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Influence of Sugar Cane Diets and a High Fibre Commercial Diet on Growth and Carcass Performance in Local Caribbean Pigs

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ABSTRACT : The aim of this study was to evaluate the effect of a milling by-product diet and two sugar cane diets on the local Creole pig breed (CR). A total of 48 CR pigs (24 females and 24 castrated males) were randomly assigned to four different groups of 12 animals. Pigs were allotted to one of 4 dietary treatments: fed with a control soya-bean meal-corn diet containing 19.1% crude protein (CP) and 15.4 MJ DE/kg (diet 1), with an experimental milling by-product diet (soya-bean meal and wheat by-products) containing 19.4% CP and 13.0 MJ DE/kg (diet 2), with ground cane stalks (GCS) or with fresh sugar cane juice (SCJ). Both GCS and SCJ were supplemented with soya-bean meal complement (400 g/d of a 48.7% CP and 16.1 MJ DE/kg diet) in order to obtain diets 3 and 4, respectively. Pigs were fed close to *ad libitum* level and had free access to water. All the pigs were slaughtered at 65 kg BW. Between 30 and 65 kg BW, growth performance was significantly ($p<0.001$) affected by dietary treatments: average daily BW gain was 657, 530, 546 and 200 g/d for diets 1, 2, 4, and 3, respectively. Average daily DM intake was 1.8, 1.9, 2.5 and 1.4 kg/d for diets 1, 2, 4, and 3, respectively. Fat cuts (backfat+leaf fat) and backfat thickness were significantly lower on diet 3 than for other treatments (127 vs. 192, 166 g/kg of left half-carcass weight and 24.6 vs. 39.0, 35.3 mm for diet 3 vs. diets 1 and 4, and diet 2, respectively; $p<0.001$). The dressing weight was significantly lower on diets 2 (82.7 vs. 84.0%; $p<0.001$). The entire empty digestive tract (DT) weight was higher on diet 2 (73.1 vs. 66.7 g/kg empty BW). However, stomach and large intestine were more developed on diet 3: 12.8 vs. 9.3 g/100 g empty DT ($p<0.001$) and 26.4 vs. 23.8 g/100 g empty DT ($p<0.05$), respectively. In conclusion, this study suggests the CR pig has the ability to reach rather good growth and carcass performance with a well-formulated sugar cane meal and/or with a milling by-product diet refined according to its low requirements. (**Key Words :** Pig, Creole, Performance, Carcass, Sugar Cane, Juice, Ground Stalks)

INTRODUCTION

The Creole (CR) pig is the most important local breed in the Caribbean region. In Guadeloupe (French West Indies, 16° Lat. N, 61° Long. W.), the local Creole pig (CR) have significant traditional and economic role supplying 40% of the fresh-meat consumed locally (Zébus et al., 2005). This breed constitutes a heterogeneous population resulting from successive crossbreeds between Iberian breeds and other European and American breeds introduced into the West Indies at early 16th century (Le Mentec, 1970). The CR pig is characterized by an early sexual maturity, low prolificacy, smaller mature size, low growth potential and higher body fat content when compared with modern European breeds such as Large White (Canope, 1982). However, CR pigs are also well-known for their rusticity and good meat quality (Depres et al., 1992; Renaudeau et al., 2005; Renaudeau et al., 2006; Renaudeau and Mourot, 2007). Currently, the feeding of the CR pigs raised in semi intensive breeding system follows that recommended for conventional breed. According to the low nutrient requirements of CR pigs, this strategy leads to high carcass fatness. This results in a gradual substitution of the CR by high lean genotype pigs with a possible extinction of this local breed in a medium term. From that it appears that adapted feeding strategies for the CR pigs must be established in order to increase the carcass quality. In order to valorise the local breed pigs, it would be possible to use an industrial diet specially formulated for CR pigs and/or using local feed resources in an organic system with a close integration between crops and livestock within the system.

In Guadeloupe and more generally in several tropical countries, milling by-products are available for pig production. The inclusion of these high-fibre products is

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associated with reduced energy content in the feed and can be used in a rationing strategy in order to limit carcass fatness.

In the Caribbean region, local feed resources have a good potential for animal feed resources. Sugar cane is a crop with very high potential for biomass production. It is traditionally cultivated and processed for sugar and rum production. However, it can be envisaged as a multipurpose crop with an important role in animal production as a non conventional feed resource (Preston and Murgueitio, 1992). Integrated systems based on sugar cane and its by-products as an energy source are well described in the literature. In fact, the use of sugar cane as the basis of pig feeding is employed in several tropical countries, especially in juice or molasses form (Preston et al., 1968; Preston, 1980; Mena, 1981; Figueroa and Ly, 1990). These studies showed that sugar cane juice can completely replace cereals as the major energy source in diets for growing and fattening pigs. However, little information is available concerning the use of whole or ground sugar cane stalks for feeding pigs.

The present study was designed to examine the influence of a high fibre diet specifically formulated according to the CR requirements and two sugar cane diets on growth performance, carcass traits, and meat quality in Creole growing pigs. The present paper focuses on the effect of the diets on growth and carcass performance.

