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THE EFFECT OF HIGH DIETARY FERMENTABLE CARBOHYDRATE CONTENT ON THE FATTENING PERFORMANCE AND CHEMICAL BODY COMPOSITION OF FATTENING PIGS

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SUMMARY

The aim of the present study was to evaluate the effect of dietary fermentable carbohydrates (FC = faecal digestible organic matter - faecal digestible crude protein- faecal digestible crude fat - starch - sugars) on the body composition and meat quality of pigs. A total of seventy two Stamboek hybrid pigs were housed in groups of six per pen (two pens with gilts and two with barrows per treatment). Three diets were formulated with a low, medium and high FC content (63, 148, 233 g/kg in the grower diets (45-75 kg) and 67, 152, 237 g/kg in the finisher diets (75-110 kg)). Feed and water were offered ad libitum. At slaughter (110 kg LW) lean meat percentage, meat quality and chemical body composition were determined. Our data indicated, that carcass grading was improved by dietary FC. Diet with the high level of fermentable carbohydrates decreased fatness of the carcass and the organ fraction. It can be concluded that the fattening performance (FI, ADG, FCR) was not affected adversely by the high FC intake, but carcass quality in pigs could be improved. Feedstuffs high in fermentable carbohydrates can be valuable ingredients for pig diets, once their energy content has been properly estimated.

Key-words: pig, fermentable carbohydrate, body composition

INTRODUCTION

Byproduct play an important role in the feeding of pigs. Some by-products – like sugar beet pulp and corn gluten feed – contain a considerable amount of fermentable carbohydrates. Fermentation of non starch polysaccharides (NSP) in the gut (mainly hindgut) of pigs results in the formation of short chain fatty acids (VFA). Experimental data show that growing and fattening pigs can cover about 17-24% of their maintenance requirement for energy via the metabolism of VFA, while sows can even cover up to 25-35% (Shi and Noblet, 1993; Rérat et al., 1987; Johnston et al., 2002). Dietary fermentable carbohydrates decrease the dressing percentage and the backfat thickness (Zhu et al., 1990; Schriver et al., 2003). The former indicates that VFA resulting from an increased fermentation in the digestive tract may alter the body composition of pigs. Therefore, the aim of the present study was to evaluate the effect of increasing levels of dietary fermentable carbohydrates on the carcass composition, meat quality, and chemical body composition of pigs.

MATERIAL AND METHODS

Animals and housing

The experiment was conducted with a total of 72 pen housed Stamboek hybrid pigs in a randomised block design. Each treatment contained four pens with six gilts or six barrows. Animals were distributed based on live weight at a start to have similar average live weight and standard deviation in each group pair (same gender, but different treatment). The average live weight was 45.5 ± 1.7 kg at the start of the experiment and 110 ± 6.1 kg at the time of slaughter.

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Treatments

Three diets were prepared for the growing (45-70 kg) and fattening period (70-110 kg) to contain a low (L), medium (M) and high (H) content of dietary fermentable carbohydrates by increasing the inclusion of corn gluten feed and dried sugar beet pulp, mainly at the expense of maize starch and soybean meal (Table 1). Ingredients were ground over a 3 mm sieve and diets were pelleted to have a diameter of 4 mm in a grower phase (phase 1), and 5 mm in the finisher phase (phase 2). All diets had similar NE content calculated according to CVB (1999) (Table 1). Dietary fermentable carbohydrates provided about 10, 23 and 36% of the total net energy content of the respective experimental diets (about 0,6, 1.4 and 2.2 MJ NE/ kg diet for treatment L, M and H, resp.). Pigs had *ad-libitum* access to the experimental diets and water.

