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Growth performance, carcass quality, and noncarcass components of indigenous Caribbean goats under varying nutritional densities¹

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ABSTRACT: Studies were conducted to determine the effects of feeding regimens on growth and carcass quality of the Creole goat, a genotype indigenous to the Caribbean. Forty kids weighing 9.0 ± 1.2 kg of BW were reared indoors after weaning. Four supplement amounts were compared (10 kids per treatment): the G0 group received the basal diet (tropical forage, 8.8 MJ of ME and 108 g of CP/kg of DM) without concentrate, whereas the G100, G200, and G300 groups were offered 130, 230, and 310 g/d of concentrate (13.6 MJ of ME and 209 g of CP/kg of DM), respectively, in addition to the basal diet. The kids were slaughtered according to the standard procedure at 22 to 24 kg of BW for assessment of carcass traits and meat quality. Total DMI increased significantly, from 51 to 78 g/kg of BW^{0.75}, for G0 to G300 kids, whereas their ADG doubled from 42 to 84 g/d ($P < 0.01$; $P < 0.01$, respectively). The G:F values reached 125 to 130 for the G200 and G300 diets and were satisfactory compared with literature values. The carcass weight and dressing percentage ($P < 0.01$) increased from group G0 to G300, from 9 to 13 kg and from 42 to 51%, respectively.

The proportions of the different cuts (related to the carcass weight) did not vary by diet. The conformation score increased significantly ($P < 0.05$) among the 4 groups from an average score of 3.2 to 4.0 (score/5). There was a significant effect ($P < 0.01$) of supplement amount on the accumulation of internal fat tissues: the kidney fat weight increased from 113 to 253 g from the G0 to the G300 group. Regardless of the feeding level and amount of internal fat, the carcasses had an acceptable fat cover score, which remained less than 2.6 (score/5). A significant effect was not observed for the ultimate pH and the main color variables of the meat. The cooking loss and the shoulder DM content varied ($P < 0.05$) with the supplement amount. By increasing the nutritional density of the diet, it was possible to obtain well-conformed and heavy carcasses, with no excessive fattening. Indigenous Creole goats have potential as meat animals when fed to gain more than 80 g/d. The optimal supplement supply with good-quality grass would be approximately 3.69 MJ of ME/d in our conditions. Further studies are required on meat sensory parameters and fatty acid profiles.

Key words: carcass, goat, growth, intake, supplementation, tropical forage

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INTRODUCTION

Caribbean goat farming systems are mainly centered on the use of the Creole goat, a hardy genotype found

throughout the region (Navès et al., 2001) that grazes pastures. The local demand for goat meat far exceeds local production (Alexandre et al., 2008), with a purchase price of approximately 25 US \$/kg of carcass. The Creole goat demonstrates increased weaner productivity (Alexandre et al., 1999) and genetic resistance to disease (Mandonnet et al., 2001). However, its medium size is considered a negative for meat production (Alexandre et al., 2008). Even so, little work has been done in this regard. Thus, during the last decade, importations of exotic heavy breeds that are not well adapted to the farming conditions in the Caribbean have resulted in an indiscriminate crossing with the native goat (Alexandre et al., 2009), with a possible loss of biodiversity. Tropical pastures are productive, but

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Table 1. Weight and growth variables of Creole kids allotted to the different experimental groups¹ based on nutritional density

Item	G0	G100	G200	G300	SEM
Birth weight, kg	2.0	2.1	1.7	2.0	0.4
Weaning weight, kg	9.2	8.7	8.5	8.6	1.25
Age at weaning, d	84	79	81	82	8.5
ADG at weaning, g/d	85.7	83.5	84.0	81.2	13.50
Initial weight, kg	10.2	9.7	9.4	9.5	1.45
Slaughter weight, kg	22.5	23.6	22.6	23.3	1.80
Feeding trial duration, d	292 ^a	228 ^b	184 ^c	164 ^d	39.0
ADG feeding trial, g/d	42.1 ^a	61.0 ^b	71.7 ^c	84.1 ^d	10.53

^{a-d}Means within the same row with different superscripts differ significantly ($P < 0.01$).

¹The G0 group received the basal diet (tropical forage ad libitum) without concentrate, the G100 group received the basal diet plus 140 g (fresh material) of concentrate/kid per day, the G200 group received 240 g of concentrate/kid per day, and the G300 group received 340 g of concentrate/kid per day.

their increased content of structural elements is poorly digestible (Humphreys, 1991). They are classified as a medium-quality diet (Aumont et al., 1991) unless managed at the right stage of maturity (>1 mo; Archimède et al., 2000) and could be a limiting factor for finishing kids. When fed a high level of nutrition, the growth performance of hardy goats is poor, relative to meat genotypes (Dhanda et al., 1999; Cameron et al., 2001). However, their voluntary intake is similar to those of exotic breeds (Luo et al., 2004). Consequently, it was hypothesized that the nutritional density of the diet required to optimize the performance of tropical kids would be different from that for exotic animals. Sahlu et al. (2004) tabulated the energy requirements of different genotypes (including indigenous ones), and the BW ranged from 15 to 55 kg and ADG ranged from 50 to 250 g/d. These tabulated data could not be appropriated for the indigenous Caribbean goat, given that it is weaned at 8 to 9 kg and is slaughtered at 18 to 20 kg of BW, with an average 35 g/d of ADG (Liméa et al., 2009). With the purpose of improving this growth rate and increasing meat production, it appeared necessary to assess the meat-producing ability of this particular biotype under increasing levels of nutritional density of the diets.

