Apparent Digestibility of Amino Acids, Energy and Proximate Nutrients in Grain Sources and Tapioca for Young Pigs

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ABSTRACT : This experiment was conducted to determine apparent ileal and fecal digestibilities of some grains for young pigs (15.6 kg BW). Ileal and fecal digestibility of corn, milo, wheat, barley, rice and tapioca were measured with pigs fitted with simple ileal T-cannula.

Rice was the highest ($p < 0.05$) and tapioca was the lowest ($p < 0.05$) in the digestibilities of gross energy. For the crude protein digestibilities, rice, barley and wheat were higher ($p < 0.05$) than corn, milo and tapioca. The average ileal digestibilities of essential amino acids (AAs) were 89.9, 85.8, 81.5, 80.9, 80.2 and 76.3% for those fed rice, barley, milo, wheat, corn and tapioca diets, respectively. Regardless of the dietary carbohydrate sources, among the dispensable amino acids, glycine had lowest digestibility except for barley and milo. The apparent ileal digestibility of lysine and methionine were 90.7, 94.0% in rice, 88.3, 86.5% in barley and 86.3, 82.3 % in wheat. The apparent fecal digestibility of average essential AAs were 90.8, 89.9, 87.7, 85.1, 82.5 and 77.9% in pigs fed the rice, barley, wheat, corn, milo and tapioca diets, respectively. The fecal digestibilities of essential AAs and nonessential AAs, in general, were higher than the ileal digestibilities, which indicating a loss of nitrogenous components in the cecum and colon. For all AAs, differences between ileal and fecal amino acid digestibilities ranged from 0.0 (valine) to 5.8 (threonine) in rice, 0.1 (arginine) to 14.5 (glycine) in barley, 2.8 (lysine) to 12.4 (glycine) in wheat, 1.0 (isoleucine) to 12.9 (glycine) in corn, 0.2 (serine, glutamic acid) to 6.5 (methionine) in milo and 0.5 (valine) to 22.1 (glycine) percentage units in tapioca diets. In conclusion, whether it is ileal or fecal, rice and barley appeared to be excellent alternative carbohydrate sources for young pigs in terms of AAs digestibility. However, energy value and cost for each grain should be considered when formulating diets.
(Key Words: Grain Sources, Apparent Ileal Digestibility, Apparent Fecal Digestibility, Cannulation, Young Pigs)

INTRODUCTION

Cereals form the basis of almost all swine diets, and tapioca is the most cheap carbohydrate source. Knowledge of the amino acid digestibility in these products may make it possible to formulate swine diets more accurately.

Corn is a traditional grain source used in diets of nursery pig. However, swine producers may have access to alternative carbohydrate products. Currently many grain sources are used in pig diets including corn, milo, wheat, barley etc. and the digestibilities of corn (Cousins et al., 1981; Furuya and Kaji, 1991; van Leeuwen et al., 1987; Green et al., 1987; Taverner et al., 1981), sorghum (Cousins et al., 1981; Owsley et al., 1981; Taverner et al., 1981), wheat (Sauer et al., 1974, 1977a, b; Furuya and Kaji, 1991; Green et al., 1987) and barley (Furuya and Kaji, 1991; Imbeah et al., 1988; Sauer et al., 1974; Sauer et al., 1981) have been examined intensively. However, the nutritional value of rice and tapioca (Salewski, 1988; Rantanen et al., 1994) have been recieved little attention compared to those commonly used grain sources. Rantenan et al. (1994) reported that rice and tapioca are good alternative carbohydrate sources for nursery pigs. They reported that pigs fed rice flour had greater average daily gain compared with those fed tapioca and pigs fed the diet containing corn showed intermediate average daily gain. Also pigs fed rice flour had improved feed to gain ratio (F/G) compared with those fed either corn or tapioca. The information on the ileal digestibility of rice is currently not available.

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Therefore, this study was conducted to determine the apparent ileal and fecal digestibilities of proximate nutrients and amino acids in several grain sources including rice and tapioca and provide relative nutritive values of rice and tapioca compared to other common carbohydrate sources.