Table 1. Main ingredients and nutrient content of experimental diets

Main ingredients, %	Fermentable carbohydrate content					
	low	medium	high	low	medium	high
	45-70 kg			70-110 kg		
Maize	20.0	20.0	20.0	10.0	10.0	10.0
Wheat	10.0	10.0	10.0	10.0	10.0	10.0
Corn gluten	3.3	1.7	0.0	4.3	2.5	0.7
Soybean meal	17.5	14.9	12.5	18.0	15.0	12.6
Fishmeal	40.0	3.4	2.9	2.0	1.7	1.4
Corn gluten feed	0.0	5.0	10.0	0.0	5.0	10.0
Dried sugar beet pulp	0.0	15.0	30.0	0.0	15.0	30.0
Maize starch	22.0	11.0	0.0	22.0	11.0	0.0
Tapioca	4.9	5.1	5.3	13.6	13.9	14.3
Molasses	4.0	4.0	4.0	6.0	6.0	6.0
Soybean oil	1.3	1.3	1.3	1.6	1.6	1.6
Animal fat	1.3	1.3	1.3	1.6	1.6	1.6
Oat hulls	2.5	1.3	0.0	2.5	1.3	0.0
Cellulose	6.0	3.0	0.0	6.0	3.0	0.0
Nutrients	45-70 kg			70-110 kg		
Dry matter[1], g/kg	881	872	862	879	880	881
Crude protein[1], g/kg	169	165	161	155	151	149
Crude fat[1], g/kg	44	46	47	46	47	48
Crude fiber[1], g/kg	82	79	75	84	80	76
Starch[1], g/kg	429	339	249	426	337	247
Fermentable carbohydrate (FCH)[2]	63	148	233	67	152	237
Net energy, MJ/kg	9.6	9.6	9.6	9.7	9.7	9.6
Net energy as FCH[3] , MJ/kg	0.6	1.4	2.2	0.6	1.5	2.3
Net energy as FCH, % of total NE	6.3	14.6	22.9	6.2	15.5	23.9
Ca[1], g/kg	6.9	6.9	6.9	5.1	5.1	5.1
Total P[1], g/kg	4.5	4.7	4.8	3.8	4.0	4.2
Digestible P, g/kg	2.5	2.5	2.4	2.0	2.0	2.0
Ile. Dig. Lysine, g/kg	8.5	8.5	8.5	6.5	6.5	6.5

[1] analysed values; [2] fermentable carbohydrates calculated as content of faecal digestible organic matter minus faecal digestible crude protein, faecal digestible crude fat minus content of starch and sugars (CVB, 1999); [3] energy value of fermented carbohydrate is 9.6 KJ NE/g (CVB, 1999)

Slaughter and meat quality measurements

When pigs reached the average live weight of 110 kg, they were transported to a commercial abattoir. Pigs were slaughtered after electrical stunning on the following day. At slaughter meat percentage was estimated based on measurements by the Henessy Grading Probe (Henessy and Chong Ltd., Auckland, New Zealand). Fat and muscle depth were measured between the 3rd and 4th last rib 6 cm off the midline. The pH was measured in the *musculus longissimus dorsi* 45 minute (pH_{45}) and 24 hours (pH_{24}) after slaughter between 3rd and 4th rib from behind, 6 cm lateral from the median in the left carcass half. 24 Hours after slaughter muscle samples were taken from the *musculus longissimus dorsi* (25 cm frontal from the last rib) for intramuscular fat content (IMF) determination. To determine IMF,

all intermuscular fat was removed from a slice of longissimus muscle. The samples were homogenized in a small laboratory cutter and the fat content was determined by the Foss-Let method.

Chemical body analyses
Two fractions were made for chemical body analyses: the left carcass (fraction 1) and the organs (fraction 2) (consisted of blood, heart, liver, pancreas, kidney, spleen, lung, gall bladder, sex organs and empty GI-tract). The two fractions were stored deep frozen (-18 ^{o}C) in plastic bags. The preparation of body fractions for chemical body analyses was carried out by the method of Kotarbinska (1971).