MATERIALS AND METHODS

The study was conducted on the Experimental Farm of the INRA Animal Production Research Unit in Guadeloupe from June 9, 2006, to March 27, 2007. The area is characterized by a humid, tropical climate with an annual rainfall of 2,860 mm and an average temperature of 25°C. All animal care, handling techniques, and slaughter procedures were approved by the Institut National de la Recherche Agronomique (INRA) Animal Care and Use Committee before the research was initiated.

Experimental Design, Diets, and Animals

Forty intact male kids of the Creole genotype, weighing 9.0 ± 1.2 kg of BW (2.5 mo old), were used in this

study. Four groups of kids (10 replicates per group) were raised indoors. Each kid was raised in an individual pen on a slatted floor. The 4 treatments (**G0**, **G100**, **G200**, and **G300**) were based on amount of concentrate in the diet. The G0 group received the basal diet without concentrate, the G100 group received the basal diet plus 140 g (fresh material) of concentrate/kid per day, the G200 group received 240 g of concentrate/kid per day, and the G300 group received 340 g of concentrate/kid per day, respectively. Kids were blocked by BW and ADG between 30 and 70 d preweaning and were randomly assigned to treatments (Table 1).

The basal diet was green tropical forage (*Digitaria decumbens* Stent.). A 30-12-18 nitrogen-phosphorus-potassium fertilizer was applied to the pasture. Grass was fertilized at a rate of 1 unit of nitrogen/ha per day of regrowth and was cut daily at 28 d of regrowth. The concentrate was a commercially available product with 90% DM, consisting of corn (*Zea mays*; 68%), soybean cake (15%), wheat bran (11%), urea (1%), and vitamin and mineral supplement (5%). The chemical composition and nutritive value are given in Table 2.

The animals received the concentrate at 0630 h, and the concentrate intake was measured from Monday to Friday every week. The experimental conditions were maintained on Saturday and Sunday, but no measurements were done because of a reduced workforce. The forage was delivered at 0830 h, and forage intake measurements and analyses were carried out monthly based on the last 2 wk of the month.

Samples of offered forage (2 subsamples of 200 g) and refusals (10%) were taken every day from Monday to Friday. One of the subsamples was kept for daily DM determination. All the samples of the feed provided for 2 wk were mixed together for each kid and a new subsample (200 g) was used for chemical analyses. The refusals were composited for each individual, mixed, and subsampled. All measurements were assessed individually.

The experiment was carried out for a total of 292 d. The experimental growth period for each group is tabulated in Table 1. After 1 mo of adaptation of the kids to the individual pen and the diet, the animals ate all

the concentrate delivered in their group, except for the G300 kids. Intake values reported in this study do not include this adaptation period.

Slaughtering Procedure

Kids were slaughtered at 22 to 24 kg of BW. They were weighed the day before slaughter, and their fasted BW was taken just before slaughter. After slaughter, the full digestive tract (**DT**) was removed, weighed, and separated into its component parts. The peritoneal fat was removed and weighed. Dressed carcasses were weighed within 1 h (**HCW**), and were then chilled for 24 h at 4°C and reweighed (cold carcass weight; **CCW**). Each cold carcass was rated (from 1 to 5) according to conformation, internal fat, and external fat based on a lamb BW grid (OFIVAL, 2005). The perirenal fat and the kidneys were removed and weighed separately. The carcass was then cut in half lengthwise, and the left side was cut according to the method of Colomer-Rocher et al. (1987) into 5 joints (shoulder, neck, ribs, flank, long leg) and weighed.

Given that the shoulder is considered as an adequate and cost-effective joint on which to assess the carcass composition in kids (Arguello et al., 2001), the right shoulder was removed, frozen, and stored (−22°C) for 2 mo. The shoulders were then cut frozen with a Magurit machine (Unitcut 545 SC model, Magurit Gefrierschneider GmbH, Remscheid, Germany), ground using a 3-mm grid (Biro AFMG 48/52, Biro, Serris, France), and homogenized. Aliquots were freeze-dried and stored (−22°C) until the animals were slaughtered. The maximum storage times did not exceed 5 mo (groups G300 and G200), 3.5 mo (group 100), and 2 mo (group G0) before chemical analysis.

Chemical Analyses and Physical Measurements

The DM contents of feeds were determined by oven-drying (Type SE-79, Le Matériel Physico-Chimique Flam et Cie, MPC, Neuilly S/Marine, France) to a constant weight at 60°C for 48 h (AOAC, 1997), whereas ash content was determined by heating samples at 550°C for 12 h according to AOAC (1997); thereafter, the OM content was calculated by the difference. Dry samples were obtained for further chemical analyses and were ground (model SK100 confort Gußeisen, F. Kurt Retsch GmbH & Co, Haan, Germany) to pass through a 1-mm stainless steel screen. The CP content was calculated after nitrogen determination by combustion using the micro-Dumas method (NA2100 Protein, CE Instruments, ThermoQuest S.p.A., Milan, Italy). The method of Van Soest et al. (1991) was followed to determine NDF and ADF (sequentially) on an ash-free basis with an Ankom²⁰⁰ Fiber Analyzer incubator (Ankom Technology, Fairport, NY). The hemicellulose and cellulose contents of ingredients were calculated as

the differences between NDF and ADF and between ADF and ADL, respectively.

Different evaluations were made on the cold carcass. The ribeye area of the fourth rib on the left side was removed to evaluate the color with a Minolta CR-300 chromameter calibrated to a white standard, using the L*, a*, b* scale (CIE, 1986). Ultimate pH was measured on the sample used to analyze color with a Bioblock Scientific IP67 pH probe (Fischer Bioblock Scientific, Illkirch-Graffenstaden, France) calibrated to pH 4 and 7 by using buffer standards.

