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REGULAR ARTICLES

Performance and characteristics of carcass and non-carcass components of lambs fed peach-palm by-product

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Abstract The objective of this study was to evaluate the effects of supplying the by-product of peach-palm (*Bactris gasipaes*) on performance and characteristics of carcass and non-carcass components of feedlot lambs. Twenty Santa Ines lambs of 150 days average age and 22.4±3.4 kg body weight were confined in individual pens. A completely randomized design was utilized with four experimental diets composed of: fresh peach-palm by-product enriched with urea, fresh peach-palm by-product + concentrate, silage of peach-palm by-product + concentrate, and silage of peach-palm by-product enriched with 15 % corn meal + concentrate. Intake was evaluated daily, and at the end of 42 days of experiments, lambs were slaughtered and the characteristics of carcass and non-carcass parts were evaluated. Performance and carcass characteristics showed differences between the animals' intake of total mixed rations (TMR) and only the diet with roughage. For the lambs that intaked TMR, the form of utilization of roughage (fresh or as silage) affected animal performance but did not change the carcass characteristics. Dry matter intake and feed conversion were influenced by the form of utilization of the silage (with and without additive). Providing fresh by-product plus concentrate improves lamb performance but does not interfere in the carcass characteristics, compared with the use of by-product in the form of silage.

Keywords Alternative feedstuffs · Feedlot · Body weight gain · Ruminants

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Introduction

The total sheep flock in Bahia exceeds three million heads, which corresponds to approximately 18 % of the Brazilian herd (IBGE 2012), but due to the qualitative and quantitative seasonality of the pasture, which is the base of animal feeding, there is decrease in productivity in the dry period of the year. One alternative to avoid this situation is the utilization of alternative feed sources that can meet their nutritional requirements.

The cultivation of peach-palm (*Bactris gasipaes* Kunth.) for the production of heart of palm yield about 40 t/day of by-product in South Bahia. This by-product offers potential for use in the feeding of ruminants in its fresh form, right after the extraction of the heart, or preserved as silage. However, the production of silage from this by-product requires appropriate technology, since it presents undesirable characteristics for the silage production, such as the average dry matter (DM) content of 140 g/kg, a factor that increases the risks of secondary fermentation. In this situation, the use of additives such as corn meal can improve fermentation in the silo, once it increases the dry matter content of the ensiled material (Oliveira et al. 2010). Moreover, the addition of corn meal increases the energy value of the silage.

The objective of this experiment was to evaluate the performance and characteristics of carcass and non-carcass components of Santa Ines lambs fed with diets containing the agro-industrial by-product from peach-palm in its fresh form, as silage or as silage enriched with 15 % corn meal as roughage.

Materials and methods

Location and animals

The experiment was conducted in the Laboratory for Research in Ruminant Feeding and Nutrition, at the Department of Agrarian and Environmental Sciences of Universidade Estadual de Santa Cruz, in the municipality of Ilheus, Bahia, Brazil.

Twenty Santa Ines lambs with initial body weight (IBW) of 22.4±3.4 kg and average age of 150 days were utilized for the experiment. Lambs were identified, wormed, and confined in 0.96 m^2 individual pens of slatted floor provided with drinkers and troughs.

Experimental design and diets

The design was completely randomized, with four experimental diets which consisted of different forms of utilization of the peach-palm by-product: FU—fresh by-product enriched with urea, FP—fresh by-product + concentrate, SP—silage of the by-product + concentrate, and SPC—silage of the by-product enriched with 15 % corn meal + concentrate. The peach-palm by-product was composed of the inner bark, tip of the stems, and stems improper for the process of production of heart of palm. The roughage/concentrate ratio utilized in total mixed rations (TMR) FP, SP, and SPC was 40:60, based on the DM of the ingredients.

Experimental diets (Table 1) were formulated according to the nutritional requirements estimated by the NRC (2007) for an average gain of 200 g/day.