MATERIALS AND METHODS

Experimental design and animal management

A total of 48 CR pigs (12 animals/diet) were studied in this experiment from 30 to 65 kg BW. This study was performed at the INRA experimental facilities in Guadeloupe (16° Lat. N, 61° Long. W; FWI) characterized by a humid tropical climate. Pigs were group-housed in a semi open experimental room equipped with four similar pens on open concrete floor. Twelve blocks were initially composed of four littermate females and castrated males. All the pigs of each pen (6 females and 6 castrated males) were fed with the same diet. At about 20 kg BW, one littermate was randomly assigned to one of the four different dietary treatments: a control soya-bean meal corn diet containing 19.1% crude protein (CP) and 15.4 MJ DE/kg (diet 1), a milling by-product diet (soya-bean meal and wheat by-products) formulated according to the estimated CR pigs requirements (diet 2: 19.4% CP and 13.0 MJ DE/kg), a sugar cane fresh juice diet (diet 4), or a ground cane stalks diet (diet 3). Both diets 3 and 4 were supplemented with 400 g/d soya-bean meal complement (48.7% CP and 16.1 MJ DE/kg) in order to reach the CR pigs' protein requirements. Diets 1 and 2 were given *ad libitum* as pellets once daily between 07:00 and 08:00 h. For diets 3 and 4, pigs were assumed to be fed close to the *ad libitum* level (140 and 110 g/d/kg BW, respectively). Practically, 1 to 1.5 tons of fresh sugar cane was delivered twice a week in our experimental facilities. For one part, sugar cane was cleaned out and milled for juice production. This juice was stocked at 4°C to prevent any fermentation reactions. For the other part, sugar cane was also cleaned out and the entire stalks were stocked at 4°C. For daily consumption, sugar cane stalks were ground in 3 cm medium-sized cut pieces, just before diet distribution. The diet 4 was made with a mix of 95% of sugar cane juice and 5% of ground cane to avoid any digestive complication. In diets 3 and 4 the protein complement was manually added before the distribution to obtain a homogenous mixture. These diets were distributed in three equal parts at 07:00, 12:00 and 18:00 h. Food refusal and spillage were collected before each distribution only for the diets 3 and 4. Climatic parameters were not controlled and pigs were exposed to natural light, ambient temperature and relative humidity levels.

The trial began after a 10-d adaptation period to experimental conditions (diet, housing) at an average BW of 30 kg and 95-d initial age. All animals had free access to water from two low pressure nipple drinkers. The trial ended when animals reached the recommended slaughtering weight for CR pigs which is 65 kg BW (Canope and Raynaud, 1982; Deprès et al., 1992).

Measurements and chemical analysis

For each diet 1 and diet 2, one sample of distributed food was taken weekly and measured for DM content. Food refusals were collected, weighed once a week and sub-samples were taken to measure their DM contents (24-h at 103°C). At the end of the experiment, all samples of allowed and refused feed were pooled for further chemical analysis. At each sugar cane delivery, samples of juice and ground cane stalks were taken. Daily food refusals or spillage of diets 3 and 4 were collected, weighed, sampled and stored at 4°C. Samples of food allowance were also collected. All these samples were weekly pooled for DM determination (96 h at 65°C), and monthly pooled, freeze dried and analysed for their chemical composition. Except for pure sugar cane juice samples which were freeze-dried, all samples of allowed and refused feed were analyzed for DM by drying to a constant weight at 65°C in a forced draught oven during four days. Dried samples were ground through a 0.75 mm screen before standard chemical analysis. Samples of feed were analysed for ash, protein (N×6.25), fat, starch and crude fibre according to the AOAC methods (AOAC, 1990), for free sugars according to Tollier and Robin (1979) and for cell wall components (NDF, ADF, ADL) according to Van Soest and Wine (1967).

All pigs were individually weighed before and after 24-h of fasting at the beginning and at the end of the experiment. At about 65 kg, animals were slaughtered by

Table 1. Ingredients and chemical composition of the experimental diets

Item	Ground cane stalks	Sugar cane juice	Protein complement	Soybean meal-corn (Diet 1)	Soybean meal-wheat (Diet 2)	Ground cane stalks diet (Diet 3)[1]	Sugar cane juice diet (Diet 4)[1]
Ingredient (%)							
Corn	-	-	-	61.2	-	-	-
Soya-bean meal	-	-	96.7	17.7	6.0	-	-
Wheat middlings	-	-	-	16.0	45.3	-	-
Wheat bran	-	-	-	1.6	45.3	-	-
Lysine	-	-	-	0.2	-	-	-
Minerals and vitamins	-	-	3.3	3.3	3.3	-	-
Ground cane stalks	100	-	-	-	-	100	5
Sugar cane juice	-	100	-	-	-	-	95
Dry matter (% DM)	25.1	20.0	88.0	87.6	87.3	28.0	23.0
Chemical composition (% DM)[2]							
Ash	2.3	1.7	9.4	5.9	7.6	3.7	2.9
Crude protein	2.2	1.6	48.7	19.1	19.4	11.0	8.6
Crude fat	1.0	0	2.8	3.8	3.9	1.4	0.5
NDF	46.6	0	15.8	15.7	31.3	41.6	4.8
ADF	30.7	0	4.1	3.3	8.4	26.2	2.3
ADL	5.3	0	0	0.1	2.1	4.3	0.3
Starch	0	0	0	40.0	26.3	0	0
Free sugar	47.0	85.7	9.7	0.2	0.2	39.1	72.5
GE (MJ/kg DM)[3]	17.6	16.5	19.3	18.5	18.4	17.9	16.8
DE (MJ/kg DM)[3]	10.1	16.1	16.1	15.4	13.0	11.1	15.8
Digestibility coefficient of energy (%)	57.4	97.8	83.7	83.2	70.3	62.1	94.1
N digestibility (%)[4]	-	-	87.2	78.7	69.3	-	-