Cooking loss was evaluated in refrigerated meat samples (rib area of the fifth rib) individually placed inside polyethylene bags in a water bath at 75°C. Samples were heated to an internal temperature of 70°C, monitored with thermocouples introduced in the core, and cooled for 15 min under running tap water. They were taken from the bags, dried with filter paper, and weighed. Cooking loss was expressed as the percentage of loss related to the initial weight.

The entire shoulder was ground, and a homogeneous sample was taken, freeze-dried, and stored (−22°C) as described above. The aliquots were finely ground in a ball grinder (Dangoumill 300, Prolabo, Paris, France) to determine DM, mineral matter, and CP, as described above. The total lipid (ether extract) was determined via the Soxhlet extraction method by using petroleum ether as the solvent and was determined gravimetrically after evaporating the solvent (AOAC, 1997).

Data Calculations and Statistical Analyses

Empty BW (**EBW**) was computed by subtracting the weight of the gut content from the slaughter weight. Dressing percentage was calculated as the ratio of the HCW on BW at slaughter (HCW/slaughter weight) and cold carcass yield was the CCW related to the EBW (CCW/EBW).

The DM deposited in the shoulder was calculated as the shoulder weight multiplied by the DM content (%) in the shoulder. The protein and lipid deposits in the shoulder were then calculated by multiplying the DM deposited in the shoulder by the CP content (%) and the lipid content (%), respectively. According to the reports of Frayssé and Darré (1990), the caloric value of retained protein was assumed to be 23.79 MJ/kg of protein and that of retained fat was assumed to be 39.20 MJ/kg of fat. These caloric values were multiplied by the protein and lipid deposits in the shoulder, respectively, to assess the caloric value retained in the protein and lipid deposits, respectively.

The experimental unit was the animal because intake, growth, and carcass traits were assessed individually. Data were analyzed using the GLM procedure (SAS Inst. Inc., Cary, NC) with level of nutritional regimen as the main effect in the model. Carcass traits, except those calculated as a proportion of BW, were studied with slaughter weight used as a covariable, which was

Table 2. Ingredient, chemical composition, and feeding value of the different components of the diet

Item	Tropical forage	Commercial pellet ¹
DM, ² %	23.3	88.9
Chemical composition, ² g/kg of DM		
CP	108	209
Ether extract	14	25
NDF	686	168
ADF	328	47
ADL	35	17
Tabulated value, ³ per kg of DM		
GE, MJ	12.6	19.5
ME, MJ	8.8	13.6

¹Composition per kilogram (as-fed basis): 680 g of corn grain, 150 g of soybean cake, 110 g of wheat bran, 10 g of urea, and 50 g of vitamin and mineral supplement.

²Nutrient composition based on laboratory analyses.

³Values from tabular nutrient values for tropical forages (Aumont et al., 1991) and pellet ingredients (Savant et al., 2002).

kept in the model only when significant ($P < 0.05$). Carcass quality scores and fat weights were studied with carcass weight used as a covariable, which was kept in the model only when significant ($P < 0.05$). The least squares means procedure (PDIF option, SAS Inst. Inc.) was used to compare means when a significant F -value was obtained. Significant effects were considered at $P < 0.05$ and trends were considered at $P \leq 0.10$.

Regressions (linear and quadratic terms) were computed (REG procedure, SAS Inst. Inc.) to predict BW gain according to supplement intake of the finishing kids and also to predict the different deposits (mass or caloric values) according to energy intake.

RESULTS

Intake

The chemical composition of the forage was 100, 686, 328, and 35 g/kg of DM for CP, NDF, ADF, and ADL, respectively. After 1 mo of adaptation, the animals in groups G100 and G200 always ate all the concentrate, whereas the amount of intake in G300 varied and was

310 g/d on average. Total DMI (Table 3) increased at the same time as the inclusion ratio of the concentrate in the diet, whereas forage DMI decreased (12% less) from forage-fed kids to supplemented ones. The forage intake then remained similar among groups G100 to G300. The energy and CP intakes varied significantly ($P < 0.01$) among feeding groups.

Nutrient Utilization for Growth

Growth ($P < 0.01$) increased from groups G0 to G300 during the finishing period (Table 3). The prediction of ADG (g/d) in terms of percentage of concentrate (**pc**) in the diet was curvilinear:

$$\text{ADG (g/d)} = 41.40 (\pm 0.909) + 1.662 (\pm 0.4167)\text{pc} \\ - 0.02004 (\pm 0.0081)\text{pc}^2, (n = 40; R^2 = 0.60; \\ \text{RSD} = 12.36; P < 0.01),$$

where RSD = residual SD.

Prediction of ADG (g/d) in terms of concentrate DMI per kilogram of BW^{0.75} (DMICmw; g/BW^{0.75}) was

Table 3. Intake and growth performance of fattening Creole kids according to level of nutritional density¹

Item	G0	G100	G200	G300	SEM
Total DMI, g/d	415 ^a	498 ^b	575 ^c	655 ^d	48.2
Forage DMI, g/d	415 ^a	373 ^b	363 ^b	379 ^b	34.4
Total DMI, g/kg of BW ^{0.75}	51.4 ^a	53.8 ^b	66.7 ^c	78.3 ^d	5.63
Forage DMI, g/kg of BW ^{0.75}	51.4 ^a	41.2 ^b	42.4 ^b	42.7 ^b	3.99
ME intake, MJ/d	3.35 ^a	4.61 ^b	6.02 ^c	7.00 ^d	0.45
ME intake, MJ/kg of BW ^{0.75}	2.56 ^a	3.50 ^b	4.61 ^c	5.38 ^d	0.31
Total lipid intake, g/d	6 ^a	8 ^a	11 ^b	13 ^b	0.9
Total CP intake, g/d	41 ^a	62 ^b	85 ^c	98 ^d	6.6
G:F, g/kg	101 ^a	122 ^b	125 ^{bc}	127 ^c	12.3

^{a-d}Means within the same row with different superscripts differ significantly ($P < 0.01$).