Laboratory analyses
Dry matter content of body fractions was determined after drying samples in a vacuum oven at 50 °C and a vacuum of 13.3 KPa, using anhydrous calcium chloride as the drying agent. After 16 h, the vacuum was changed to 0.2 kPa and the samples were weighed every 4 h until they reached constant weight. Nitrogen content of feed and body fractions were determined in the samples by Kjeldahl analysis according to ISO 5983 (1997). Crude fat content was determined by extraction of samples with petroleum-ether and drying the extract at 103 °C to a constant weight according to ISO 6492 (1985). Ash was analysed by burning oven-dried samples in a muffle furnace at 550°C according to ISO 5984 (1978). The starch content of feed samples was determined by measuring the optical rotation of the sample solution obtained after partially hydrolisation of its starch content (ISO 6493:2000). Sugar content was determined by the Luff Schoorl (EG, 1971) method. Fermentable carbohydrates were calculated as follows: FC = faecal digestible organic matter - faecal digestible crude protein - faecal digestible crude fat - starch - sugars (CVB, 1999).

Statistical analyses
The effects of the treatments were tested by the GLM procedure of SAS (SAS Institute Inc., Cary, NC) according to the following general model:
$Y_{ijk} = \mu + FC_i + G_j + e_{ijk.}$
Where: μ = overall mean; FC = dietary treatments (i=1,2,3); G = gender (j=1,2), e_{ijk} = residual error. Treatment means were compared with the Tukey test.

RESULTS AND DISCUSSION

Fattening performance
The effects of the dietary treatments on the fattening performance of the pigs are given in Table 2. Performance was not significantly affected by treatments, but the treatments receiving diets with a medium and high content of fermentable carbohydrates tended to show a lower body weight gain and decreased feed conversion ratio compared to treatment receiving a diet with a low content of fermentable carbohydrates. Similarly to the results of Pluske et al. (1998), it was not approved that high dietary fermentable carbohydrate reduces the voluntary feed intake due to increased gut fill.

Carcass and meat quality
In spite of the similar slaughter weight, carcass weight of animals on the treatment receiving the diet with the highest dose of fermentable carbohydrates was significantly lower than on the other diets (Table 3). On the other hand, the weight of the gastro-intestinal tract increased with fermentable carbohydrates added in to the diet. Also in other studies, diets with a high content of fermentable carbohydrates and decreased dressing proportion were observed (Zhu et al. 1990, Pluske et al. 1998). This effect is associated with an increased gut fill. Also larger weight of tissue of GI tract may play a role. Increased rates of hind-gut fermentation cause an increase in volatile fatty acid (VFA) production and an increased large intestinal weight (Stanogias and Pearce 1985, Pond et al. 1988, Rijnen 1993). Intestinal hypertrophy occurred in pigs fed diets high in complex carbohydrates (NSP and resistant starch) (Jin et al. 1994, Topping et al. 1997). This can be partly related to the formation of butyrate, which can be trophic to the colonic mucosal lining (Pluske et al. 1998). Jansman et al. (2001) demonstrated that a diet containing 15% sugar beet pulp increased significantly the portal and arterial concentration of the acetic- and propionic acid, but to a lesser extent butyric acid. Butyric acid may

have been used by the gut lining. The former may have contributed to the explanation of the higher weight of the gastro-intestinal tract found in the present study.

Table 2. The effect of different fermentable carbohydrate (FC) content of the diets on the zootechnical performance of pigs (45-110 kg)

FC content	FI[1] (g/d)	ADG[2] (g)	FCR[3] (kg/kg)
Low[4]	2418	876	2.76
Medium[4]	2505	850	2.95
High[4]	2352	822	2.86
SEM	57	13	0.05
P treatment	0.24	0.07	0.06

[1] feed intake; [2] average daily gain; [3] feed conversion ratio; [4] 63, 148, 233 g/kg FC (45-70 kg) and 67, 152, 237 g/kg FC (70-110 kg) in low, medium and high treatment, respectively

