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ORIGINAL ARTICLE

Digestibility and nitrogen retention of diets containing different levels of fibre in local (Mong Cai), F1 (Mong Cai × Yorkshire) and exotic (Landrace × Yorkshire) growing pigs in Vietnam

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Summary

Total tract digestibility and nitrogen retention of three diets containing different levels of fibre [200, 260 and 320 g/kg neutral detergent fibre (NDF) in dry matter] were determined in three breeds of growing pig at an initial age of approximately 3.5 months. The breeds were local (Mong Cai, MC), F1 crossbred (MC × Yorkshire) and exotic (Landrace × Yorkshire, LY), allocated at random within breed (block) to double 3 × 3 Latin squares. The main fibrous ingredients of the experimental diets were rice bran, cassava residue meal and non-dehulled groundnut cake meal. Digestibility of organic matter (OM), crude protein (CP), NDF, crude fibre, gross energy (GE) and ether extract (EE) decreased as the level of dietary NDF increased ($p < 0.001$). The r^2 values for the relationship between NDF level and digestibility of OM, CP, GE and EE were 83%, 83%, 80% and 82% respectively. On average, an increase in NDF content of 1% unit resulted in a decrease in OM, CP, GE and EE digestibility of 0.67%, 0.75%, 0.50% and 0.42% units respectively. Digestibility of energy and nutrients was the highest for MC and the lowest for LY ($p < 0.01$), with intermediate values for F1. There was a negative effect of NDF level on nitrogen (N) retained as a proportion of intake ($p < 0.05$). Nitrogen retention and utilization were significantly higher ($p < 0.001$) for LY than for MC and F1 pigs.

Introduction

It has been estimated that of the smallholder farmers in the rural areas of northern Vietnam, which raise pigs, more than 95% keep only one to three pigs per household (Lich and Tuyen, 2001). A major problem of feeding pigs at smallholder level in South East Asia is the limited availability and high cost of concentrate feed. Therefore, local feeds and agricultural by-products are commonly utilized, as these are cheap and available in large amounts, and are thus suitable for small farmers who cannot afford the inputs needed for intensive pig production.

The main constraint of local feeds and agricultural by-products, from a nutritional point of view, is their high fibre (HF) content. When included at high levels in pig diets, this may reduce the digestibility of energy and dietary components (Fernandez and Jørgensen, 1986; Noblet and Le Goff, 2001) and result in a poor performance.

There is an increasing trend to rear exotic and F1 crossbred pigs in the rural areas in the north of Vietnam. However, local breeds (e.g. Mong Cai, MC) and F1 crossbred pigs (MC sow crossed with an exotic boar) are considered to utilize diets containing HF levels more efficiently than exotic breeds (e.g. Landrace × Yorkshire, LY), although few comparative studies have been carried out to confirm any breed differences in overall diet digestibility. There is some evidence that indigenous breeds and their crosses with exotics can digest HF diets more efficiently than exotic breeds (Fevrier et al., 1992; Kanengoni et al., 2002; Ndindana et al., 2002). Recently, Khieu et al. (2005) showed that MC pigs were more efficient in digesting dietary fibre fractions than improved pigs. In contrast, a study carried with an indigenous Cuban breed was unable to confirm any breed differences in terms of digestibility (Ly et al., 1998).

The aim of this experiment was to compare the digestibility of dietary components and nitrogen utilization in local, F1 crossbred and exotic breed growing pigs given diets with different fibre levels supplied by typical, locally available feeds.

Materials and methods

Animals and experimental procedure

Six castrated male pigs of each breed [MC, F1 crossbred (MC × Yorkshire) and LY] at around 3.5 months of age and with an average initial body weight (BW) of 28 ± 0.4, 34 ± 0.3 and 38 ± 0.3 kg, respectively, were allocated at random within breed (block) to double 3 × 3 Latin squares. All the pigs were vaccinated against pasteurellosis and hog cholera, and were kept individually in metabolism cages and given free access to drinking water through nipple drinkers. The metabolism cages were placed indoors, with maximum temperatures ranging from 25 °C to 33 °C.