[1] Pigs fed with the diets 3 and 4 were daily supplemented with 400 g of the protein complement.
[2] Mean chemical compositions obtained from 2, 1, 5, 29, and 14 samples respectively for the diet 1, diet 2, protein complement, ground cane stalks, and sugar cane juice. The chemical compositions of diets 3 and 4 were calculated from those of protein complement, ground cane stalks, and sugar cane juice.
[3] Estimated from chemical composition of each diet according to the equation of Noblet et al. (2003).
[4] Estimated according to AFZ-INRA tables (Sauvant et al., 2002).

electric stunning after a 24-h fasting period. The gastrointestinal tract was weighed before and after being emptied, internal organs (trachea, heart, lungs, liver, kidneys, spleen and genitals) and the warm carcasses were weighed separately. Digestive tract components (stomach, small intestine, large intestine, caecum, oesophagus and mesentery+internal fat) were weighed separately. Small and large intestine length were also measured. Caecum volume was estimated by water filling. After cooling for 24-h period at 3°C, carcasses were weighed and the left half-carcasses were dissected according to the normalized European procedure (Daumas et al., 1998). Backfat thickness was measured on 3 sites (i.e., atlas vertebra, 7th dorsal vertebra and last sacral vertebra) in the left half-carcass.

Calculations and statistical analysis

Average DM intake was measured weekly for diets 1 and 2, and daily for diets 3 and 4, as the difference between the amount of DM allowed and refused. Daily gain was calculated with live BW values measured after a 24-h fasting period. Gross energy (GE) and digestible energy (DE) values of feed were estimated from their chemical composition according to Noblet et al. (2003). Digestibility of nitrogen (dN) was estimated according to tables of composition and nutritional values of feed raw materials (Sauvant et al., 2002).

Growth performance and carcass traits were submitted to an analysis of variance including the effect of diet, block, sex and the diet×sex interaction as fixed effects (GLM procedure, SAS Institute, 1997). Means comparison was performed according to the Pdiff option of GLM procedure of SAS, using Tukey test for contrasts.

RESULTS

One castrated male was eliminated during the trial because of pulmonary infection in diet 4. Therefore, following results were obtained on a total of 47 CR pigs.

Chemical composition of the dietary ingredients

The chemical analysis of the dietary ingredients is shown in Table 1. As anticipated, dry matter (DM) contents were lower in diets 3 and 4. As expressed in percentage of DM, diets 2 and 3 had high level of dietary fibre (NDF), whereas the fibre contents were low in diets 1 and 4 (41.6

Table 2. Effects of dietary treatment on DM intake and its chemical composition (least-square means)[1]

Item treatment	Diet 1	Diet 2	Diet 3	Diet 4	RSD[2]	Statistical analysis [2] D
Number of pigs	12	12	12	11	-	-
Dry matter (% DM) [3]	87.6	87.3	28.0	23.0	-	-
Average daily intake (g) [3]						
DM	1,799 [a]	1,926 [a]	1,392 [b]	2,494 [c]	311	***
Ash	106.7 [a]	146.8 [b]	58.2 [c]	70.8 [d]	16.4	***
Crude protein	343.6 [a]	374.0 [a]	198.0 [b]	216.4 [b]	43.3	***
Crude fat	68.9 [a]	74.1 [a]	24.0 [b]	12.5 [c]	9.0	***
NDF	281.5 [a]	602.1 [b]	349.6 [a]	33.8 [c]	95.0	***
ADF	59.9 [a]	161.6 [b]	199.6 [b]	0 [c]	57.1	***
ADL	1.3 [a]	40.1 [b]	23.6 [c]	0 [a]	10.0	***
Starch	719.5 [a]	506.5 [b]	0 [c]	0 [c]	77.4	***
Free sugars	3.6 [a]	3.9 [a]	722.1 [b]	1,905 [c]	185.0	***

[1] Diet 1 = Soya-bean meal-corn diet; Diet 2 = Soya-bean meal-wheat diet; Diet 3 = Ground cane stalks diet; Diet 4 = Sugar cane juice diet.
[2] RSD = Residual standard deviation. From an analysis of variance including the effect of diet (D). Statistical significance, *** $p<0.001$.
[a, b, c] Means without common letter were significantly affected by dietary treatment ($p<0.05$).
[3] For each diet, means are obtained from 8, 10, 209 and 90 samples respectively for the diets 1, 2, 3 and 4.