The high dietary fermentable carbohydrate content reduced the backfat thickness (Table 3) similarly to the findings of others (Zhu et al. 1990, Shriver et al. 2003). The lean meat percentage in pigs receiving the diet with the highest level of fermentable carbohydrates was significantly higher compared to the group receiving the low FC diet. This can be a direct effect of the reduced backfat thickness. Dietary energy source had no effect on the intramuscular fat content of the pigs. The measured values for IMF are similar to those found out for high lean gain pigs (Affentrager et al. 1996, Blanchard et al. 1999). The pH 45 minutes and 24 hours after slaughter was similar in all treatments and showed characteristics of DFD meat. Since no large effects of the dietary treatments on the pH of meat could be expected, the most probable reason is the stress prior to slaughter.

Table 3. The effect of increasing levels of dietary fermentable carbohydrates (FC) on body weight, weight of the carcass and gastro-intestinal tract, carcass and meat quality of pigs

FC content	LW[1] (kg)	CW[2] (kg)	GI[3] (kg)	Backfat (mm)	Lean meat (%)	IMF[4] (%)	pH_{45}	pH_{24}
Low[5]	109.4	88.4[a]	4.6[a]	25.4[a]	53.2[a]	1.93	7.10	6.47
Medium[5]	110.1	88.3[a]	5.1[b]	23.4[ab]	53.7[ab]	1.65	6.98	6.45
High[5]	109.1	85.2[b]	5.0[ab]	21.0[b]	55.4[b]	1.67	7.06	6.41
SEM	0.3	2.17	0.57	4.55	2.66	0.98	0.36	0.26

[1] Live weight as measured at the day prior to slaughter in the fed state; [2] Carcass weight; [3] Weight of empty gastrointestinal tract; [4] Intramuscular fat content; [5] 63, 148, 233 g/kg FC (45-70 kg) and 67, 152, 237 g/kg FC (70-110 kg) in low, medium and high treatment, respectively; [a,b] Means in the columns lacking a common superscript differ ($P<0.05$)

Body composition

Results of backfat thickness of pigs on different treatments suggested that the high dietary fermentable carbohydrate content should result in significantly lower fat content in the carcass (Table 4). However, not only the amount of fat in the carcass, but the fat content of organ fraction was reduced in animals receiving the diet with the highest content of FC. This indicates that dietary fermentable carbohydrates reduce the body fat content in overall. The former may be related to the assumption that the tabulated energetic values of fibrous feedstuffs, as used during diet formulation in the present study, may have been higher than their actual values. Thus, the possible lower energy intake of pigs fed the diets with the medium or high content of fermentable carbohydrates, may have resulted in a decreased fat content in the body and reduced the backfat thickness. Le Goff et al. (2003) reported that the DE values of maize bran is very different for growing pigs, finishers and sows (10.6, 12.6, 15.2 MJ/kg DM, respectively). The tabulated value of NRC (1998) is 15.6 MJ DE/ kg DM. Thus the tabulated energetic value of maize bran seems to be applicable to adult sows only. This could apply to other fibrous

feedstuffs as well. Therefore, it is clear that fibrous pig feeds should be attributed an energy value that depends on the body weight or age (Le Goff and Noblet 2001). The improved digestibility of energy in older pigs is not only the result of the intrinsic capacity of the intestinal flora. The longer retention time due to a larger volume of the hindgut tract could be an important factor as well (Le Goff et al. 2003).