The experiment included three periods. Each period lasted 12 days, of which 7 days were for adaptation and 5 days for faecal collection. The pigs were fed *ad libitum* in the adaptation periods and then in the collection periods restricted to 80% of the mean intake in the previous adaptation period. During both adaptation and collection, the feed was given in equal amounts twice per day at 8:00 and 16:00 hours, and in the adaptation periods, remaining feed was removed and weighed and fresh feed added. Faeces and urine were collected twice daily after each meal. Ten per cent of the total faeces and urine was sampled at each collection time and stored in a refrigerator at 4 °C. At the end of each collection period, samples of faeces and urine were pooled and taken for analysis.

Experimental diets

Three diets, with low fibre (LF), medium fibre (MF) and HF content, were studied. They were based on maize meal, soybean meal, fishmeal, rice bran (RB), non-dehulled groundnut cake meal (GNM), cassava residue meal (CRM) and feed additives. Rice bran was obtained from a local rice-milling factory. Non-dehulled groundnut cake is the by-product after extracting the oil from groundnuts. Cassava residue is the by-product from processing cassava roots for starch, and was sun dried for 2–3 consecutive days before use. All the ingredients were ground to pass through a 1.5-mm sieve. The diets were isonitrogenous [17.0% crude protein (CP) in dry matter (DM)] and isoenergetic [13.2 MJ metabolizable energy (ME)/kg DM). Metabolizable energy contents of the experimental diets were calculated using tabulated data for the feed ingredients (Chinh et al., 1995).

Rice bran, CRM and GNM were the main fibre sources and the ratio between these in the experimental diets was kept constant (RB:CRM:GNM was 50:25:25 respectively). A vitamin and mineral premix was included at 0.25% of DM. Dicalcium phosphate was included to balance the total Ca and P, and soybean oil was supplemented to equalize the ME content of the diets. The chemical composition of the feed ingredients is shown in Table 1, and the ingredient and nutrient composition of the experimental diets is shown in Table 2.

Chemical analysis

Urine samples were analysed for total nitrogen only in fresh form. Feed and faeces were dried at 60 °C for 24 h and ground to pass through a 1-mm sieve before analysis. The samples were analysed in dry form for DM, ash, CP (N × 6.25), crude fibre (CF) and ether extract according to standard AOAC (1990) methods. Neutral detergent fibre (NDF) was analysed using the method of Goering and Van Soest (1991) and gross energy (GE) content was determined using an automatic adiabatic bomb calorimeter (Gallenkamp, London, UK).

Table 1 Chemical composition [% of dry matter (DM)] and metabolizable energy (ME, MJ/kg DM) content of the feed ingredients

Ingredient	DM*	CP*	CF*	NDF*	Ca*	P*	ME†
Maize meal	88.1	9.1	4.5	14.5	0.0	0.5	14.6
Rice bran	87.6	9.5	18.5	50.5	0.1	1.6	9.2
Cassava residue	88.3	1.8	16.5	45.6	0.1	0.1	8.7
Groundnut cake	90.9	25.5	14.6	40.5	0.2	0.6	14.0
Soybean cake	84.5	48.6	6.7	16.2	0.3	0.7	13.9
Fishmeal	90.3	40.0	0.9	3.1	5.3	3.1	13.7

CP, crude protein; CF, crude fibre; NDF, neutral detergent fibre.
*Analysed data.
†From Chinh et al. (1995).

