CHAPTER 2

Macronutrient digestibility in Kadon pigs fed diets with isonitrogenous amounts of various carbohydrate sources

K. Vasupen[*], C. Yuangklang, S. Wongsuthavas, P. Srenanul, J. Mitchaothai[1] and A. C. Beynen[2]

Faculty of Natural Resources, Rajamangala University of Technology Isan, Phang Khon, Sakon Nakhon 47160, Thailand,

[1]Department of Clinic for Swine, Faculty of Veterinary Medicine, Mahanakorn University of Technology, Bangkok, Thailand and

[2]Department of Nutrition, Faculty of Veterinary Medicine, Utrecht University, The Netherlands

Tropical Animal Health and Production, in press

Abstract

In this experiment, the apparent digestibility of diets with isonitrogenous amounts of different carbohydrate sources was determined in Kadon pigs, native to the North-East of Thailand and kept on small-holder farms. Eight male and eight female pigs were used in a 4x4 Latin square design with diets containing either ground corn (GC), rice bran (RB), broken rice (BR) or cassava chips (CC). The diet with BR induced the highest digestibilities for protein and energy, but also had the highest ingredients costs. In essence, the diet with CC had produced the second highest digestibilities, whereas this diet was 18% less expensive than the diet with BR. The N retention was expressed as % of N intake, it was found to be highest in the pigs fed the diet containing BR, which is explained by the high protein digestibility and thus their low N output with feces. The outcome of this study may contribute to the formulation of pig diets when aiming at optimizing ingredient costs and growth performance.

Key Words: Broken rice, Cassava chips, Ground corn, Kadon pigs, Nitrogen retention, Rice bran

Introduction

In the rural, North-Eastern area of Thailand, small numbers of a species of native pigs are kept. The so-called Kadon pigs are believed to be on the edge of extinction. In 2003, the Kadon pig was designated as a protected species of production animals. At the Department of Animal Science of the Sakon Nakhon Agricultural Research and Training Center, Kadon pigs are bred that descend from 20 animals from the Kudbark district in Sakon Nakhon province. The production of Kadon pigs is suitable for small-holder farms because they attain puberty at low body weight, reproduce well on a low plane of nutrition and have good disease resistance (Serres, 1992). Growing Kadon pigs fed a diet based on rice gain approximately 200 g/day (Vasupen *et al.*, 2004). Meat from Kadon pigs is more popular among local people than that of exotic breeds because the texture and flavor are considered to be better. In spite of all advantages, the Kadon pigs have been put aside by the intensive, large-scale production of exotic pigs and even on small-holder farms exotic pigs are usually kept.

Carbohydrates from cereal grains are the main source of energy in pig diets. In the North-East of Thailand, ground corn, broken rice and rice bran are commonly used for the formulation of pig diets, while cassava chips may be used as an alternative, depending on availability and price of the various carbohydrate sources. So far there was no information on the impact of the type of carbohydrate source on macronutrient digestibility in Kadon pigs. It was the objective of this study to determine macronutrient digestibility in Kadon pigs fed diets containing different either ground corn, rice bran, broken rice or cassava chips. These carbohydrate sources not only contain different amounts of non-structural carbohydrates, but also different amounts of protein, fat and fiber. It was decided not to balance the diets for the multiple variables in the carbohydrate sources, but the dietary protein concentration was kept constant by varying the amount of soybean meal. Thus, the experimental diets differed in their contents of fat, fibre and non-structural carbohydrates, but not their calculated content of protein. In fact, the carbohydrate sources were compared in terms of equal protein supply or rather on an isonitrogenous basis. This approach can be defended as the protein component of the carbohydrate sources is the most expensive one and therefore is practical. However, it is appreciated that the multiple variables in the diet complicate the interpretation of the digestibility results.

Material and Methods

Eight male and 8 female, growing Kadon pigs were used. The average body weight of the males was 8.4±1.7 kg and that of the females was 10.4±1.8 kg. The experiment had a 4x4 Latin square design with 4 experimental diets and 4 periods of 12 days each. The diets contained either ground corn (GC), rice bran (RB), broken rice (BR) or cassava chips (CC) as carbohydrate source.