Table 3. Effects of dietary treatment on performance in CR growing pigs (least square means)[1]

Item treatment	Diet 1	Diet 2	Diet 3	Diet 4	RSD[2]	Statistical analysis [2]		
						D	S	B
Number of pigs	12	12	12	11	-	-	-	-
Fattening length, d	53[a]	64[a]	191[b]	67[b]	14.1	***	NS	NS
Body weight (BW), kg								
Initial	30.8[a]	30.4[a]	26.2[b]	29.2[ab]	4.1	*	NS	*
Final	64.8[a]	64.3[a]	64.1[a]	64.6[a]	2.2	NS	NS	NS
Average BW gain, g/d	657[a]	530[b]	200[c]	546[b]	58.4	***	NS	NS
Feed conversion, kg DM/kg BW gain	2.9	3.4	5.8	4.1	-	-	-	-
Backfat thickness [3], mm	37.3[a]	35.3[a]	24.6[b]	40.7[a]	5.4	***	NS	NS

[1] Diet 1 = Soya-bean meal-corn diet; Diet 2 = Soya-bean meal-wheat diet; Diet 3 = Ground cane stalks diet; Diet 4 = Sugar cane juice diet.
[2] RSD = Residual standard deviation. From an analysis of variance including the effect of diet (D), sex type (S), block effect within sex (B) and interaction between diet and sex. This interaction was not significant for all the analyzed parameters.
NS: Not significant; * $p<0.05$, *** $p<0.001$.
[a, b, c] Means without common letter were significantly affected by dietary treatment ($p<0.05$).
[3] Mean of the backfat thickness measured on the atlas vertebra, 7[th] dorsal vertebra and last sacral vertebra levels.

and 31.3 vs. 15.7 and 4.8%, respectively for diets 3 and 2 vs. diet 1 and 4). In diets 1 and 2, the energy source was mainly provided by starch and fat, whereas in both of sugar cane-based diets, energy was mainly from free sugars. Estimated GE of the allowed feed was similar for each diet whereas DE increased from 11.1 to 15.8 MJ/kg DM, respectively for diet 3 and 4. Estimated dN was slightly low in diet 2 (69.3%) and it was 78.7 and 87.2% respectively for diet 1 and the protein complement.

Growth performance

The chemical composition of DM intake is presented in Table 2. As expected, daily DM intake is different among dietary treatments ($p<0.001$), with a higher value for diet 4 (2,494 g/d) and a lower value for diet 3 (1,392 g/d). No significant difference was observed between diet 1 and 2 (1,863 g/d on average, $p = 0.393$). Daily protein intake was higher in diets 1 and 2 than in diets 3 and 4 (359 vs. 207 g/d; $p<0.01$). Similar results were reported for crude fat intake. According to the chemical composition of diets, NDF, ADF and ADL daily consumptions were higher in diets 2 than in diets 3, 1 and 4 respectively. Regarding the carbohydrate source, the daily starch intake was higher in diet 1 than in diet 2 (720 vs. 507 g/d, $p<0.001$) and free sugars intake was higher in diet 4 than in diet 3 (1,905 g vs. 722 g/d, $p<0.001$).

As presented in Table 3, average BW gain was significantly ($p<0.001$) affected by dietary treatments with a higher value for diet 1 (i.e., 657 g/d) and a lower value for diet 3 (i.e., 200 g/d). In consequence, the age at slaughter was about twice higher for diet 3 than other treatments (286 vs. 148, 159, and 162 days for diets 1, 2 and 4, respectively; $p<0.001$). The initial BW for the diet 3 was lower at the beginning of the experiment (26.2 vs. 30.2 kg; $p<0.05$). This difference could be assigned to a direct effect of the dietary treatment during the 10-d adaptation period with subsequent negative effects in the growth rate. Backfat thickness measured at slaughter was significantly lower ($p<0.001$) in diet 3 (24.6 vs. 40.7, 37.3 and 35.3 mm for diets 4, 1 and 2, respectively). Even if the effect of diet on feed conversion ratio could not be tested statistically (data

Table 4. Effects of dietary treatment on carcass traits in CR pigs slaughtered at 65 kg BW (least square means)[1]

Item treatment	Diet 1	Diet 2	Diet 3	Diet 4	RSD[2]	Statistical analysis [2]		
						D	S	B
Number of pigs	12	12	12	11	-	-	-	-
Slaughter BW (kg)	64.8^{a}	64.3^{a}	64.1^{a}	64.6^{a}	2.2	NS	NS	NS
Empty BW (EBW, kg)	62.2^{a}	61.2^{a}	60.7^{a}	62.3^{a}	2.2	NS	NS	NS
Carcass traits (g/kg EBW)								
Empty digestive tract	66.1^{a}	73.1^{b}	68.6^{a}	65.5^{a}	4.6	**	**	NS
Viscera [3]	36.4^{a}	39.3^{a}	32.9^{a}	36.6^{a}	3.1	NS	NS	*
Dressing weight[4]	843^{a}	827^{b}	836^{a}	841^{a}	7.9	***	NS	NS
Carcass drip loss	23.0^{a}	24.7^{ab}	27.2^{b}	23.1^{a}	3.4	*	NS	NS
Carcass composition (g/kg)[5]								
Shoulder	244^{a}	252^{a}	251^{a}	239^{a}	15	NS	NS	NS
Loin	228^{a}	227^{a}	255^{b}	215^{a}	15	***	NS	NS
Ham	196^{a}	207^{bc}	217^{c}	197^{ab}	10	***	NS	NS
Belly	116^{a}	114^{a}	97^{b}	123^{a}	10	***	NS	NS
Backfat	153^{a}	136^{a}	100^{b}	155^{a}	18	***	NS	NS
Leaf fat	35^{ab}	31^{b}	26^{b}	41^{a}	8	***	NS	**