MATERIALS AND METHODS

A total of 36 crossbred barrows (Landrace × Large White, 15.6 kg of BW) were housed individually on metabolism cage on the basis of body weight. The six experimental diets contained corn, sorghum, wheat, barley, rice or tapioca as a main energy sources. Cr_2O_3 was added to each diet to provide an indigestible marker. Diets were formulated to contain about from 3,059 to 3,307 kcal ME per kg diet, with vitamins and minerals over the estimated NRC (1988) requirement. All diets contained 6% casein to provide minimal amounts of crude protein as suggested by Batterham (1994) who suggested that at least 10.5% crude protein should be included in the experimental diets for the determination of apparent ileal amino acids digestibility. However, in tapioca diet the crude protein content still was under the recommended level. Ingredients and chemical composition of experimental diets are shown in table 1.

Table 1. Composition of experimental diets for digestion trial (%)

	Corn	Milo	Wheat	Barley	Rice	Tapioca
Ingredients:						
Corn	64.00	–	–	–	–	–
Milo	–	63.74	–	–	–	–
Wheat	–	–	63.87	–	–	–
Barely	–	–	–	63.82	–	–
Rice	–	–	–	–	63.45	–
Tapioca	–	–	–	–	–	63.59
Soybean oil	4.00	4.00	4.00	4.00	4.00	4.00
Lactose	18.00	18.00	18.00	18.00	18.00	18.00
Casein	6.00	6.00	6.00	6.00	6.00	6.00
Limestone	0.00	0.23	0.42	0.36	0.00	0.00
DCP (18%)	3.95	3.98	3.66	3.77	4.50	4.36
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vit.-min. mix.[1]	2.50	2.50	2.50	2.50	2.50	2.50
Antibiotics[2]	1.00	1.00	1.00	1.00	1.00	1.00
Chromic oxide	0.25	0.25	0.25	0.25	0.25	0.25
ME (kcal/kg)	3,307.40	3,209.27	3,226.31	3,058.73	3,206.11	3,147.12
CP (%)	10.36	10.59	12.97	12.26	9.87	6.64
Lysine (%)	0.47	0.46	0.56	0.56	0.48	0.36
Methionine (%)	0.24	0.23	0.27	0.23	0.21	0.14

[1] Supplied per kilogram of diet: Vitamin A, 2,000,000 IU; Vitamin D_3, 400,000 IU; Vitamin E, 250 IU; Vitamin K_3, 200 mg; Vitamin B_1, 20 mg; Vitamin B_2, 700 mg; Riboflavin, 10,000 mg; Pantothenic calcium, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 mg; Folacin, 200 mg; Vitamin B_{12}, 13 mg; Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe, 4,000 mg; Folic acid, 40 mg; BHT, 5,000 mg; Co, 100 mg; sucrose to make 1 kg vit.-min. mixture.

[2] Supplied per kilogram of diet: Chlortetracycline, 110 mg; Sulfathiazole, 110 mg; penicillin, 55 mg.

Each pig was fitted with a simple T-cannula located at the distal ileum approximately 7 cm from the ileocecal junction. After one day fasting, hipnodil and stresnil (Janssen Co. Belgium) anesthesia were administered via intravenous injection. The cannula and surgical procedure used in this study were made according to the method suggested by Walker et al. (1986a). Following surgery, procain penicillin (2 ml) was administered before closing the incision site and injected daily for consecutive 5 d at a dose of 20,000 IU/kg body weight. Immediately following surgery, the pigs were transferred to individual metabolism crates (90-cm × 60-cm × 50-cm). Crates were equipped with woven plastic floor and automatic watering system. The room temperature was maintained at

32℃ for the first five days after surgery and 30℃ (± 2) for the rest of the experiment. Pigs were fed on a *ad libitum* basis until they fully recuperated from the surgery. Then each pig was fed a restricted amount of feed (about 5% of the BW/day) twice daily at 08:00 and 20:00 hour and had *ad libitum* access to water throughout the trial.