Each pig was individually housed in a metabolic cage with slatted floor and had free access to tap water from a nipple drinker. Each period included 7 days as pre-treatment and 5 days for sample collection. Pigs were fed twice daily at 07.00 am and 16.30 pm. The animals were fed ad libitum and feed leftovers were always removed before feeding.

Feces were collected quantitatively twice daily from the wire-mesh under the cages, and stored at –20°C until analysis. Urine was collected into a container via a funnel underneath the wire-mesh. It was removed twice daily and stored at –20 ˚C. To prevent nitrogen (N) losses during collection and storage, 10 ml of 25% H_2SO_4 was added daily to each container. Diets and feces were analyzed for their proximal components, dry matter, nitrogen, crude fat, crude fiber and ash (AOAC, 1990). The energy value was analyzed by adiabatic bomb calorie meter as described by Mitchaothai et al.(2007). The amount of protein was calculated as amount of nitrogen x 6.25. The nitrogen-free extract (non-structural carbohydrates) was assessed as residual fraction. Urine samples were used for N analysis.

The total tract apparent digestibility of macronutrients was calculated as intake minus excretion and expressed as a percentage of intake. N retention was calculated as N intake – N.excretion with feces plus urine. The data were statistically analyzed using the General Linear Model of SAS Software (1985).

Results and Discussion

Table 1 shows the analyzed composition of the four carbohydrate sources. CC was lowest in protein and RB was highest. RB was rich in crude fiber and crude fat and CC was high in fiber only. The ash contents of BR and GC were lowest and RB was highest. The amount of non-structural carbohydrates decreased in the order of CC, BR, GC, and RB.

Table 1. The analyzed composition of the four carbohydrate sources.

	GC	RB	BR	CC
Dry matter, %	87.2	90.8	87.5	90.1
Organic matter, % of DM	98.9	91.2	99	95.2
Crude protein, % of DM	9.5	10.9	7.0	1.9
Crude fat, % of DM	3.5	16.3	3.0	0.7
Crude fibre, % of DM	1.7	8.6	2.0	6.4
Ash, % of DM	1.1	8.8	1.0	4.8
Nitrogen-free extract, % of DM	84.2	55.4	87.0	86.2

The calculated protein concentration of the four diets was identical, but chemical analysis showed that the diet with GC was somewhat higher in protein than the other three diets. As would be anticipated, the diet containing RB was rich in fat and fiber and the diets with CC was high in fibre only. The calculated energy values of the GC, RB, BR and CC diets were 3,284, 2,859, 3,232 and 3,203 kcal metabolizable energy/kg, respectively. The calculated prices of the GC, RB, BR and CC diets were 9.22, 7.93, 9.70 and 7.98 THB/kg, respectively (46 THB = 1 Euro). Thus, on an energy basis, the ingredient price of the CC diet was lowest.

The total tract digestibility values for the macronutrients are shown in Table 3. The diet effects on digestibility did not differ significantly between sexes ($P > 0.05$). In both male and female Kadon pigs, the diets with BR or CC induced significantly higher digestibilities for dry matter, organic matter, crude protein and nitrogen-free extract than did the diets containing either GC or RB. It is known that a high crude fiber content of the diet interferes with protein and carbohydrate digestibility in pigs (Anderson and Lindberg, 1997a, 1997b). The low digestibilities for protein and carbohydrates in pigs fed the diet with RB may relate to the high fiber content of the diet. The high digestibilities found for the CC diet, which also was high in fiber, are in agreement with data published by Wilfart et al. (2007).