The dietary lysine to energy ratio primarily determines the rate of protein and fat deposition. In the present study diets were formulated to have a similar ratio of apparently ileal digestible lysine to the net energy. Therefore, the suggested underestimation of the energetic value of treatment with the high FC diet, should affect the protein deposition in the body as well. Möhn et al. (2000) reported, that reduced energy intake decrease the protein deposition in the body. In our study, however, the protein content of carcass and organs was similar (Table 4). Acetyl CoA is a metabolite shared in common by the metabolism of glucose, fatty acids and some amino acids. The carbon atoms in acetyl CoA can arise from carbohydrate via pyruvic acid produced in the glycolysis or the catabolism of fatty acids and certain amino acids. Acetyl CoA is the fuel for the Krebs-cycle, which provides most of the energy needs of the cells. If the energy level of the cell is high because of carbohydrate catabolism, the flow of acetyl CoA into the Krebs cycle will be slowed down, and acetyl CoA could be diverted into the synthesis of fatty acids (lipid) (Conn et al. 1987). Fatty acids can be metabolised into triglicerides, which are transported as lipoproteins into the adipose tissue for storage and muscle for energy supply. Cells can utilise the triglycerides as energy source when they are degraded into free fatty acids and glycerol. This process is regulated by lipoprotein lipase. Under isocaloric conditions, this enzyme has a high level of activity in adipose tissue. However, in the case of a low energy supply, lipoprotein lipase is highly active in muscle, liver, and cardiac tissues. These mechanisms can explain why body fatness was clearly affected by VFA, whereas body protein deposition and content are not affected.

Table 4. The effect of increasing levels of dietary fermentable carbohydrates (FC) on the chemical body composition of pigs (g/kg)

FC content	Organs				Carcass			
	Dry matter	Crude protein	Crude fat	Crude ash	Dry matter	Crude protein	Crude fat	Crude ash
Low[1]	279[a]	145	124[a]	8.6	471[a]	156	285[a]	30
Medium[1]	277[a]	145	121[ab]	9.1	466[a]	157	278[ab]	29
High[1]	263[b]	145	107[b]	8.7	442[b]	159	255[b]	28
SEM	19.2	6.6	20.3	0.64	31.7	9.0	35.4	3.7

[1] 63, 148, 233 g/kg FC (45-70 kg) and 67, 152, 237 g/kg FC (70-110 kg) in low, medium and high treatment, respectively

[a,b] Means in the columns lacking a common superscript differ ($P<0.05$)

CONCLUSION

Diets containing a high level of fermentable carbohydrates (230 g/kg) can be fed to pigs during the growing and fattening period without detrimental effect on fattening performance. Lean meat percentage, however, can be improved as a consequence to the reduced overall fat content of the body. Feedstuffs high in fermentable carbohydrates can be valuable ingredients for pig diets, once their energy content has been properly estimated.

REFERENCES

1. Affentranger, P., Gerwig, C., Seewer, G.J.F., Schwörer, D., Künzi, N. (1996): Growth and carcass characteristics as well as meat and fat quality of three types of pigs under different feeding regimes. Livestock Production Science 45:187-196.
2. Blanchard, P.J., Ellis, M., Warkup, C.C., Hardy, B., Chadwick, J.P., Deans, G.A. (1999): The influence of rate of lean and fat tissue development on pork eating quality. Animal Science 68:477-485.