[1] Diet 1 = Soya-bean meal-corn diet; Diet 2 = Soya-bean meal-wheat diet; Diet 3 = ground cane stalks diet; Diet 4 = sugar cane juice diet.
[2] RSD = Residual standard deviation. From an analysis of variance including the effect of diet (D), sex type (S), block effect within sex (B) and interaction between diet and sex. This interaction was not significant for all the analyzed parameters.
NS: Not significant; * p<0.05, ** p<0.01, *** p<0.001.
[a, b, c] Means without common letter were significantly affected by dietary treatment (p<0.05).
[3] Viscera = Trachea, heart, lungs, liver, kidneys, spleen and genitals.
[4] Dressing weight = (cold carcass weight/EBW)×1,000.
[5] Expressed as a proportion of left half-carcass weight.

Table 5. Effects of dietary treatment on digestive tract composition (least square means)[1]

Item treatment	Diet 1	Diet 2	Diet 3	Diet 4	RSD[2]	Statistical analysis [2]		
						D	S	B
Number of pigs	12	12	12	11	-	-	-	-
Digestive tract components (g/100 g empty DT)								
Stomach	8.9^{a}	9.5^{a}	12.8^{b}	9.4^{a}	1.0	***	NS	**
Small intestine	25.3^{a}	25.6^{a}	20.7^{b}	21.2^{b}	3.5	**	NS	NS
Large intestine	22.5^{a}	24.9^{ab}	26.4^{b}	23.9^{ab}	3.0	*	NS	NS
Caecum	3.5^{a}	3.4^{a}	3.6^{a}	3.6^{a}	0.5	NS	NS	NS
Mesentery+oesophagus	39.8^{ab}	36.7^{a}	36.5^{a}	45.2^{b}	6.0	**	NS	NS
Caecum volume, ml	1,135^{ab}	1,323^{a}	1,337^{a}	1,049^{b}	210	**	**	NS

[1] Diet 1 = Soya-bean meal-corn diet; Diet 2 = Soya-bean meal-wheat diet; Diet 3 = Ground cane stalks diet; Diet 4 = Sugar cane juice diet.
[2] RSD = Residual standard deviation. From an analysis of variance including the effect of diet (D), sex type (S), block effect within sex (B) and interaction between diet and sex. This interaction was not significant for all the analyzed parameters.
NS: Not significant; * p<0.05, ** p<0.01, *** p<0.001.
[a, b, c] Means without common letter were significantly affected by dietary treatment (p<0.05).

for consumption were not individual inside each treatment), values for diets 2, 3, and 4 were numerically higher than in diet 1.

Carcass traits

Carcass performance was affected by treatment (Table 4). Slaughter BW and dietary treatments did not affect the empty BW (i.e., 61.6 kg on average, p = 0.238). The weight of the empty digestive tract was significantly higher in diet 2 than the other treatments (73.1 vs. 66.7 g/kg; p<0.01). The internal organ compartment (i.e., viscera) was not affected by dietary treatment. The carcass drip loss increased in diet 3 when compared with the other groups (27.2 vs. 23.6 g/kg; p<0.05). The dressing weight of the carcass was significantly lower in diet 2 and 3 than in diets 1 and 4 (78.9 vs. 80.1%; p<0.001). Expressed in g/kg of left half-carcass weight, fat cuts weight (backfat+leaf fat) was significantly lower (p<0.001) in diet 3 than in other groups (127 vs. 166 and 192 g/kg respectively for diet 2 and, diets 1 and 4). In contrast, lean cuts weight (ham+loin) was significantly higher in diet 3 (472 vs. 424 g/kg; p<0.001).

Digestive tract measurements

The effects of dietary treatments on the relative weights of all digestive tract components are reported in Table 5. Although the entire digestive tract weight was not affected by the dietary treatment for diets 1, 3 and 4 (Table 4), stomach and large intestine parts were more developed in diet 3 in comparison to the other treatments: 12.8 vs. 9.3 g/100 g ($p<0.001$) and 26.4 vs. 23.8 g/100 g ($p<0.05$) respectively. The relative weight of small intestine was lower in diets 3 and 4 than in diets 1 and 2 (21.0 vs. 25.5 g/100 g; $p<0.01$). Mesentery (+oesophagus) was more extended in diet 4 than in other dietary treatments (45.2 vs. 37.6 g/100 g; $p<0.01$). Although caecum weights were not different between treatments (p = 0.948), their volume was affected by diets with higher values for diets 2 and 3 ($p<0.01$).