Table 2. Ingredient and analyzed composition of the experimental diets expressed as percentage of the diets as fed

Ingredient	GC diet	RB diet	BR diet	CC diet
Ground corn (GC)	70.0	0.0	0.0	0.0
Rice bran (RB)	0.0	78.0	0.0	0.0
Broken rice (BR)	0.0	0.0	68.0	0.0
Cassava chips (CC)	0.0	0.0	0.0	58.0
Soybean meal	28.0	20.0	30.0	40.0
Salt	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.5	0.5	0.5	0.5
Premix*	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0
Macronutrient				
Dry matter, %	88.8	91.8	89.3	90.5
Organic matter, % of DM	95.0	90.4	96.6	94.0
Crude protein, % of DM	17.5	16.1	16.2	16.5
Crude fat, % of DM	3.4	13.7	2.5	1.9
Crude fibre, % of DM	3.5	8.3	3.8	7.2
Ash, % of DM	5.0	9.6	3.4	6.0
Gross energy, kcal/kgDM	4,688.3	4,259.2	4,235.7	4,193.6

*1 kg of vitamin and mineral premix contained: vitamin A 650 mg (325,000 IU); vitamin D_3 750 mg (75,000 IU); vitamin E 150 mg (75 IU); vitamin B_{12} 1 mg; vitamin K_3 80 mg; riboflavin 300 mg; niacinamide 1,200 mg; pantothenic acid 540 mg; choline chloride 6,000 mg; Fe 4,700 mg; Zn 6,500 mg; Mn 4,500 mg; Co 20 mg; Cu 1,400 mg ; I 45 mg and carrier material 973.164 g.

The apparent fat digestibility was highest in the pigs fed the diet with RB, but the difference compared to the other diets reached statistical significance in the female pigs only. The higher fat digestibility for the RB diet may be explained by its high fat content. A high fat intake will diminish the lowering effect of endogenous fecal fat on the calculated value for apparent fat digestibility. The digestibilities for dry matter and organic matter are determined by the efficiency of digestion of the sum of protein, fat, fibre and nitrogen-free extract. The digestibility of the nitrogen-free extract will have the greatest impact because this extract represents the largest fraction of the diet. The energy digestibility for the four diets followed the pattern of the digestibilities of dry matter, organic matter and nitrogen-free extract.

Table 3. Calculated composition of the experimental diets

Nutrients	GC	RB	BR	CC
Nitrogen-free extract, % of DM	70.6	52.3	74.1	68.4
ME, kcal/kgDM	3284	2859	3232	3203
Lys, % of DM	0.85	0.90	0.90	1.01
Met, % of DM	0.30	0.30	0.30	0.24
Met+Cys, % of DM	0.60	0.62	0.60	0.50
Trp, % of DM	0.18	0.21	0.21	0.22
Thr, % of DM	0.64	0.66	0.63	0.65
Ile, % of DM	0.69	0.66	0.72	0.74
Leu, % of DM	1.59	1.24	1.31	1.27
Phe. % of DM	0.88	0.82	0.87	0.88
Arg. % of DM	1.09	1.28	1.26	1.21

Under the conditions of *ad libitum* intake and the diets having nutrient levels well above the requirements, it would be expected that growth and N retention would be similar for the four experimental diets. However, due to feed refusals the mean feed intake was lowest in the pigs fed the diet with RB so that N intake also was lowest in these pigs (Table 5). As a consequence, N retention in the pigs fed the RB diet was significantly lower than in their counterparts fed the other experimental diets (Table 5). When N retention was expressed as % of N intake, it was found to be highest in the pigs fed the diet containing BR, which is explained by the high protein digestibility and thus their low N output with feces. As based on the amino acid composition of the diet and urinary N excretion, the low N retention in pigs fed the RB diet was not caused by an amino acid imbalance of the diet.

In a separate experiment we used six female pigs that were fed soybean meal and the premix in a 99:1 (w/w) ratio. The measured apparent crude protein digestibility was found to be 92.2 % (SEM = 1.0 %). Using this outcome, the digestibility of the protein component of GC, RB, BR and CC was calculated to be 44.3, 49.9, 67.1 and – 111.4 %, respectively. The aberrant value for the protein in CC may relate to its low protein level. In the CC diet a large proportion of the protein comes from soybean meal so that the calculated apparent digestibility for the protein component of CC becomes inaccurate.