Table 2 Ingredient [% of dry matter (DM)] and chemical (% or MJ/kg DM) composition of the experimental diets

	Diet		
Ingredient	LF	MF	HF
Maize meal	58.75	34.85	10.55
Rice bran	10	20	30
Cassava residue	5	10	15
Non-dehulled groundnut meal	5	10	15
Soybean meal	15	15	15
Fishmeal (40% CP)	5	5	5
Mineral–vitamin premix*	0.25	0.25	0.25
Dicalcium phosphate	0.5	0.4	0.2
Soybean oil	0	4	8.5
NaCl	0.5	0.5	0.5
Chemical composition			
Crude protein (%)	17.4	17.2	17.4
Crude fibre (%)	7.1	9.4	11.8
Neutral detergent fibre (%)	20.5	26.3	32.3
ME (MJ/kg DM)	13.2	13.2	13.2
GE (MJ/kg DM)	19.3	19.4	19.3

LF, low fibre; MF, medium fibre; HF, high fibre; ME, metabolizable energy, GE, gross energy.
*Content per kg premix: vitamin A, 126 × 10^3 IU; vitamin D_3, 42 × 10^2 IU; vitamin E, 21 × 10^3 IU; vitamin B_{12}, 157 × 10^2 IU; Ca, 11–19%; Cu, 11 000–17 000 mg; Fe, 4900–10 000 mg; Zn, 6650–14 250 mg; Co, 11.2–24.0 mg; I, 70.0–150.0 mg; Se, 21.0–45.0 mg.

Statistical analysis

The data collected were analysed using the ANOVA general linear models procedure of Minitab Reference Manual Release 13.31 (2000).

The mathematical model was as follows:

$$Y_{ijkl} = \mu + A_i + B_j + P_k + D_l + (B_j \times D_l) + \varepsilon$$

where Y_{ijkl} is the digestibility or nitrogen retention, μ the overall mean, A_i the effect of animal, B_j the effect of breed, P_k the effect of period, D_l the effect of diet, $P_k \times D_l$ the effect of the interaction between breed and diet and ε the error effect. As breed by diet interactions and effects of period and animal on digestibility, feed and nutrient intake, and nitrogen balance were non-significant, they are not shown in the tables.

The relationship between NDF content in the diet and nutrient digestibility was determined using linear regression equations.

Results

Effect of fibre content in the diet and breed on daily feed intake

The effects of breed and fibre level in the diet on DM intake (DMI), nitrogen intake (NI), ME intake, GE intake and NDF intake are shown in Table 3. As the diets were balanced for N and ME contents and fed restrictedly, fibre level in the diet did not affect DMI, NI and energy intake ($p > 0.05$). Daily feed intake, expressed as g/kg metabolic BW, was higher for MC than LY ($p < 0.05$).

Effect of fibre level in the diet and breed on nutrient digestibility

The total tract apparent digestibility (TTAD) of all nutrients (Table 4) decreased with increasing fibre level in the diet ($p < 0.001$) for all three breeds. On average, an increase in NDF content of 1.0% unit resulted in mean decreases in organic matter (OM), CP and energy digestibility of 0.67%, 0.75% and 0.50% units respectively. Mong Cai had the highest TTAD values, followed by F1 and LY ($p < 0.01$). The differences in TTAD of NDF and CF between breeds (55.8% and 45.5% for MC compared with 50.5% and 41.1% for LY, respectively) were higher than for between-breed differences in the TTAD of other dietary components.

The data in Table 5 show the relationship between the NDF level (% of DM) in the diet and the TTAD of dietary components for MC, F1 and LY pigs and overall. These relationships were linear and negative, and were highly significant ($p < 0.01$) except for TTAD of CF in F1 pigs. In general, the regression coefficient of the relationship between the TTAD of CF and NDF was the lowest in all three breeds. The closest relationships were found between the NDF and the TTAD of CP and energy. The slopes of the regression lines for TTAD of CP and OM were steeper for LY compared with MC ($p < 0.05$).