Ileal samples were collected continuously in vinyl bags between 08:00 h and 24:00 h at 2-h intervals on collection days. Collected samples were immediately frozen and stored at −20℃, freeze dried (Ilsin Eng. Co, Korea), ground with a 1 mm mesh Wiley mill, and used for analysis. A fresh fecal samples were collected for 24 hours in pans placed under individual metabolic crate on the seventh and eighth day after five to six days of adaptation periods. Chemical analyses of the experimental diets, intestinal digesta, feces were carried out according to the AOAC (1990) methods and Cr was measured by atomic absorption spectrophotometer (Shimadzu, AA625, Japan). Amino acid contents were determined following acid hydrolysis in 6N HCl at 110℃ for 16 hours (Mason, 1984), using an amino acid analyzer (LKB 4150 alpha, Pharmacia Instrument Co, England). Statistical analysis was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) Procedure of SAS (1985) package program.

Table 2. Amino acid profiles of carbohydrate sources (as fed-basis)

	Corn	Milo	Wheat	Barley	Rice	Tapioca
CP (%)	10.48	11.54	14.76	13.72	7.70	4.40
EAA (%)						
THR	0.32	0.32	0.40	0.35	0.19	0.11
VAL	0.43	0.43	0.62	0.59	0.31	0.12
MET	0.15	0.21	0.23	0.11	0.16	0.22
ILU	0.24	0.49	0.56	0.30	0.19	0.22
LEU	0.95	1.32	1.02	0.85	0.52	0.30
PHE	0.59	0.78	0.76	0.66	0.76	0.54
HIS	0.33	0.34	0.44	0.26	0.27	0.42
LYS	0.27	0.22	0.46	0.38	0.20	0.13
ARG	0.61	0.44	0.77	0.52	0.70	0.29
Sub-total	3.89	4.55	5.26	4.02	3.30	2.35
NEAA (%)						
ASP	0.57	0.67	0.77	0.71	0.46	0.27
SER	0.38	0.47	0.76	0.52	0.29	0.14
GLU	1.76	2.26	3.63	3.31	1.03	0.32
PRO	0.92	1.04	1.35	1.54	0.48	0.17
GLY	0.35	0.34	0.62	0.51	0.28	0.15
ALA	0.53	0.89	0.56	0.36	0.32	0.12
TYR	0.62	0.68	0.73	0.67	0.60	0.66
Sub-total	5.13	6.35	8.42	7.62	3.46	1.83
Total (%)	9.02	10.90	13.68	11.64	6.76	4.18

RESULTS AND DISCUSSION

Apparent digestibilities of dry matter (DM), gross energy (GE), crude Fat (CF) and crude protein (CP) from various carbohydrate sources at both the terminal ileum and over the total digestive tract are presented in table 3. The ileal DM digestibilities were not significantly different among grain sources except tapioca diet. Barley, rice and wheat had similar DM, GE, CP and CF digestibilities measured at both the end of the small intestine and over the total digestive tract which tended to be higher than corn, milo and tapioca. Values for corn and milo tended to be intermediate, and tapioca had the lowest values. These results may be at least to some extent a reflection of the different amino acids balance and crude protein content of the experimental diets (Batterham, 1994; Chae, 1996). The ileal or fecal digestibilities of DM, GE and CP in corn were similar to those of milo in this experiment which was similar to the previous studied results (Cousins et al., 1981; Lin et al., 1987). Fecal or ileal digestibilities of DM, GE and CP in wheat were similar to those of barley which was not in agreement with the results estimated by some works who reported those of wheat were higher than those of barley (Just et al., 1985; Lin et al., 1987; Sauer et al., 1974; Sauer et al., 1977; Sauer et al., 1981). Possibly it is due to different kind of barley used in each study and the crude protein content of each experimental diet. Apparent digestibility values are affected by the level of crude protein in the diet (Batterham, 1994). Apparent digestibility is underestimated if it is determined in diets low in crude protein. To avoid this problem, Sauer et al. (1989) recommended at least 15-16% crude protein and Batterham (1994) recommended at least 10.5% crude protein in the diets.