Table 4. Effects of experimental diets on macronutrient and energy digestibility

Digestibility (% of intake)	Sex	GC	RB	BR	CC	SEM
Dry matter	male	86.4^{b}	81.9^{c}	94.0^{a}	92.0^{a}	0.56
	female	88.7^{c}	83.6^{d}	94.6^{a}	91.9^{b}	0.58
	combined	87.2^{b}	82.8^{c}	94.3^{a}	91.5^{a}	0.91
Organic matter	male	88.4^{b}	85.3^{c}	95.7^{a}	93.8^{a}	0.35
	female	89.4^{c}	86.2^{d}	95.8^{a}	93.8^{b}	0.47
	combined	88.9^{b}	85.8^{c}	95.7^{a}	93.8^{a}	0.69
Crude protein	male	73.6^{bc}	67.9^{c}	87.1^{a}	79.0^{b}	2.48
	female	74.5^{bc}	70.1^{c}	84.9^{a}	78.7^{ab}	2.33
	combined	74.0^{c}	69.0^{d}	86.0^{a}	78.8^{b}	1.13
Crude fat	male	87.0	89.9	89.3	86.4	0.71
	female	86.0^{c}	89.9^{a}	88.2^{b}	81.6^{d}	0.86
	combined	86.5^{ab}	89.9^{a}	88.7^{a}	84.0^{b}	1.21
Crude fibre	male	57.4	57.2	58.4	56.5	1.87
	female	56.2	51.5	62.4	55.8	1.81
	combined	56.8	54.4	60.4	56.2	1.30
Nitrogen-free extract	male	89.4^{b}	87.3^{b}	97.4^{a}	96.2^{a}	0.39
	female	91.5^{c}	87.9^{d}	97.8^{a}	96.7^{b}	0.43
	combined	90.4^{b}	87.6^{c}	97.6^{a}	96.5^{a}	0.63
Energy	male	87.2^{bc}	84.9^{c}	94.3^{a}	90.2^{b}	0.47
	female	88.6^{bc}	85.7^{c}	93.9^{a}	91.5^{ab}	0.67
	combined	87.9^{bc}	85.3^{c}	94.1^{a}	90.9^{b}	0.81

[a, b, c, d] Means in the same row with different superscripts differ significantly ($P < 0.05$)

Table 5. Effects of experimental diets on nitrogen balance.

	Sex	GC	RB	BR	CC	SEM
DM intake (g/d)	male	790.4	620.6	820.8	770.1	43.0
	female	868.3	743.3	894.1	761.0	47.7
	combined	829.3	681.9	857.4	765.6	32.1
N intake (g/d)	male	22.1	16.0	21.3	20.3	2.29
	female	24.3	19.1	23.2	20.1	2.56
	combined	23.2^{a}	17.6^{c}	22.2^{ab}	20.2^{ab}	1.68
N faecal output (g/d)	male	7.3^{a}	5.7^{ab}	3.6^{b}	4.7^{ab}	1.06
	female	7.0^{a}	6.0^{a}	3.1^{b}	4.9^{ab}	0.70
	combined	7.1^{a}	5.8^{ab}	3.4^{c}	4.8^{bc}	0.62
N absorbed (g/d)	male	14.8^{ab}	10.3^{b}	17.7^{a}	15.6^{ab}	1.79
	female	17.4^{ab}	13.1^{b}	20.0^{a}	15.1^{ab}	2.13
	combined	16.1^{b}	11.7^{b}	18.9^{a}	15.4^{ab}	1.37
N urinary output (g/d)	male	1.8	1.4	1.4	1.7	0.34
	female	1.2	0.9	1.4	1.2	0.21
	combined	1.5	1.2	1.4	1.5	0.21
N retention (g/d)	male	13.0^{ab}	8.8^{b}	16.2^{a}	13.9^{a}	1.67
	female	16.2	12.2	18.6	13.9	2.08
	combined	14.6^{a}	10.5^{b}	17.4^{a}	13.9^{ab}	1.33
N retention (g/kg$^{0.75}$*d)	male	1.6	1.4	2.0	1.8	0.26
	female	1.9^{a}	1.3^{b}	2.0^{a}	1.6^{ab}	0.18
	combined	1.8^{ab}	1.4^{b}	2.0^{a}	1.7^{ab}	0.15
N retention/N absorbed (%)	male	88.7^{ab}	82.9^{b}	91.3^{a}	89.4^{ab}	2.49
	female	92.6	90.9	92.5	92.7	1.75
	combined	90.7^{ab}	86.9^{b}	91.9^{a}	91.1^{ab}	1.59
N retention /N intake (%)	male	61.2^{ab}	53.3^{b}	75.0^{a}	70.5^{a}	4.95
	female	65.9^{b}	61.7^{b}	80.0^{a}	70.0^{b}	3.18
	combined	63.5^{bc}	57.5^{c}	77.5^{a}	70.2^{ab}	2.93