DISCUSSION

Impact of a milling by-product diet (diet 2) on CR growth performance

Growth performance obtained in the present study with the control diet 1 are in accordance with previous trials carried out in our experimental facilities with CR pigs fed with the same diet (i.e., 673 g/d; Renaudeau et al., 2005). In the latter study, CR pigs exhibited lower growth rate and high fat deposition than Large White pigs which commercially depreciates the carcass value. These authors suggested that the greater ability of CR pig to deposit fat is related to a combination of its low lean tissue accretion rate and the use of extra energy available for fat deposition. From that, it can be suggested that high carcass fatness of CR pigs under intensive breeding conditions could be reduced by more adequate nutrition strategies. One of the objectives of the present study was to test the effect of a milling by-products diet on performance and carcass quality in CR pigs. In comparison with standard diet 1, pigs fed diet 2 exhibited reduced carcass fatness with significant reduction in growth rate. First, the reduced growth performance can be related to high fibre chemical composition of diet 2 and its consequences in the energy or protein digestibility coefficient. In fact, the presence of dietary fibre in diet is known to decrease energy and nitrogen apparent digestibility (Jorgensen et al., 1996). In our experiment, the estimated digestibility coefficients for N and energy were lower in diet 2 than in diet 1 control dietary treatment (i.e., 69.3 vs. 78.7% and 70.3 vs. 83.2%, respectively). In 30 to 60 kg BW range CR pigs, the average protein content of BW gain is 11.6% and it can be estimated that about 24.6% of digestible protein is deposited as body protein (Renaudeau et al., 2006). From these data, it can be calculated that about 288 g/d of digestible protein is needed to allow 611 g/d ADG (i.e., value obtained for the diet 1 control-group). Taking into account the daily intake of protein and the N digestibility value, the corresponding value for diet 2 group was 262 g/d. Summarizing, the failure to achieve a similar growth rate in diet 2 than in control dietary treatment may be the consequence of the low digestive protein supply. Considering fat cuts (i.e., back and leaf fat) and lean cuts (i.e., ham and loin) as indicators of carcass fatness, our results report leaner carcass for diet 2 than for control diet. This effect of high-fibre diet reducing pig-carcass fatness was also reported by Skiba et al. (2006). However, the effect of diet 2 on the fatness of the carcass was less marked than anticipated. In fact, even if the optimal ratio between protein and energy (P/E) is not well defined in CR pigs, it can be hypothesized that the P/E ratio in diet 2 was too low, which led to an increase in energy availability for fat gain. This could explain the lack of marked effect of the diet on carcass fatness. Concerning carcass traits, our results show a reduced dressing percentage in diet 2 than in control diet. This result is mainly related to both higher relative weights of viscera and digestive tract in the diet 2 in relation with a direct effect of dietary fibre on gastrointestinal tract development (Jorgensen et al., 1996).

Impact of sugar cane diet (diet 3) on CR growth performance

In the present study, the average BW gain obtained with diet 3 was lower than the value reported by Bravo et al. (1996) in 80 kg Duroc×Yorkshire pigs (i.e., 370 g/d) giving similar amounts of offered ground sugar cane stalks (i.e., 7 kg/d) and complemented with 540 g/d of a 40% CP soya-bean meal diet. Apart from difference in pig's characteristics (BW and genotype), the discrepancy between both sets of results could be explained by change in protein complementation. Moreover, Bravo et al. (1996) did not mention the size of the ground sugar stalks they used to feed pigs. According to Mederos et al. (2004) a change in particle size of chopped sugar cane stalks is associated with variation of feed efficiency. From that, it can be assumed that difference in growth performance between both sets of results could be also attributed to a difference in the particles size of the ground sugar cane stalks. In our study, the average BW gain of diet 3 pigs was dramatically reduced when compared with the other dietary groups. First, our results show a low daily DM intake in diet 3. It is commonly accepted that diets with high fibre content are generally associated to a high water holding capacity. The increase of the gastrointestinal distension related to the ponderous characteristic of such diet generates local satiety signals which are associated to a rapid reduction of voluntary feed intake (Wenk, 2001). In consequence, pigs fed with diet 3 high fibre diet were physically unable to increase their consumption in order to compensate the low energy concentration of the diet. However, it can be suggested that the time dedicated to consumption of diet 3 and sugar extraction by chewing would also limit the ability of the pigs to increase their feeding level. In addition, this effect was emphasized by the DE intake in relation to the reduced digestible coefficient of energy in diet 3. According to the net energy system, the metabolic utilization of high fibre diets is accompanied by an increase of heat expenditure and a decrease of retained energy (Noblet et al., 1994). In other words, the extraction of juice by chewing from diet 3 might involve a supplementary energetic cost with a negative consequence in the net energy value of the diet. To sum up, the low growth performance recorded for pigs fed with diet 3 was a consequence of a concomitant reduction of voluntary feed ingestion, low digestibility of the diet and low efficiency for metabolic utilization of ground sugar cane energy for growth. In our knowledge, the effect of ground (or chopped) sugar cane on carcass performance is poorly described in the literature. According to present results, diet 3 pigs exhibited leaner carcasses than the other groups in relation with the energy restriction imposed by the dietary treatment. It is well known that leaner carcasses lose more water during the maturation process of the meat (Lebret et al., 1999). In consequence, the higher carcass drip loss recorded in diet 3 was connected to its higher lean content. The present study showed an increase of relative weight of stomach and large intestine and more developed caecum in pigs fed diet 3. Wenk (2001) also reported that long-term feeding of high levels of dietary fibre could alter the anatomical and physiological characteristics of the digestive tract of pigs. From a physiological point of view, the enlargement of such organs is consistent with the fact that caecum, the proximal and ascending colon of pigs have been shown to be the most important sites of the hind-gut for microbial fermentation of carbohydrates like dietary fibre (Bach Knudsen and Hansen, 1991; Jorgensen et al., 1996; Wenk, 2001). The higher development of stomach in diet 3 resulted more in mechanical actions due to texture and ponderous characteristics of ground sugar cane stalks (Wenk, 2001).