Effect of fibre level in the diet and breed on nitrogen retention and utilization

Faecal nitrogen was higher in HF than MF and LF ($p < 0.001$) (Table 6) but was not affected by breed. Landrace × Yorkshire had the lowest urinary nitrogen, followed by F1 and MC ($p < 0.001$), but there was no effect of diet on urinary N or N balance ($p > 0.05$). Both fibre level in the diet, and breed, had significant effects in nitrogen retention, expressed as a proportion of NI ($p < 0.001$). Nitrogen balance (g/kg metabolic BW) and nitrogen retention expressed as a proportion of N digested were the highest for LY, lowest for MC and intermediate for F1 ($p < 0.05$) but were not affected by diet. Average daily gain (ADG) of LY was the highest, followed by

Table 3 Effect of dietary fibre level and breed on daily feed and nutrient intake (g or MJ/kg metabolic live body weight/day)

	Diet (D)			Breed (B)					
Item	LF	MF	HF	MC	F1	LY	SEM	p-Value (D)	p-Value (B)
BW (kg)	43.2	42.6	42.4	34.2	43.6	50.6	–	–	–
DMI	1443	1438	1467	1275^{a}	1485^{b}	1588^{c}	58.0	0.813	0.001
DMI#	87	87	89	90^{a}	88^{ab}	84^{b}	1.23	0.269	0.011
NI	2.39	2.36	2.47	2.48^{a}	2.43^{ab}	2.32^{b}	0.03	0.089	0.012
NDFI	17.8^{a}	22.8^{b}	28.8^{c}	23.8^{a}	23.4^{ab}	22.2^{b}	0.31	0.001	0.007
GEI	1.67	1.68	1.72	1.74^{a}	1.70^{ab}	1.62^{b}	0.02	0.281	0.010
MEI	1.14	1.15	1.18	1.19^{a}	1.17^{ab}	1.11^{b}	0.02	0.255	0.012

Body weight (BW, kg) = (initial BW + final BW)/2; DMI, dry matter intake (g/head/day); DMI#, dry matter intake (g/kg metabolic body weight/day); NI, nitrogen intake (g/kg metabolic body weight/day); NDFI, neutral detergent fibre intake (g/kg metabolic body weight/day); GEI, gross energy intake (g/kg metabolic body weight/day); MEI, metabolizable energy intake (g/kg metabolic body weight/day); LF, low fibre; MF, medium fibre; HF, high fibre; MC, Mong Cai; F1, MC × Yorkshire; LY, Landrace × Yorkshire; Values within a row with different superscript are significantly different ($p < 0.05$).

Table 4 Effect of fibre level in the diet and breed on the total tract apparent digestibility of nutrients (%)

	Diet (D)			Breed (B)					
Item	LF	MF	HF	MC	F1	LY	SEM	p-Value (D)	p-Value (B)
DOM	86.9^{a}	83.4^{b}	78.5^{c}	84.2^{a}	82.7^{ab}	81.9^{b}	0.41	0.001	0.003
DCP	81.9^{a}	77.4^{b}	73.4^{c}	78.6^{a}	78.1^{a}	76.1^{b}	0.36	0.001	0.009
DNDF	55.8^{a}	53.0^{b}	50.0^{c}	54.8^{a}	52.4^{b}	50.5^{b}	0.48	0.001	0.001
DCF	46.0^{a}	43.3^{b}	40.8^{b}	45.5^{a}	43.5^{ab}	41.1^{b}	0.64	0.001	0.001
DE	83.9^{a}	81.3^{b}	77.9^{c}	82.1^{a}	81.0^{ab}	80.1^{b}	0.35	0.001	0.010
DEE	65.5^{a}	62.9^{b}	60.5^{c}	63.7^{a}	63.2^{ab}	62.0^{b}	0.36	0.001	0.001

DOM, digestibility of organic matter; DCP, digestibility of crude protein; DNDF, digestibility of neutral detergent fibre; DCF, digestibility of crude fibre; DE, digestibility of energy; DEE, digestibility of ether extract; LF, low fibre; MF, medium fibre; HF, high fibre; MC, Mong Cai; F1, MC × Yorkshire; LY, Landrace × Yorkshire; Values within a row with different superscript are significantly different ($p < 0.05$).

