shown in Table 3, the apparent ileal digestibilities of energy (DE), crude protein (CP), dry matter (DM), and organic matter (OM) in brown rice were significantly higher than those of maize ($p<0.05$). There were no significant differences in apparent and true ileal digestibilities of starch between brown rice and maize ($p>0.05$).

The content of gross starch in brown rice was 82.4% (DM basis, Table 1), which was similar to that found by Farrell (1994) and obviously higher than that in maize. We found the starch was not completely digested at the distal end of the small intestine in this experiment. The true ileal digestibility of starch of brown rice and maize was 96.6% and 97.7%, respectively. It was previously considered that the starch could be digested almost completely in the ileum. However, some recent evidence showed that a considerable quantity of starch escapes digestion in the small intestine and reaches the large intestine to be a potent carbohydrate resource for fermentation (Bird et al., 2000; Wang, 2000).

The digestibilities of most amino acids were significantly higher in brown rice than in maize ($p<0.01$, Table 3), especially for the essential amino acids such as threonine, valine, isoleucine, phenylalanine, lysine and tryptophan. The digestibilities of most nonessential amino acids in brown rice were significantly higher than those of maize except for proline, which conversely showed a lower digestibility in brown rice than in maize.

The digestibilities of amino acids of maize in this

Table 4. Apparent faecal digestibilities of energy, CP, DM and OM derived from marker and all-faeces collection methods

Item (%)	Maize	Brown rice	SEM[1]	p value
Marker method				
Energy	87.6	92.1	0.98	0.001
Crude protein	82.0	84.2	2.56	0.420
Dry matter	88.2	91.4	0.91	0.007
Organic matter	90.2	94.4	0.79	0.001
All-faeces collection method				
Energy	87.7	92.5	0.80	0.000
Crude protein	82.3	85.0	1.40	0.090
Dry matter	88.3	91.7	0.73	0.001
Organic matter	90.3	94.6	0.54	0.000

[1] Standard error of mean (n = 6).

Table 5. Difference in apparent digestibilities between the end of the small intestine and over the total tract[1]

Item (%)	Maize	Brown rice	SEM[2]	p value
Energy	11.6	8.8	1.84	0.19
Crude protein	16.9	8.3	2.95	0.02
Dry matter	12.1	9.5	1.81	0.18
Organic matter	11.4	9.1	1.56	0.19

[1] Total tract minus small intestine digestibility. All values are means of six observations.

[2] Standard error of mean (n = 6).

experiment were comparatively low. This result might be due to the following reasons. One reason may be that the fibre content in the maize was correlatively higher than that of brown rice and the balance of nonessential amino acids in maize was poorer. Another reason might be contributed by the lower levels of feeding. Limit-fed to 4.0% of average body weight/d might not be enough and there might be a greater proportion of endogenous N contributing to amino acid content.

There is an abundance of information on apparent ileal amino acid digestibilities of feedstuffs with low protein content. As discussed by Sauer and Ozimek (1986), there is much more variation in the apparent ileal amino acid digestibilities for each cereal grain compared with high-protein supplements. For example, the apparent ileal digestibilities of lysine and threonine in maize ranged from 71.0 to 82.0% and from 53.8% to 78.9%, respectively; the apparent ileal digestibilities of lysine and threonine in wheat ranged from 62.3 to 81.0% and from 61.9 to 78.4%, respectively. Fan et al. (1994) investigated the effect of dietary amino acid level on apparent ileal amino acid digestibility with maize-starch based soybean meal diets. The conclusion was that the dietary amino acid levels quadratically affected the apparent ileal amino acid digestibilities. He suggested that the plateau apparent ileal amino acid digestibilities, which were independent of the dietary amino acid content, should be determined. To estimate the plateau apparent ileal amino acid digestibilities, the amino acid contents in the assay diet should exceed the corresponding threshold levels.

When determining the apparent amino acid digestibilities of cereal grains with the direct method, only cereal provides amino acids in the assay diet. Then the dietary levels of some amino acids, including the limiting ones, were lower than the threshold levels of amino acid that needed to be determined. Lin et al. (1987) reported that the apparent ileal digestibilities of lysine and threonine in maize (10.5% CP) were 77.5 and 72.4% in studies in which their dietary levels were 0.31 and 0.36%, respectively. However, Green et al. (1987) reported lysine and threonine in maize (9.7% CP) of 56.8 and 60.2% in which the dietary contents were 0.21 and 0.24%, respectively. The distinct difference in dietary contents of lysine and threonine between two studies above (reaching 0.10 and 0.11 percent units, respectively) might contribute to the large differences in lysine and threonine digestibilities (20.7 and 12.2% units, respectively). It seems that small differences in the dietary contents of these amino acids will elicit a relatively large change in their apparent ileal digestibilities. Based on the aforementioned discussion, it is questionable whether the direct method is valid to determine the digestibilities of limiting amino acids in cereal grain. Perhaps another method needs to be used to determine apparent ileal amino acid digestibilities in brown rice in the future.