Impact of sugar cane juice diet (diet 4) on CR growth performance

In contrast with diet 3, pigs fed diet 4 showed a high daily feed intake when compared with diet 1-control pigs (2,494 vs. 1,799 g DM/d/kg BW). The average DM intake was close to the values reported by Van and Men (1992) and Ngoan et al. (1998) (i.e., 38.6 vs. 38.5 and 39.6 g/d/kg BW, respectively). It could be suggested that this high DM intake observed could be assigned to a combined effect of both liquid form of diet 4 and juice palatability. When compared with control-diet 1 pigs, the growth rate obtained in diet 4 was in accordance with other results reported in Mexico, Vietnam and Venezuela (Mena, 1981; Van and Men, 1992; Gonzàlez et al., 2006). These results support the concept that sugar cane juice is an appropriate energy source for monogastric animals in tropical and sub-tropical conditions (Speedy et al., 1991; Mui et al., 1996). According to these authors, the replacement of cereals by sugar cane juice did not affect pig's growth performance. In our study, the BW gain of pigs fed diet 4 was lower than the corresponding value measured in diet 1. This effect can be explained by a lower crude protein intake in diet 4 than in diet 1. This protein imbalance resulted in fatter carcasses in diet 4 pigs. Our work shows no difference between diet 1 and 4 for the digestive tract composition, except for small intestine and mesentery components. For this latter component, the higher relative weight observed in diet 4 pigs was related to an important internal fat deposition due to excess of available energy. The comparison between diet 4 and diet 1 control-diet indicated that further studies are required to define an appropriate daily allowance of sugar cane juice and/or protein supplement in order to obtain good performance and avoid fatty carcasses.

When diet 4 was compared with diet 3, the large difference of growth rate between latter diets was attributed to large difference in net energy consumption as the daily crude protein intake did not differ in both diets (207 g/d on average).

CONCLUSION

This study suggests that rather good growth performance and carcass quality for CR pigs can be obtained with a well-formulated sugar cane meal especially when sugar cane juice is used. The diet 3, with low energetic density of its dietary fibre content, results in an energetic rationing and a reduced growth rate in CR pigs. It can be suggested that diet 3 can be used for feeding CR pigs in integrated farming system in which the growth performance is not maximized but is compensated by low inputs and valuables outputs like meat with higher quality and/or excreta used as fertilizers to produce natural protein supplement for crops. In contrast, rather good performance is measured in CR pigs fed with diet 4. The detrimental consequences in diet 4-pigs carcass quality could be resolved with a decrease of the amount of allowed juice and a well-balanced protein supply. Other studies are required to elaborate the dietary approach based on the use of sugar cane with the aim to find the best compromise between growth performance and carcass quality criteria. An improved high-fibre industrial diet suitable for CR pig requirements has to be formulated and well-balanced, paying attention to protein supply.

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REFERENCES

AOAC. 1990. Official Methods of Analysis. 15th edn. Association of Official Analytical Chemists, Arlington, Virginia.

Bach Knudsen, K. E. and J. A. Hansen. 1991. Gastrointestinal implications in pigs of wheat and oat fractions: 2. Microbial activity in the gastrointestinal tract. Br. J. Nutr. 65:233-248.

Bravo, M., M. Lasso, M. A. Esnaola and T. R. Preston. 1996. Preliminary studies on the use of chopped sugar cane stalks as the basal diet for fattenings pigs. Livestock Research for Rural Development 8(3). http://www.cipav.org.co/lrrd/lrrd8/3/bravo83.htm.

Canope, I. 1982. Etude des intéractions entre le type génétique et le régime alimentaire chez le porc en milieu tropical humide. Ph.D. Thesis, Institut National Polytechnique de Toulouse, Toulouse, France.

Canope, I. and Y. Raynaud. 1982. Relation entre le poids d'abattage et les caractéristiques de croissance et de carcasses chez le porc Créole. J. Rech. Porcine Fr. 14:37-44.

Daumas, G., D. Causeur, T. Dhorne and E. Schollhammer. 1998. Les méthodes de classement des carcasses de porc autorisées en France en 1997. J. Rech. Porcine Fr. 30:1-6.

Deprès, E., F. Tamisier, M. Naves and D. Rinaldo. 1992. Comparaison de porcs Créole et Large White pour les performances de croissance et la qualité de la viande en fonction de l'âge de l'abattage. J. Rech. Porcine Fr. 24:17-24.

Figueroa, V. and J. Ly. 1990. Alimentacion porcina no convencional. Col. GEPLACEA. Serie Diversificaciòn. Mexico. pp. 215.

Gonzàlez, D., C. Gonzàlez, A. Ojeda,W. Machado and J. Ly. 2006. Growth performance of pigs feed sugar cane juice (Saccharum officinarum) and mulberry leaf meal (Morus alba). Arch. Latinoam. Prod. Animal. 14:42-48.

Jorgensen, H., X. Zhao and B. O. Eggum. 1996. The influence of dietary fibre and environmental temperature on the development of the gastrointestinal tract, digestibility, degree of fermentation in the hind-gut and energy metabolism in pigs. Br. J. Nutr. 75:365-378.