Table 3. Apparent ileal and fecal digestibilities of proximate nurtients in carbohydrate sources (%)

	Corn	Milo	Wheat	Barley	Rice	Tapioca	SE
Dry matter;							
Terminal ileum	83.87^{a}	84.30^{a}	82.20^{a}	84.54^{a}	85.93^{a}	71.39^{b}	1.21
Total tract	84.57^{c}	84.75^{c}	87.78^{b}	89.84^{a}	89.38^{ab}	80.50^{d}	0.69
Difference	0.7	0.5	5.6	5.3	3.5	9.1	
Gross energy;							
Terminal ileum	84.12^{ab}	76.67^{b}	83.87^{ab}	85.85^{a}	90.48^{a}	76.28^{b}	1.40
Total tract	85.04^{b}	85.17^{b}	89.58^{a}	90.77^{a}	91.03^{a}	83.89^{b}	0.64
Difference	0.9	8.5	5.7	4.9	0.6	7.6	
Crude protein;							
Terminal ileum	77.81^{c}	76.93^{c}	82.27^{b}	82.74^{ab}	86.76^{a}	74.22^{c}	0.98
Total tract	82.72^{b}	80.28^{bc}	89.01^{a}	89.61^{a}	88.70^{a}	77.88^{c}	0.97
Difference	4.9	3.4	6.7	6.9	1.9	3.7	
Among grain sources							
Dry matter	83.72^{b}	84.03^{b}	84.99^{ab}	87.19^{a}	87.65^{a}	75.94^{c}	0.74
Gross energy	84.08^{bc}	80.92^{c}	86.72^{ab}	88.31^{ab}	90.75^{a}	80.08^{c}	0.81
Crude protein	80.26^{b}	78.61^{bc}	85.64^{a}	86.17^{a}	87.73^{a}	76.05^{c}	0.74
Between region		Dry matter		Gross energy		Crude protein	
Terminal ileum		81.66^{b}		83.02^{b}		80.16^{b}	
Total tract		85.68^{a}		87.38^{a}		84.59^{a}	
Probability (P):							
Sources		0.0001		0.0001		0.0001	
Region		0.0001		0.0003		0.0001	
Sources × Region		0.0091		0.1625		0.3371	

[a,b,c,d] Figures with different superscripts within the same row are significantly different ($p < 0.05$).

DM, GE and CP digestibility for the total digestive tract was higher ($p < 0.05$) than estimates obtained at the ileum in all diets. The differences of digestibilities between at the terminal ileum and for the total digestive tract ranged 0.5 (milo) to 9.1 (tapioca), 0.6 (rice) to 8.0 (milo) and 1.9 (rice) to 6.9 (barley) for DM, GE, and CP, respectively. Regardless of the region where the digestibility was measured, rice and barley showed the best digestibility of DM, GE and CP. Tapioca was the worst in digestibility of all nutrients measured. Values obtained from total digestive tract was higher in all parameters measured than values from terminal ileum. Interaction between sources and region (terminal ileum and total digestive tract) was found in DM digestibility, while no interaction was found in GE and CP digestibility.

Table 4 presents mean values of apparent ileal amino acid digestibilities of various carbohydrate sources given to young pigs. Rice and barley had the highest total average amino acids and essential amino acids digestibilities, tapioca had the lowest ($p < 0.05$) digestibilities. There were no significant differences in apparent ileal digestibilities of all essential amino acids except for isoleucine between rice and barley. Corn and milo, in general, had similar amino acid digestibilities which were similar to the result reported by Taverner et al. (1981). Amino acid digestibilities for barley, in general, were similar to or greater ($p < 0.05$) than those for wheat, corn and milo which was contrast with the results by Sauer et al. (1981) who reported those of barley was lower than those of wheat and Furuya and Kaji (1991) who estimated apparent average total amino acids digestibilities of barley were similar to that of corn. This might be a result of different diets used in both study. Sauer et al. (1981) used single grain diet (96.8% grain) for the determination of the ileal digestibility, but in this study about 64% grain used with certain amounts of lactose and casein.