¹The G0 group received the basal diet (tropical forage ad libitum) without concentrate, the G100 group received the basal diet plus 140 g (fresh material) of concentrate/kid per day, the G200 group received 240 g of concentrate/kid per day, and the G300 group received 340 g of concentrate/kid per day.

Table 4. Carcass weights, yields, quality scores, and proportions of retail cuts of fattening Creole kids according to level of nutritional density¹

Item	G0	G100	G200	G300	SEM
Age at slaughter, d	402 ^a	333 ^b	290 ^c	272 ^d	58.4
Slaughter weight, kg	22.5	23.6	22.6	23.3	1.8
Cold carcass weight, kg	8.9 ^a	10.6 ^b	11.1 ^b	12.3 ^c	0.8
HCW, kg	9.3 ^a	11.0 ^b	11.6 ^{bc}	12.9 ^c	0.9
Empty BW, kg	15.3 ^a	18.7 ^b	18.4 ^b	19.2 ^b	1.5
Dressing, ² %	42 ^a	47 ^b	51 ^c	51 ^c	2.6
Carcass output, ³ %	59	56	61	59	2.7
Conformation score ⁴	3.2 ^a	3.4 ^a	4.0 ^b	3.6 ^b	0.5
External fat score ⁴	2.0	2.1	2.6	2.4	0.8
Internal fat score ⁴	2.4 ^a	3.1 ^b	3.7 ^c	4.1 ^c	0.7
Color score ⁴	2.5 ^a	2.3 ^a	2.0 ^b	2.1 ^b	0.4
Shoulder proportion, %	19.3	19.8	19.7	19.5	0.98
Neck proportion, %	12.7	13.2	13.2	12.5	1.58
Breast proportion, %	14.2	15.1	15.0	15.0	1.17
Leg proportion, %	30.8	30.5	29.6	30.7	1.85
Rib + loin proportion, %	23.0	21.4	22.5	22.3	1.89

^{a-d}Means within a row without a common superscript letter differ ($P < 0.01$); the covariable slaughter weight in the GLM model was significant ($P < 0.01$) for most of the items except for carcass yields; the covariable carcass weight in the GLM model was significant ($P < 0.01$) for most of the items except for fat and color scores.

¹The G0 group received the basal diet (tropical forage ad libitum) without concentrate, the G100 group received the basal diet plus 140 g (fresh material) of concentrate/kid per day, the G200 group received 240 g of concentrate, and the G300 group received 340 g of concentrate.

²Dressing percentage = HCW/slaughter weight.

³Carcass output = cold carcass weight/empty BW.

⁴Conformation, fat, and color scores were determined according to OFIVAL (2005), on a scale from 1 to 5.

linear (the quadratic terms were not significant $P > 0.05$):

$$\begin{aligned} \text{ADG (g/d)} &= 42.28 (\pm 3.893) + 1.247 (\pm 0.1649) \\ &\times \text{DMICmw (g/BW}^{0.75}), (n = 40; R^2 = 0.67; \\ &\text{RSD} = 12.76; P < 0.01). \end{aligned}$$

Prediction of ADG (g/d) in terms of ME intake (MEI; MJ/d) was linear (the quadratic terms were not significant $P > 0.05$):

$$\begin{aligned} \text{ADG (g/d)} &= 0.570 (\pm 0.938) + 12.565 (\pm 1.335) \\ &\times \text{MEI (MJ/d)}, (n = 40; R^2 = 0.76; \\ &\text{RSD} = 10.91; P < 0.01). \end{aligned}$$

The G:F increased with the addition of concentrate to the ration (25 to 30 points more) between kids fed forage and those receiving concentrate as well (Table 3). No difference was observed between the kids that received the 2 greatest amounts of concentrate (G200 and G300).

Carcass and Noncarcass Components

Carcass weight and dressing percentage (Table 4) increased ($P < 0.01$) with the addition of concentrate to the ration. The type of diet did not have a significant effect on the cold carcass yield. A difference ($P < 0.01$) was observed for the EBW (3 to 4 kg between kids fed

forage and kids fed mixed diets) even though the animals were slaughtered at a statistically identical BW. The proportions of carcass cuts (Table 4) were similar ($P > 0.05$) regardless of the feeding groups of the kids.

Feeding system had an effect on abdominal fat deposits ($P < 0.01$; Table 5), mainly attributable to heavier peritoneal and kidney fat ($P < 0.01$) in G300 kids, 2.3-fold more compared with their G0 counterparts. The main offal components, classified as DT, red organs (liver, heart, lungs, kidneys), and head, skin, feet (**HSF**), are presented in Table 5. As for the DT, forage-fed kids had a heavier reticulorumen ($P < 0.01$) and large intestine, whereas weights of the small intestine were less, but values for these last traits did not reach significance. Differences ($P < 0.05$) were observed for the total weight of the white offal and the proportion of white offal relative to EBW for G0 kids as compared with the other 3 groups. In relation to red organs, concentrate-fed kids had heavier ($P < 0.01$) liver weights, whereas kidney, heart, and lung weights were not affected by the feeding system. The skin from supplemented kids was heavier ($P < 0.01$) than that from kids fed forage only.