Le Mentec, J. C. 1970. Etude monographique du porc local en Guadeloupe. Bulletin Technique d'Information. 251:435-446.

Lebret, B., L. Lefaucheur and J. Mourot. 1999. La qualité de viande de porc. Influence des facteurs d'élevage non génétiques sur les caractéristiques du tissu musculaire. INRA Prod. Anim. 12:11-28.

Mederos, C. M., V. Figueroa, A. Garcia, E. Aleman, R. M. Martinez and J. Ly. 2004. Growth performance of pigs fed hand-chopped sugar cane stalks. Livestock Research for Rural Development. 16(3). http://www.cipav.org.co/lrrd/lrrd16/3/med16014.htm.

Mena, A. 1981. Sugar cane juice as an energy source for fattening pigs. Tropical Animal Production. 6:338-344.

Mui, N. T., T. R. Preston, D. V. Binh, L. V. Ly and N. T. Dung. 1996. Effect of season of planting (and harvesting) of sugar cane on the nutritive value of the juice for fattening pigs. Livestock Research for Rural Development. 8(4). http://www.cipav.org.co/lrrd/lrrd8/4/mui842.htm.

Ngoan, L. D., R. B. Ogle, P. Sarria and T. R. Preston. 1998. Effect of replacing sugar cane juice with African palm oil (*Elaeis guineensis*) on performance and carcass characteristics of pigs. Livestock Research for Rural Development. 10(1). http://www.cipav.org.co/lrrd/lrrd10/1/ngoan101.htm.

Noblet, J., V. Bontems and G. Tran. 2003. Estimation de la valeur énergétique des aliments chez le porc. INRA Prod. Anim. 16:197-210.

Noblet, J., X. S. Shi, H. Fortune, S. Dubois, Y. Lechevestrier, C. Corniaux, D. Sauvant and Y. Henry. 1994. Teneur en énergie nette des aliments chez le porc. Mesure, prédiction et validation aux différents stades de sa vie. J. Rech. Porcine Fr. 26:235-250.

Preston, T. R. 1980. A model for converting biomass (sugar cane) in animal feed and fuel. Animal Production System for the Tropics. International Foundation for Science, Stockholm. Pub. Number 8.

Preston, T. R., N. A. MacLeod, L. Lassota, M. B. Willis and M. Velazquez. 1968. Sugar cane products as energy sources for pigs. Nature 219:727-730.

Preston, T. R. and E. Murgueitio. 1992. Strategy for sustainable livestock production in the tropics. CONDRIT. Ltda: Cali. p. 89.

Renaudeau, D., M. Hilaire and J. Mourot. 2005. A comparison of growth performance, carcass and meat quality of Creole and Large White pigs slaughtered at 150 days of age. Anim. Res. 54:43-54.

Renaudeau, D., B. Bocage and J. Noblet. 2006. Influence of energy intake on protein and lipid deposition in Creole and Large White growing pigs in a humid tropical climate. Anim. Sci. 82:937-945.

Renaudeau, D., M. Giorgi, F. Silou and J. L. Weisbecker. 2006. Effect of breed (lean or fat pigs) and sex on performance and feeding behaviour of groupe housed growing pigs in a tropical climate. Asian-Aus. J. Anim. Sci. 19(4):593-601.

Renaudeau, D. and J. Mourot. 2007. A comparison of carcass and meat quality characteristics of Creole and Large White pigs slaughtered at 90 kg BW. Meat Sci. 76:165-171.

SAS Institute Inc. 1997. SAS/STAT User's Guide: Version 7. 4th edn. SAS Institute Inc., Cary, North Carolina.

Sauvant, D., J. M. Perez and G. Tran. 2002. Tables de composition et de valeur nutritive des matières premières destinées aux animaux d'élevage. AFZ-INRA. pp. 1-301.

Skiba, G., St. Raj, D. Weremko and H. Fandrejewski. 2006. The compensatory response of pigs previously fed a diet with an increased fibre content. 2. Chemical body components and composition of daily gain. Anim. Feed Sci. Technol. 15:403-415.

Speedy, A. W., L. Seward, N. Langton, J. Du Plessis and B. Dlamini. 1991. A comparison of cane juice and maize as energy sources in diets for growing pigs with equal supply of essential amino acids. Livestock Research for Rural Development. 3(1). http://www.cipav.org.co/lrrd/lrrd3/1/speedy.htm

Tollier, M. Th. and J. P. Robin. 1979. Adaptation de la méthode à l'orcinol sulfurique au dosage automatique des glucides neutres totaux: conditions d'application aux extraits d'origine végétale. Ann. Technol. Agric. 28:1-15.

Van Soest, P. J. and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. Journal of the AOAC 50:50-55.

Van, B. H. and L. T. Men. 1992. Feeding of sugar cane juice and "A" molasses to fattening pigs. Livestock Research for Rural Development. 4(3). http://www.cipav.org.co/lrrd/lrrd4/3/viet4.htm

Wenk, C. 2001. The role of dietary fibre in the digestive physiology of the pig. Anim. Feed Sci. Technol. 90:21-33.

Zébus, M. F., G. Alexandre, J. L. Diman, J. L. Paul, E. Despois and E. Phaeton. 2005. Diversité des élevages porcins en Guadeloupe: première évaluation technico-économique. J. Rech. Porcine Fr. 37:407-412.