F1 and MC ($p < 0.001$), and ADG was higher for LF than for HF ($p < 0.05$).

Discussion

The mean BWs of the three breeds differed substantially, as a result of the lower growth potential of the MC breed that has a mature BW of less than 100 kg. Although absolute DM and nutrient intakes were lower for MC than for LY, they were significantly higher when expressed as a proportion of metabolic BW. The probable explanation for this is that the capacity of the gastrointestinal tract of the MC is higher than that of F1 and LY, which would be of particular importance in the case of HF diets. Results in a previous study also showed that an indigenous pig (Chinese Meishan, MS) had a higher capacity of the gastrointestinal tract than an improved breed (Fevrier et al., 1992). As the diets were balanced for N and ME contents and fed restrictedly, fibre level in the diet did not affect DMI, NI and energy intake.

Level of fibre in the diet is the most important factor affecting dietary components and energy digestibility (Fernandez and Jørgensen, 1986; Noblet and Perez, 1993). The principal mechanism is that the dietary fibre acts as a poorly digested diluent, and increases gastric viscosity, the production of endogenous nitrogen and the flow rate of digesta (Jørgensen et al., 1996). Dietary fibre has also been shown to decrease the rate of gastric emptying of digesta and to inhibit the exposure of enzymes to digesta, which is an additional factor reducing digestibility (Rainbird and Low, 1986). For young pigs, the negative effects of dietary fibre on digestibility of dietary components and energy are higher than that in finishing and adult pigs (Fernandez and Jørgensen, 1986; Noblet and Le Goff, 2001; Le Goff et al., 2002a,b, 2003).

The negative impact of increasing dietary NDF content on the digestibility of dietary components

Table 5 Regression equations by breed of NDF level in the diet (% of DM) and the total tract apparent digestibility (%) of nutrients

Item	Intercept	SD	Slope	SD	r^2	p-Value
Overall						
DCP	96.2	1.73	−0.71	0.07	83	0.001
DOM	101	1.70	−0.69	0.06	83	0.001
DE	94.6	1.40	−0.52	0.05	80	0.001
Mong Cai						
DCP	92.0	1.86	−0.51	0.07	92	0.001
DOM	98.7	2.93	−0.56	0.11	78	0.002
DE	93.2	1.74	−0.43	0.07	86	0.001
F1 crossbred (Mong Cai × Yorkshire)						
DCP	97.3	2.05	−0.73	0.08	93	0.001
DOM	100	2.09	−0.67	0.08	91	0.001
DE	93.1	0.43	−0.46	0.02	99	0.001
Landrace × Yorkshire						
DCP	99.3	1.51	−0.89	0.06	97	0.001
DOM	100	1.38	−0.87	0.05	96	0.001
DE	97.3	1.05	−0.68	0.04	98	0.001

DOM, digestibility of organic matter; DCP, digestibility of crude protein; DNDF, digestibility of neutral detergent fibre; DCF, digestibility of crude fibre; DE, digestibility of energy; DEE, digestibility of ether extract.

and energy in the current study was smaller than that in the previously reported studies in growing pigs (Noblet and Perez, 1993; Lindberg and Andersson, 1998; Ndindana et al., 2002). This could be due to different chemical properties of the fibre sources used in the studies (Henry, 1976, Chabeauti et al., 1991). Furthermore, the range of NDF levels in the current study was fairly small, which may have had an impact on the estimated effect of NDF on the digestibility values from the regression analysis.