3. Conn, E.E., Stumpf, P.K., Bruening, G., Doi, R.H. (1987): Outlines of biochemistry. John Wiley & Sons Inc., New York p 393-446.
4. CVB (1999): Veevoedertabel 1999 – gegevens over de chemische samenstelling, verteerbaarheid en voederwaarde van voedermiddelen. (In Dutch) Centraal Veevoederbureau, Lelystad, The Netherlands.
5. EG. (1971): E.E.C. Publ. No. L155/29.
6. ISO (1978): Animal feeding stuffs - Determination of crude ash. ISO 5984 International Organization for Standardization.
7. ISO (1985): Animal feeding stuffs - Determination of fat content. ISO 6492 International Organization for Standardization.
8. ISO (1997): Animal feeding stuffs - Determination of nitrogen content and calculation of crude protein content - Kjeldahl method. ISO 5983 International Organization for Standardization.
9. ISO (2000): Animal feeding stuffs - Determination of starch content - Polarimetric method. ISO 6493 International Organization for Standardization.
10. Jansman, A.J.M., Van Leeuwen, P., Bongers L.J. (2001): Effect of fermentable components in the diet on the portal flux of glucose, and volatile fatty acids in growing pigs. In: Lindberg JE, Ogle B, editors. Digestive Physiology of Pigs. p 92-94.
11. Jin, L., Reynolds, L.P., Redmer, D.A., Caton, J.S., Crenshaw, J.D. (1994): Effects of dietary fiber on intestinal growth, cell proliferation and morphology in growing pigs. Journal of Animal Science 72:2270-2278.
12. Johnston, L.J., Renteria, A., Shurson, J. (2002): Fiber nutrition of sows. In: Proc. 63rd Minnesota Nutrition Conf. Eagan, MN. p 217-231.
13. Kotarbinska, M. (1971): The chemical composition of the body in growing pigs. Roczniki Nauk Rolniczych ser. B 9:129-135.
14. Le Goff, G., Noblet, J. (2001): Comparative total tract digestibility of dietary energy and nutrients in growing pigs and adult sows. Journal of Animal Science 79:2418-2427.
15. Le Goff, G., Noblet, J., Cherbut, C. (2003): Intrinsic ability of the faecal microbial flora to ferment dietary fibre at different growth stages of pigs. Livestock Production Science 81:75-87.
16. Möhn, S., Gillis, A.M., Moughan, P.J,, de Lange, C.F.M. (2000): Influence of dietary lysine and energy intakes on body protein deposition and lysine utilization int he growing pig. Journal of Animal Science 78:1510-1519.
17. NRC (1998): Nutrient Requirements of Swine. 10th ed. Nat. Acad. Press, Washington, DC.
18. Pluske, J.R., Durmic, Z., Pethick, D.W., Mullan, B.P., Hampson, D.J. (1998): Conformation of the role of rapidly fermentable carbohydrates int he expression of swine dysentery in pigs after experimental infection. Journal of Nutrition 128(10):1737-1744.
19. Pond, W.G., Jung, H.G., Varel, V.H. (1988): Effect of dietary fiber on young adult genetically lean, obese and contemporary pigs: body weight, carcass measurements, organ weights and digesta content. Journal of Animal Science 66:699-706.
20. Rerat, A., Fiszlewicz, M., Giusi, A., Vaugelade, P. (1987): Influence of meal frequency on postprandial variations in the production and absorption of volatile fatty acids in the digestive tract of conscious pigs. Journal of Animal Science 64:448-456.
21. Rijnen, M. (2003): Energetic utilization of dietary fiber in pigs. [Ph.D. Thesis], Wageningen University, Wageningen Istitute of Animal Sciences, Wageningen, The Netherlands.
22. Shriver, J.A., Carter, S.D., Sutton, A.L., Richert, B.T., Senne, B.W., Pettey, L .A. (2003): Effects of adding fiber sources to reduced-crude protein, amino acid-supplemented diets on nitrogen excretion, growth performance, and carcass traits of finishing pigs. Journal of Animal Science 81:492-502.
23. Shi, X.S., Noblet, J. (1993): Contribution of the hindgut to digestion of diets in growing pigs and adult sows: Effect of diet composition. Livestock Production Science 34:237- 252.
24. Stanogias, G., Pearce, G.R. (1985): The digestion of fibre by pigs. 3. Effects of the amount and type of fibre on physical characteristics of segments of the gastrointestinal tract. British Journal of Nutrition 53:537-548.
25. Topping, D.L., Gooden, J.M., Brown, I,L,, Biebrick, D.A., McGrath, L., Trimble, R.P., Choct, M., Illman, R.J. (1997): A high amylose (amylomaize) starch raises proximal large bowel starch and increases colon length in pigs. Journal of Nutrition 127:615-622.

26. Zhu, J.Q., Fowler, V.R., Fuller, M.F. (1990): Digestion of unmolassed sugar beet pulp in young growing pigs and implications for the growth-supporting values of fermented energy. Animal Production 50:531-539.

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