Table 4. Apparent ileal digestibilities of amino acids in carbohydrate sources (%)

	Corn	Milo	Wheat	Barley	Rice	Tapioca	SE
Essential amino acids							
THR	67.97[c]	77.79[b]	80.46[ab]	82.97[a]	82.93[a]	69.74[c]	1.29
VAL	81.09[b]	82.48[b]	84.09[b]	88.56[a]	89.94[a]	73.22[c]	1.19
MET	80.77[b]	83.88[b]	82.30[b]	86.50[ab]	94.04[a]	77.35[b]	1.51
ILE	85.97[ab]	79.49[bc]	78.87[bc]	81.87[bc]	89.85[a]	77.81[c]	1.17
LEU	88.44[ab]	84.88[b]	85.32[b]	87.46[ab]	92.10[a]	83.98[b]	0.86
PHE	71.93[c]	76.79[bc]	82.73[b]	84.40[ab]	92.49[a]	81.72[b]	1.62
HIS	83.02[b]	81.12[b]	80.32[b]	83.91[ab]	87.67[a]	71.15[c]	1.13
LYS	86.74[b]	85.04[bc]	86.34[b]	88.31[ab]	90.71[a]	82.94[d]	0.62
ARG	75.93[c]	81.66[bc]	82.50[bc]	88.02[ab]	89.74[a]	68.59[d]	1.61
Sub-mean	80.21[cd]	81.46[bc]	80.92[bcd]	85.78[ab]	89.94[a]	76.28[d]	1.03
Non-essential amino acids							
ASP	80.24[c]	82.86[bc]	82.43[bc]	84.29[a]	87.44[a]	75.41[d]	0.85
SER	76.16[b]	81.14[a]	84.41[a]	84.91[a]	84.71[a]	69.25[c]	1.21
GLU	87.13[b]	87.00[b]	91.70[a]	91.00[a]	90.74[a]	81.90[c]	0.76
PRO	88.80[a]	80.88[ab]	90.77[a]	90.87[a]	90.74[a]	69.55[b]	2.24
GLY	68.13[b]	65.01[b]	69.93[b]	70.70[b]	80.64[a]	51.90[c]	1.87
ALA	78.69[ab]	82.83[a]	71.77[bc]	81.70[a]	86.21[a]	66.56[c]	1.57
TYR	68.30[bc]	56.77[c]	74.45[ab]	68.96[bc]	86.59[a]	80.17[ab]	2.66
Sub-mean	78.21[bc]	76.64[c]	80.78[bc]	81.78[b]	86.73[a]	70.68[d]	1.11
Mean	79.33[c]	79.35[c]	81.77[bc]	84.03[b]	88.53[a]	73.83[d]	1.01

[a,b,c,d] Figures with different superscripts within the same row are significantly different ($p < 0.05$).

The average ileal digestibilities of all essential amino acids were higher ($p < 0.05$) in pigs fed the rice and barley diet than in those fed any other carbohydrate sources, and values in pigs fed corn diet had similar to or greater than values in pigs fed milo and tapioca except for threonine and phenylalanine ($p < 0.05$). The results were in agreement with the reports by Cousins et al. (1981) who found corn and sorghum diets had similar essential amino acid digestibilities, while contrasted with the result by Sauer et al. (1977b) who reported essential amino acid digestibilities in barley were less digestible than those in corn, and the result by Furuya and Kaji (1991) who reported the average digestibility of the nine indispensable amino acids in barley was lower than wheat.