The caloric values of the different deposits according to diet group are represented in Figure 1, in addition to the prediction equations of these traits in terms of ME intake (MJ/d). The quadratic terms of the equations did not reach significance. The rate of energy use was significantly (comparison of slopes, $P < 0.01$), 54-fold, greater in the caloric value of abdominal fat tissues than in the caloric value of protein deposits in

Table 5. Weights of offal and noncarcass components of fattening Creole kids according to level of nutritional density¹

Item	G0	G100	G200	G300	SEM
Gut fill, g	7,266 ^a	4,828 ^b	4,220 ^c	4,186 ^c	1,341
Reticulorumen, g	611 ^a	541 ^b	464 ^c	521 ^d	68
Omasum, g	70	64	60	57	12
Abomasum, g	120	124	100	82	18
Small intestine, g	274	242	383	396	88
Large intestine, g	449	445	398	375	45
Omental fat, g	190 ^a	225 ^b	319 ^c	454 ^d	106
Kidney fat, g	113 ^a	139 ^b	255 ^c	253 ^c	83
Intestinal fat, g	275 ^a	277 ^a	392 ^b	388 ^b	73
Head, g	1,731	1,803	1,849	1,837	77.4
Feet, g	516 ^a	601 ^b	608 ^b	658 ^c	39.2
Skin, g	1,312 ^a	1,742 ^b	1,783 ^{bc}	1,856 ^c	140.1
Heart + trachea + lung, g	387	473	474	472	68
Liver, g	304 ^a	345 ^b	352 ^b	375 ^c	36
Kidney, g	53	54	58	59	6

^{a-d}Means within a row without a common superscript letter differ ($P < 0.01$); the covariable slaughter weight in the GLM model was significant ($P < 0.01$) for most of the items except skin weight; the covariable carcass weight in the GLM model was significant ($P < 0.01$) for most of the items except for fat weights.

¹The G0 group received the basal diet (tropical forage ad libitum) without concentrate, the G100 group received the basal diet plus 140 g (fresh material) of concentrate/kid per day, the G200 group received 240 g of concentrate/kid per day, and the G300 group received 340 g of concentrate/kid per day.

the shoulder. The use of energy for the caloric value of protein deposits in the shoulder was 1.7-fold greater ($P < 0.01$) than for the caloric value of lipid deposits.

Carcass Quality

Nutritional level did not have a significant effect on fat cover score (Table 4). The quantity of concentrate in the ration significantly ($P < 0.05$) influenced the internal fat score. This was 1.5 points more from one extreme of the groups to the other. In addition, there was a significant ($P < 0.01$) effect of supplementing concentrates on the weight of the peritoneal, intestinal, and kidney fat tissues. The latter increased by 2.2-fold from the group without concentrate in the ration to the group that was fed the maximum percentage of concentrate. A significant variation ($P < 0.05$) was observed on carcass conformation scores, with the least score attributed to forage-fed kids.

Diet had an effect ($P < 0.01$) on the ultimate pH and on the cooking loss of the meat (Table 6) but had no effect on the color variables L* (lightness) and b* (yellowness). The a* color parameter, accounting for redness, was less ($P < 0.05$) in group G300 compared with the 3 other treatments. The ash, lipid, and CP ratios for the carcasses did not vary significantly in relation to group (Table 6), whereas the DM content did ($P < 0.05$).

DISCUSSION

Intake

The increase in total feed intake with increasing amount of concentrate in the diet is in agreement with

previous studies showing that the addition of energy and protein pellets resulted in improvements in total digestibility and DMI with goats fed temperate (Morand-Fehr, 1991) and tropical forages (Haddad, 2005).

The DMI of Creole kids fed mixed diets (groups G200 and G300) were similar to those reported for other tropical breeds when expressed relative to metabolic BW (Haddad, 2005; Phengvichith and Ledin, 2007; Sanon et al., 2008). However, these intakes were less than those reported by Fernandes et al. (2007) or Ryan et al. (2007) for Boer crossbred goats, likely because of the greater amounts of concentrate in the diets and greater BW.

Nutrient Utilization for Growth

Kid ADG increased progressively with the increasing nutritional density of the diet. The growth value (42 g/d) observed for the G0 group (i.e., kids fed on grass alone) was greater than the values reported by Zemmelink et al. (1991) in West Africa and by Alexandre et al. (1997) in Guadeloupe, with tropical kids raised on pasture. This could be explained by the exposure to parasitic infestations (Mandonnet et al., 2003) associated with pasture grazing compared with indoor feeding.

Analysis of the equation that predicted growth in terms of concentrate intake indicated that the growth potential of animals used in the experiment was 84 g/d. Greater growth values (120 g/d) were found previously for tropical goats (Mahgoub et al., 2005; Ryan et al., 2007), but the animals were fed high-energy diets (60 to 80% of concentrate in the diet). Moreover, the relative growth rate, calculated as the ratio of ADG to birth weight, reached 4.5% for Creole bucks and was very similar to rates reported in the cited studies (Omani,