^{a,b,c} Means in the same rows with different superscripts differ significantly ($P < 0.05$)

In conclusion, the present data indicate that in Kadon pigs fed diets with different carbohydrate sources differences in macronutrient digestibility can be measured. The diet with BR induced the highest digestibilities for protein and energy, but also had the highest ingredients costs. In essence, the diet with CC had produced the second highest digestibilities, whereas this diet was 18% less expensive than the diet with BR. Thus, when compared on an isonitrogenous basis, cassava chips may be used instead of ground corn, rice bran or broken rice in order to reduce costs of diets to be used in pig production, including on small-holder farms. The carbohydrate sources with different protein contents must be fed in combination with different amounts of protein sources. In this experiment, soybean meal was used as a protein source. Clearly, the price of the protein source also has an impact on the comparision of the whole diet costs using different carbohydrate sources.

Acknowledgement

The authors express their sincere gratitude to Assoc. Prof. Dr. Boonlom Cheva-Isarakul, Chiang Mai University for valuable discussions and criticism. This work was supported by Rajamangala University of Technology Isan.

References

Andersson, C. and Lindberg., J.E., 1997a. Forages in diets for growing pigs, 1 Nutrient apparent digestibilities and partition of nutrient digestion in barley-based diets including lucerne and white-clover meal. Animal Science, 65, 483-491.

Andersson, C. and Lindberg., J.E., 1997b. Forages in diets for growing pigs, 2. Nutrient apparent digestibilities and partition of nutrient digestion in barley-based diets including red-clover and perennial ryegrass meal. Animal Science, 65, 493--500.

AOAC., 1990. Official Methods of Analysis. Association of Official Analytical Chemists, Washington, DC.

Mitchoathai, J., C.Yuangklang, S.Wittayakun, K.Vasupen, S.Wongsuthavas, P. Srinanul, R. Hovenier, H. Everts, A.C. Beynen. 2007. Effect of dietary fat type on meat quality and fatty acid composition of various tissues in growing-finishing swine. Meat Science, 76: 95-101.

SAS Software, 1985. SAS/STAT Guide for Personal Computers, 6th ed., (SAS Institute, Inc. North Carolina)

Serres, H., 1992. Manual of pig production in the tropical, (Redwood Press, Melksham, London)

Vasupen, K., Sarnklong, C., Yuangklang, C., Wongsuttravas, S., Srinanuan, P. and Kesorn, P., 2004. Effect of dietary protein levels on growth performance of native swine in Sakon Nakhon province. In: Proceedings of the Agricultural Seminar, Animal Science/Animal Husbandry, Department of Animal Science, Faculty of Agriculture, Khon Kaen University, Thailand. pp. 599-605.

Wilfart, A., L. Montagne, P.H. Simmins, J. van Milgen and J. Noblet. 2007. Sites of nutrient digestion in growing pigs: Effect of dietary fiber. J. Anim. Sci. 85:976-983.