Absolute difference in essential amino acids digestibilities among experimental diets ranged from 7.8 percentage unit for lysine to 21.2 percentage unit for arginine. The ileal digestibility of lysine, methionine and threonine was higher ($p < 0.05$) in pigs fed rice or barley diet than in those fed any of the carbohydrate sources. The apparent ileal digestibility values of lysine and methionine were in good agreement with the result estimated by Taverner et al. (1981) who reported that the apparent ileal digestibilities of lysine and methionine in barley were equivalent to or greater than values for corn.

Apparent fecal digestibilities of amino acids of various carbohydrate sources offered to young pigs are presented in table 5. Over the total digestive tract, milo and tapioca, with exceptions for methionine, phenylalanine and alanine, were less digestible ($p < 0.05$) than any other diets. Rice and barley had more digestible essential and non-essential amino acids than corn, milo and tapioca. In general, apparent fecal digestibilities followed the same pattern as the apparent ileal digestibility, but the values tended to be higher when measured over the total digestive tract due to the disapperance of amino acids in the hind gut. So, the fecal digestibility may overestimate the real availability of amino acids since all amino acids would be deaminated by microorganisms to yield ammonia and various amines of no nutritional value in the large intestine as described by Fauconneau and Michel (1970), Michel (1966) and Zebrowska (1973). The fecal digestibilities of essential amino acids were higher ($p < 0.05$) in pigs fed the rice and barley than in those fed the other carbohydrate diets. In addition, the fecal digestibility of lysine was highest ($p < 0.05$) in pigs fed the rice, barley, wheat or corn diet than in those fed the milo and tapioca diet.

Table 5. Apparent fecal digestibilities of amino acids in carbohydrate sources (%)

	Corn	Milo	Wheat	Barley	Rice	Tapioca	SE
Essential amino acids							
THR	80.58[b]	81.56[b]	87.99[a]	89.55[a]	88.71[a]	76.13[c]	1.10
VAL	84.87[bc]	83.67[c]	88.64[ab]	91.39[a]	89.95[a]	73.69[d]	1.31
MET	79.31[b]	90.38[ab]	87.43[ab]	94.66[a]	94.16[a]	78.51[b]	2.02
ILU	84.95[ab]	79.82[b]	86.30[ab]	86.75[ab]	88.25[a]	71.38[c]	1.43
LEU	91.33[a]	87.50[b]	90.23[ab]	90.82[ab]	93.05[a]	82.24[c]	0.84
PHE	81.31[bc]	75.83[c]	88.87[ab]	86.62[ab]	91.40[a]	86.29[ab]	1.43
HIS	89.93[a]	78.31[b]	89.22[a]	89.05[a]	89.04[a]	77.18[b]	1.20
LYS	90.71[a]	85.92[bc]	89.13[ab]	92.12[a]	92.24[a]	83.54[c]	0.78
ARG	82.63[bc]	79.70[c]	87.22[ab]	88.15[ab]	90.56[a]	72.33[d]	1.41
Sub-mean	85.07[bc]	82.52[c]	87.65[ab]	89.90[a]	90.82[a]	77.92[d]	1.03
Non-essential amino acids							
ASP	84.52[ab]	83.30[b]	86.45[ab]	88.52[a]	88.64[a]	74.60[c]	1.09
SER	81.49[b]	80.98[b]	90.33[a]	90.45[a]	81.00[b]	74.27[c]	1.33
GLU	90.74[b]	87.24[c]	94.87[a]	95.07[a]	89.58[bc]	83.98[d]	0.83
PRO	92.48[a]	85.80[b]	96.31[a]	95.09[a]	92.17[a]	85.74[b]	1.03
GLY	81.00[a]	70.11[b]	82.37[a]	85.16[a]	85.50[a]	73.99[b]	1.21
ALA	86.11[a]	85.34[a]	78.11[b]	86.19[a]	85.13[a]	67.91[c]	1.57
TYR	76.77[ab]	59.79[b]	85.31[a]	78.88[ab]	86.92[a]	73.22[ab]	2.85
Sub-mean	84.73[a]	78.94[b]	87.68[a]	84.48[a]	86.99[a]	76.24[b]	1.07
Mean	84.92[ab]	80.96[bc]	88.05[a]	89.28[a]	89.14[a]	77.19[c]	1.03

[a,b,c,d] Figures with different superscripts within the same row are significantly different ($p < 0.05$).