As for the apparent faecal digestibilities of amino acids between brown rice and maize, there might be a little difference from the present apparent ileal digestibilities. Zhang et al. (1999b) reported with direct determination that the apparent faecal digestibilities of most amino acids in brown rice were higher than that in maize but not significant ($p>0.05$), except methionine, tyrosine and arginine ($p<0.05$). He et al. (1994) studied the digestibility of brown rice with direct methods, and reported that the apparent faecal digestibilities of most amino acids were higher for brown rice than maize, but there was no difference in tyrosine.

As shown in Table 4, the apparent faecal digestibilities of nutrients including DE, DM, and OM of brown rice are significantly higher than those of maize ($p<0.05$). The differences were 4.5, 3.2 and 4.2% units in marker method and were 4.8, 3.4 and 4.3% units in all-faeces collection method, respectively. The relative differences between apparent digesta digestibilities and faecal digestibilities reduced. The difference of apparent faecal digestibilities of CP between brown rice and maize was not significant ($p>0.05$).

An estimate of large intestinal digestion and microbial action on energy, crude protein (CP), dry matter (DM) and organic matter (OM) is given in Table 5, determined by subtracting ileal digestibilities from faecal digestibilities. Net disappearances of DE, CP, DM and OM occurred by action of microflora in the large intestine, which indicated that some nutrients were degraded at the end of the digestive tract. The disappearance rates of all the

Table 6. Metabolism of crude protein and gross energy in brown rice

Item	Maize	Brown rice	SEM[1]	p value
GE Metabolizable rate (%)	86.6	91.4	0.69	0.00
Metabolizable energy (MJ/kg)	14.13	14.24	0.26	0.36
Nitrogen retention rate (%)	48.0	54.7	3.50	0.08
Biological value of CP (%)	59.1	64.6	4.09	0.23
Net protein utilization (%)	47.8	54.9	3.54	0.07

[1] Standard error of mean (n = 6).

nutrients in brown rice were lower than that in maize. Significant difference was found in the disappearance rates of CP between brown rice and maize (p = 0.02), which suggested that more nutrients, especially the CP of maize escaped from small intestine digestion of growing pigs in these experiments.

It was also mentioned by He et al. (1994) that the apparent faecal digestibilities of DM, ether extract (EE) and nitrogen free extracts (NFE) in brown rice were significantly higher than that in maize (p<0.01). Zhang et al. (1999a) reported that apparent faecal digestibilities of DM, OM and NFE were significantly higher (p<0.05) and the apparent faecal digestibilities of CP and EE were significantly higher (p<0.01) for a Chinese brown rice than for a maize diet. A kind of Chinese fodder brown rice (CP 10.8%) and maize (CP 7.4%) were compared with the direct method for their digestibility and metabolic characteristics in growing pigs (Zhang et al., 1999b). The results showed that the apparent faecal digestibilities of DM, CP and NFE were significantly higher (p<0.01) and the apparent faecal digestibilities of OM, EE and DE were significantly higher (p<0.05) for the brown rice than maize. The aforementioned reports were in agreement with the present report.

As shown in Table 6, the apparent metabolizable rate of energy was higher for brown rice than maize and the difference was highly significant (p<0.01). This partially accorded with the result reported by He et al. (1994) who studied the digestibility of nutrients in Chinese brown rice and found that the apparent digestibility and apparent metabolizable rate of energy were higher, but not significant, for brown rice than maize; and yet the apparent metabolizable rate of dry matter was significantly higher for brown rice than maize (p<0.01). Zhang et al. (1999b) reported that the apparent metabolizable rate of energy was 92.16%, 7.02 percent unit higher for brown rice than maize (p<0.05), which was very similar to the results of the present experiment（91.4%, 4.8 percent unit higher).

As shown in Table 6, the nitrogen retention rate in the brown rice was higher than that in maize (p = 0.08). The net protein utilization was higher for brown rice than maize (p = 0.07), and so was the biological value of CP although the difference was not significant. These results demonstrated that the balance of amino acids was better for brown rice than for maize.

A few studies have reported that the balance of amino acids in brown rice was better than that in maize (He et al., 2000; Li et al., 2002). After analysing 18 samples, He et al. (2000) concluded that lysine, threonine and isoleucine were the first three limiting amino acids in brown rice for non-ruminant animals. But we found that the balance between isoleucine and leucine is much better in brown rice than that in maize (Table 1), which was also mentioned by He et al. (1994). Other amino acids also showed a commendable balance, which could be seen after comparing amino acids in the brown rice and maize with the ideal amino acid model in NRC (1998). This might be beneficial to the biological value, helping to improve the nitrogen retention rate in brown rice.

In conclusion, the digestibilities of most nutrients in Chinese brown rice are higher than those of maize in growing pigs and Chinese brown rice is a considerable energy resource, at least under the present study conditions. Since the cost of Chinese brown rice is similar to that of maize in recent years, it is a feasible and effective feeding strategy to use brown rice in the diet of the growing pig.

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