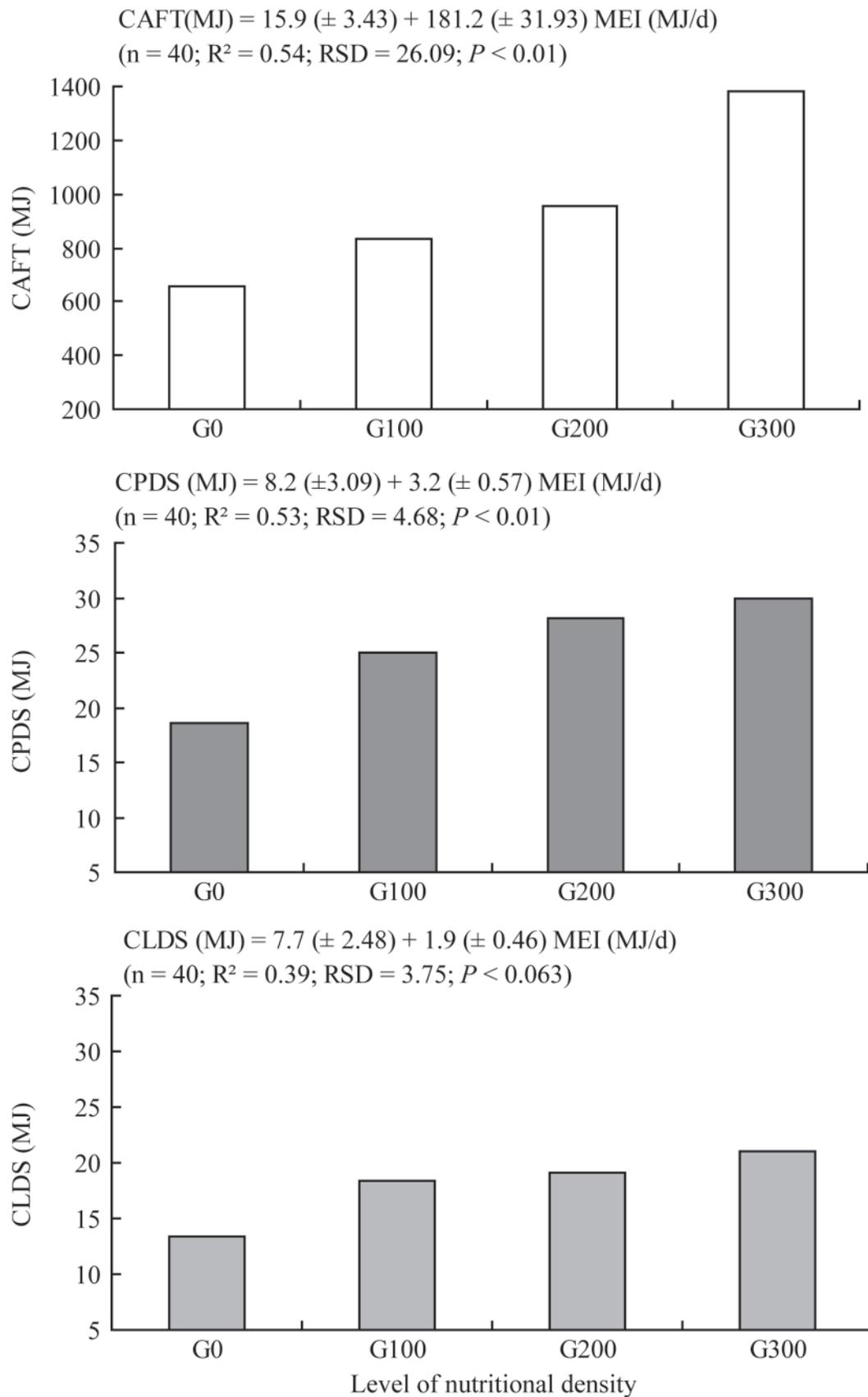


Figure 1. Calculated caloric values (MJ) of abdominal fat tissues (CAFT; top panel), protein deposits in the shoulder (CPDS; middle panel), and lipid deposits in the shoulder (CLDS; bottom panel) according to the nutritional density of the diets and terms of regression of these traits against ME intake (MEI; MJ/d). The G0 group received the basal diet (tropical forage ad libitum) without concentrate, the G100 group received the basal diet plus 140 g (fresh material) of concentrate/kid per day, the G200 group received 240 g of concentrate/kid per day, and the G300 group received 340 g of concentrate/kid per day. RSD = residual SD.

Table 6. Ultimate pH and instrumental color variables measured on LM and chemical composition of the shoulder of fattening Creole kids according to level of nutritional density¹

Item	G0	G100	G200	G300	SEM
Physical measurement					
Cooking loss, %	33.0 ^a	31.5 ^a	24.4 ^b	25.6 ^b	4.5
Ultimate pH	5.69 ^a	5.84 ^a	5.56 ^b	5.52 ^b	0.1
L (lightness)	39.5	41.5	40.9	40.3	2.3
a (redness)	17.0 ^a	16.9 ^a	16.7 ^a	14.9 ^b	1.7
b (yellowness)	5.1	6.3	5.9	4.6	1.6
Chemical composition					
DM, %	31.2 ^a	32.9 ^b	33.7 ^c	33.2 ^{bc}	1.1
Ash, g/kg of DM	9.4	11.1	10.2	10.6	0.9
Total lipids, g/kg of DM	28.2	28.6	29.5	27.2	2.6
CP, g/kg of DM	62.2	61.8	62.3	63.4	5.4

^{a-c}Means within a row without a common superscript letter differ ($P < 0.05$).

¹The G0 group received the basal diet (tropical forage ad libitum) without concentrate, the G100 group received the basal diet plus 140 g (fresh material) of concentrate/kid per day, the G200 group received 240 g of concentrate/kid per day, and the G300 group received 340 g of concentrate/kid per day.