Table 6 shows the differences between ileal and fecal digestibilities that were calculated by substracting ileal digestibility values from fecal digestibility values. A positive value in Table 6 indicates the amount of disappearance or extent of digestion in the large intestine in percentage units, while a negative value indicates a synthesis of that amino acid in the large intestine. Digestibilities of essential amino acids and nonessential amino acids, in general, were higher when measured over the total digestive tract than at the end of the small intestine, indicating a loss of nitrogenous components in the cecum and colon. Greater disappearance in the large intestine occured, in general, for amino acids with the lower digestibilities at the end of the small intestine, which were threonine, glycine, in all diets. Perhaps low digestibilities for these amino acids at the end of the small intestine are a result of their high concentration in endogenous secretion or slow absorption of these amino acids. Differences among the grains followed the pattern seen for ileal amino acid digestibilities reported by Cousins et al. (1981). This relationship agrees with the reports of Sauer et al. (1977a), who evaluated wheat flour, wheat and wheat offal; Sauer et al. (1977b), who evaluated corn, wheat and barley; and Taverner and Farrell (1981), who evaluated wheat, sorghum, corn and barley. Poppe et al. (1983) found that the difference between the digestibility of nitrogen at the ileum and in the feces was only 1.8 digestibility units for pigs fed casein-based diet.

Table 6. Differences between apparent fecal and ileal digestibilities of amino acids in carbohydrate sources (fecal digestibility - ileal digestibility)

	Corn	Milo	Wheat	Barley	Rice	Tapioca
Essential amono acids						
THR	12.6	3.8	7.5	6.6	5.8	6.4
VAL	3.8	1.2	4.6	2.8	0.0	0.5
MET	−1.5	6.5	5.1	8.2	0.1	1.2
ILU	−1.0	0.3	7.4	4.9	−1.6	−6.4
LEU	2.9	2.6	4.9	3.4	1.0	−1.7
PHE	9.4	−1.0	6.1	2.2	−1.1	4.6
HIS	6.9	−2.8	8.9	5.1	1.4	6.0
LYS	4.0	1.0	2.8	3.8	1.5	0.6
ARG	6.7	−2.0	4.7	0.1	0.8	3.7
Sub-mean	4.9	1.1	6.7	4.1	0.9	1.6
Non-essential amino acids						
ASP	4.3	0.4	4.0	4.2	1.2	−0.8
SER	5.3	−0.2	5.9	5.5	−3.7	5.2
GLU	3.6	0.2	3.2	4.1	−1.2	2.1
PRO	3.7	4.9	5.5	4.2	1.4	16.2
GLY	12.9	5.1	12.4	14.5	4.9	22.1
ALA	7.4	2.5	6.3	4.5	−1.1	1.4
TYR	8.5	3.0	10.9	9.9	0.3	−7.0
Sub-mean	6.5	2.3	6.9	2.7	0.3	5.6
Mean	5.6	1.6	6.3	5.3	0.6	3.4

Higher digestibilities over the total digestive tract than digestibilities at the end of the small intestine have been reported for crude protein and most amino acids in soybean meal (Holmes et al., 1974; Tanksley et al., 1981; Sauer et al., 1982).

Conclusionally, whether measured at the end of the small intestine or over the total digestive tract, the digestibilities of proximate nutrients and amino acids in pigs fed rice diet were the highest, and those of pigs fed tapioca were the lowest. However, since it is generally agreed that ileal measurement if preferred to the fecal method as a means of determining amino acids digestibility (Furuya and Kaji, 1991), ileal digestibility should be considered in formulating pig diets. In addition, when choosing grain soruces, the energy value and cost for each grain should be considered.

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