The current study supports the contention that indigenous pig breeds can digest HF diets more efficiently than exotics. The MC pigs digested OM, energy and other dietary components more efficiently than LY pigs. Similarly, Ndindana et al. (2002) concluded that the digestibility of diets containing graded levels of maize cobs was higher in indigenous Zimbabwean pigs than in an exotic breed (Large White). This result was due to the disproportionately longer small intestine and colon in indigenous pigs compared with exotic pigs. In a study by Khieu et al. (2005), MC pigs had a higher digestibility of ADF and CF than LY pigs. To our knowledge, there are no data available relative to the anatomy and physiology of the digestive tract of MC pigs. It appears likely that the effect of breed on digestibility depends on dietary fibre level, because in some breeds this effect is only seen when they are fed very HF diets. For example, Fevrier et al. (1992) found that there were no differences in digestibility between Chinese MS and Large White (LW) pigs fed LF diets, but the MS pigs digested HF diets more efficiently. In contrast, Ly et al. (1998) found that the digestibility of most dietary components in very HF diets was not higher in Cuban Creole than in LW pigs.

Increasing fibre level in the diet resulted in a linear increase in the faecal N excretion, while there was no effect on the urinary N excretion and N retention. This suggests that the N utilization was unaffected by the increase in dietary fibre level in the current study, despite a reduction in the faecal apparent digestibility of CP. The increase in faecal N excretion was most likely associated with increased bacterial protein output (Morgan and Whittemore, 1988, Canh et al., 1998) because of the fermentation of dietary fibre components (Bach Knudsen et al., 1991).

Nitrogen retention and utilization were significantly higher for the LY and F1 breeds, probably as a result of the higher genetic potential of the improved breeds in terms of protein deposition. These results are in line with recent data from Khieu

Table 6 Effect of fibre level in the diet and breed on nitrogen (N) intake, excretion, balance (mg/kg metabolic body weight/day) and utilization (%) and average daily gain (ADG, g)

	Diet (D)			Breed (B)					
Item	LF	MF	HF	MC	F1	LY	SEM	p-Value (D)	p-Value (B)
N intake	2390	2360	2470	2480[a]	2430[ab]	2320[b]	30	0.089	0.012
N in faeces	440[a]	530[b]	650[c]	530	530	560	10	0.001	0.102
N in urine	1040	900	940	1160[a]	990[b]	730[c]	40	0.065	0.001
N balance	910	930	880	790[a]	900[a]	1030[b]	50	0.725	0.011
N utilization*	38.6[a]	39.5[a]	35.8[b]	32.0[a]	37.3[b]	44.6[c]	20	0.047	0.002
N utilization†	47.2	50.9	48.9	40.5[a]	47.8[b]	58.7[c]	40	0.455	0.001
ADG	653[a]	611[ab]	589[b]	407[a]	616[b]	831[c]	13.1	0.012	0.001

MC, Mong Cai; F1, MC × Yorkshire; LY, Landrace × Yorkshire.
Values within a row and factor withdifferent superscript are significantly different ($p < 0.05$).
*Nitrogen retained as a proportion of nitrogen intake.
†Nitrogen retained as a proportion of nitrogen digested.

et al. (2005), showing that LY pigs had higher N utilization than MC pigs. Kyriazakis et al. (1993) in a comparative study on diet selection by indigenous Chinese MS pigs and improved pigs (LY) showed that the MS pigs fed a low protein diet, had higher growth rate and protein tissue deposition compared with medium and high protein diets. Furthermore, they had the highest proportion of tissue deposition of protein vs. protein intake compared with the pigs fed medium and high protein diets. However, on medium protein diets LY was superior with respect to growth performance and protein tissue deposition, both compared with MS and with the low protein diet. These and our results suggest that for optimum growth performance, indigenous pigs, such as the MC, should be given a lower protein diet than the improved pigs.

Conclusions

The results from this study confirm that HF content in the diet has negative effects on energy and dietary component digestibility in growing pigs, and also reduced nitrogen retention as a proportion of nitrogen intake. The MC breed digested energy and dietary components more efficiently than LY, although nitrogen retention was lower. From these data, it is suggested that HF diets are more appropriate for indigenous than for exotic pigs, and that dietary protein content in diets for MC pigs can be lower than that in diets for exotic and crossbred pigs.

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