4.1%; crossbred Boer, 4.3%). Based on these traits, there seemed to be some scope for improvement of meat production with the indigenous Caribbean goat reared under adequate feeding systems. In essence, the relatively good levels of growth observed could be proof of the good quality of the diets, their effective utilization by the animal, or both. The G:F ratio could assess the biological efficiency of this tropical genotype, because it is a trait used in breed comparison or evaluation, given its economic impact (Urge et al., 2004; Mahgoub et al., 2005; Shrestha and Fahmy, 2007). The G:F ratios, which were calculated to be approximately 100, may be low but this could be explained by the fibrous nature of the basal diet made of tropical forage, which is known for its high fiber content (Humphreys, 1991) and which is frequently reported for goats fed an unbalanced diet (Mahgoub et al., 2005; Almeida et al., 2006). The values of 125 to 130 obtained in our study for diets with increased energy and protein intakes were satisfactory and were within the range of values available in the literature ($n = 63$ papers) reviewed by Luo et al. (2004). The values reported in tropical studies for goats reared in similar conditions were 125 (Crossbred Boer; Ryan et al., 2007) and 133 (Omani Batina; Mahgoub et al., 2005).

Further studies are required to model the kid growth curve, as was done by Tsukahara et al. (2008), with more experimental data that could be implemented under varying feeding conditions. Probably there could have been a curvilinear answer, which seemed to be reflected in the feed conversion ratio. The quadratic terms of the regression equation did not reach significance. However, the G:F did not vary between the G200 and G300 groups. It could be deduced, from an economic point of view, that the supply of supplement with adequate-quality grass for optimal growth would be approximately 3.69 MJ of ME/d (achieved with 240 to 310 g/d of concentrate in our experiment). This could make it possible to establish recommendations for intensive finishing systems for Creole kids in Carib-

bean zones. Given that the local demand for goat meat far exceeds local production, the potential exists for development of the local goat meat market (Alexandre et al., 2008). Consequently, there is a tendency toward intensification of production systems (Mahieu et al., 2008) to increase the goat meat offered in the commodity chain.

In fact, we had some difficulty assessing the nutrient requirements of indigenous kids because the literature on tropical goats is contradictory; the energy requirement (ME in kJ) for 1 g of ADG was estimated to be 38.1 (Zemmelink et al., 1991; West African Dwarf), 24.3 (Mandal et al., 2005; Indian goats), and 19.8 (Luo et al., 2004; diverse indigenous goats).

Comparison of the different slopes in the regression equations for deposits and ME intakes would suggest that these hardy indigenous animals preferentially tended to deposit more abdominal fat tissue than protein mass, and finally lipid mass. This apparent differential use of energy for different deposits must be studied further to have a better description of the composition of gain in growing Creole kids and to provide more adequate feed recommendations, as stated by Sahlou et al. (2004).

Carcass Yields and Cuts

The carcass weight and the dressing percentage of Creole kids improved with the progressive addition of concentrates in the diet, although the effect of slaughter weight was not a factor in our study. The greater dressing percentage for G200 and G300 animals was probably due to better body development as well as a lighter DT. Cold carcass output relative to EBW did not differ significantly from one group to another. The present yield (mean of 59%) was in the upper range of the values reported by Cameron et al. (2001), Mahgoub et al. (2005), and Sen et al. (2004). This was an encouraging result for these first intensive finishing experiments with this hardy tropical genotype. Confor-

mation scores were also affected by additional energy intake. These observations are in line with previous works demonstrating that the level of energy in the ration significantly affected carcass traits (Haddad, 2005; Mahgoub et al., 2005; Ryan et al., 2007; Sanon et al., 2008).

The increase in weights of primal carcass cuts was directly related to the increase in carcass weight. The proportion of carcass in the total of the leg, shoulder, and neck remained similar (approximately 63%) regardless of the group. The leg represented 30% of the carcass and varied on the same scale as the well-conformed genetic breeds (28 to 33%), as reported by Sen et al. (2004), Webb et al. (2005), and Ryan et al. (2007).

Offal and Noncarcass Components

Determination of the weight of the offal and noncarcass components is of interest because of their large contribution (>50%) to maintenance energy expenditure (Ortigue, 1991). The progressive inclusion of pellets in the diet had an increasing effect on abdominal fat deposits as well as on the internal fat score, which is related to the kidney and pelvic fat. Similar conclusions have been reported in the literature on goats; however, the trend for increasing fat weights was less in the current study (2.3-fold more) than in other studies (3- to 4-fold more). For example, Phengvichith and Ledin (2007) reported 800 vs. 200 g of peritoneal fat, and Ryan et al. (2007) reported 760 vs. 250 g of perirenal fat for supplemented vs. nonsupplemented kids, respectively. In addition, the increase in fat weights was less in our study than in other studies because of the decreased concentrate level used in the present study (58% compared with 90%). The abdominal fat deposits represented 4% of the EBW, whereas other authors reported 6 to 7% (Cameron et al., 2001; Sen et al., 2004; Phengvichith and Ledin, 2007). Regardless of the feed level and the internal fat weights, the Creole kid carcasses had an acceptable fat cover score (from 2 to 2.6 on a scale ranging from 1 to 5) because consumers in Guadeloupe value low-fat goat meat (Alexandre et al., 2008). Goats are well known to have fat deposits mainly in the abdominal cavity (Kempster, 1981). We must maintain this apparent ability of Creole kids to deposit less external fat by using an adapted feed strategy in order not to depreciate the carcass and to avoid a detrimental long-term impact on human health. In addition, comparison of the slopes for use of energy intake in terms of different deposits and fat tissues showed that the Creole goat had a greater tendency to deposit fat tissues in the abdomen and had less tendency to deposit fat tissues in muscle. Further studies are required to increase the database for a better description of tissue partitioning.

The feeding system influenced the weight of the red organs, DT, and HSF, but the proportions in relation to EBW were similar among kids fed mixed diets. Breed, age, sex, and slaughter weight are the main factors

that influence the noncarcass weight (Warmington and Kirton, 1990). In the present study, breed and slaughter weight were fixed factors, whereas age at slaughter was determined by the ADG, depending on the feeding system that affected noncarcass weight. Increasing concentrate amounts reduced reticulorumen weights and large intestine weights, whereas the weights of the small intestine increased. A possible explanation is that in kids fed forage diets, the large amounts of digesta present in the DT would give rise to net tissue growth (Wester et al., 1995). Digesta were not assessed per se, but the increasing gut fill would support this hypothesis. Moreover, the DT could be affected by the physical characteristics of the diet. Kouakou et al. (1997) reported with sheep that the physical attributes of low- to moderate-quality tropical grasses affected mass and energy consumption by splanchnic tissues.

Regarding the red organs, forage-fed kids had lighter liver weights, whereas kidney, heart, and lung weights were not affected by the feeding system. These results are in line with the conclusions of Haddad (2005) in goats. Joy et al. (2008) reported in sheep that the weight of offal components with low metabolic activity varied slightly with diet, given that these components are early maturing and are less affected by dietary effects in growing, compared with mature, animals. On the other hand, the lighter liver weights would be in accordance with a decreasing plane of nutrition, eliciting a reduced metabolic rate and mass of metabolically active tissue, such as the liver (Wester et al., 1995).

The weights of the head and feet were greater for the G300 kids, and this could be linked to their age at slaughter, which was younger than for their counterparts. These results are in agreement with the report of Hammond (1962), who found that bones develop quickly in the early stages of life to support muscle growth. The greater weights and proportions of skin in the G300 carcasses were similar to data reported elsewhere (Ngwa et al., 2007; Sebsibe et al., 2007).

Carcass Quality

The cooking loss varied according to the feeding levels of the kids, contrary to the conclusions of Kannan et al. (2006) and Madruga et al. (2008), who observed that dietary treatment did not have an effect on this trait. However, these authors did not have forage-fed kids in their experiment; in addition, variations attributable to genotype have been reported (Dhanda et al., 1999; Kadim et al., 2004), which could explain the differences between the cited studies. Differences in cooking loss are often linked to differences in ultimate pH and fat content. In our study, decreased pH and greater fat proportions were observed for G300 kids, compared with G0 kids, and are in line with their decreased cooking loss. The limited fat content in the meat of G0 kids possibly exacerbated cooking losses, as reported by Webb et al. (2005). The values observed in the present study seemed to be less than those reported frequently

by others (Webb et al., 2005). The cooking loss of goat meat is of interest, because the water retained in the cooked product is the major contributor to the attribute of juiciness (Webb et al., 2005). It is therefore recommended that in the future, the eating quality of Creole goat meat be assessed by way of sensory evaluation.

The color variables recorded in the present study were within the range of values reported by Abdullah and Musallam (2007) and Lee et al. (2008). Values for the L^* and b^* parameters did not reach significance. This is in agreement with results in the native black goat of Jordan reported by Abdullah and Musallam (2007), who found that these variables were not affected by nutritional regimen. The a^* parameter (redness) of the G300 meat was less than for the others. This effect of concentrate intake was probably an indirect effect via growth rate. In fact, the G300 kids were younger when slaughtered than the kids on other treatments, and a darker red color is associated with older animals, such as those consuming decreased amounts of supplement. It is generally reported that a red meat characterizes mature animals because of their greater concentration of muscle pigment (Frayssé and Darré, 1990).

The chemical composition of the carcass was within the values reported by Frayssé and Darré (1990). A similar increasing effect of supplement amount on DM content has been reported in the carcass (Mahgoub et al., 2005; Almeida et al., 2006; Fernandes et al., 2007) or in lean tissue (Abdullah and Musallam, 2007; Lee et al., 2008). Lipid content did not change in our experiment because the amount of energy used was less than in other studies in which increased fat deposition was observed. In the present study, the kids were slaughtered at a similar slaughter weight among treatments, whereas the slaughter weights were different within groups in the cited experiments (at least 10 kg difference), inducing different fattening levels. In addition, the different conclusions of the different experiments were linked to the kid breed. It is known that variations exist between goat genotypes in carcass composition and tissue partitioning (Dhanda et al., 1999; Oman et al., 1999).

The question with an indigenous hardy genotype such as the Caribbean Creole goat is how to increase the carcass weight and conformation with increasing energy density in the diet while producing lean and desirable meat. Under an adequate nutritional regimen, the Caribbean Creole goat appeared as an acceptable meat-producing animal, even though it is not selected for this trait. In this initial experimental phase, dose-effect relationships were studied by using concentrate supplements for goats in confinement conditions to establish adapted recommendations for intensive finishing of indigenous goats in the Caribbean basin zones. As prices of grain and other feedstuffs increase because of the global energy situation, nutrition research may be dominated by studies that optimize the feeding of

by-products (Moore et al., 2002). An optimal supply of supplement with adequate-quality grass would be approximately 3.69 MJ/d of ME. By increasing the nutritional density, it was possible to obtain desirable carcasses, with no excessive fattening. However, increased concentrate consumption can alter the fatty acid profile in goat meat resulting from changes in the activity of rumen bacteria (Banskalieva et al., 2000). Bas et al. (2005) reported that the lipid and cholesterol content of muscles was greater in goats raised indoors and fed concentrate than in those raised outdoors under the harsh conditions of Morocco. In our conditions, the goat meat fatty acid composition deserves more research attention, especially when intensive systems of nutrition are being tested to increase goat meat production. For the group fed without the addition of concentrate, the daily growth rate was nevertheless significant, which means that when tropical forage is managed effectively (Archimède et al., 2000), it remains a good basal diet for native tropical goats.

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