Diet FU was enriched with urea to provide 100 g/kg DM of crude protein (CP) in the total diet so that even with a low protein level there would be no detriment to rumen fermentation (Lazzarini et al. 2009). The other diets were formulated so as to contain the same amount of nitrogen with 160 g/kg DM CP (Table 1).

Lambs were fed twice daily (0800 and 1600 hours) and the amount supplied was adjusted daily according to the amount of orts from the previous day. Orts remained at around 100 g/kg of the total supplied, in order to promote feeding ad libitum.

Experimental period and data collection

Animals went through a period of 20 days for adaptation. Afterwards, they were weighed for determination of the IBW. Lambs were weighed three times for monitoring of their body development, at an interval of 14 days, totaling 42 days of experimental period. The last weighing determined the final body weight (FBW). All weighing sessions were conducted after a feed deprivation period of 16 h. For the calculation of average daily gain (ADG), the following formula was utilized: $ADG=(FBW-IBW)/\text{days in feedlot}$.

Intake (feed supplied—orts) was recorded daily for determination of dry matter intake (DMI) and feed conversion (FC), calculated by the formula $FC=DMI/ADG$.

After being deprived of solids for 16 h, lambs were weighed for determination of slaughter weight (SW) and stunned by brain concussion and section of the carotid artery and jugular vein.

After bleeding, gastrointestinal tract (GIT), respiratory tract, skin, head, paws, and genitals were removed and weighed for calculation of the hot carcass weight (HCW). All non-carcass parts were weighed separately.

Empty body weight (EBW) was calculated by the difference between SW and the weight of the gastrointestinal content. Subsequently, carcasses were transported to a cold storage compartment at 4 °C, where they were kept for 24 h. After cooling, carcasses were weighed again for determination of the cold carcass weight (CCW) and cooling loss ($CL\%=(HCW-CCW)/HCW\times100$).

Other variables obtained were as follows: hot carcass dressing ($HCD\%=HCW/SW\times100$), cold carcass dressing ($CCD\%=CCW/SW\times100$), and true dressing ($TD\%=HCW/EBW\times100$).

Tails were separated from the carcasses, which were sawn into half-carcasses with a band saw. Left half-carcasses were transversely sectioned between the 12th and the 13th ribs, exposing the transverse section of the longissimus dorsi muscle. Loin eye area (LEA) was determined with the aid of a plastic film, as described by Cartaxo et al. (2011). Back fat thickness (BFT) was measured at the same point with the aid of a digital caliper.

Linear measures internal carcass length (ICL), external carcass length (ECL), rump circumference (RC), leg length (LL), rump width (RW), and compactness index (CI) were obtained according to Gomes et al. (2011). Chest depth (CD) was measured according to Xenofonte et al. (2009).

The left half-carcass were divided into eight cuts (Furusho-Garcia et al. 2004), which were weighed separately. Internal fat was considered as the sum of mesenteric, omental, cavitary, and perirenal fats.

Statistical analyses

IBW was adopted as covariable for variables FBW, total weight gain (TWG), and ADG. The comparison among diets was made through decomposition of the sum of squares, related to this source by means of orthogonal

Table 1 Composition of ingredients and nutrients of experimental diets

Composition	Experimental diets			
	FU	FP	SP	SPC
Ingredients (g/kg DM)				
Fresh by-product	980	400	–	–
Silage of the by-product	–	–	400	–
Silage of the by-product enriched with 15 % corn meal	–	–	–	400
Ground corn	–	180	180	173
Soybean meal	–	407	407	417
Urea	10	3	3	–
Mineral mixture[a]	10	10	10	10
Nutrients (g/kg DM)				
Dry matter[b]	143	568	575	621
Organic matter	925	944	943	954
Crude protein	109	163	157	154
Ether extract	61	78	79	106
Neutral detergent fiber[c]	608	400	426	312
Acid detergent fiber[c]	458	225	255	131
Non-fibrous carbohydrates	147	303	282	383
Total digestible nutrients	605	754	789	891

FU fresh by-product enriched with urea, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate

[a]Composition: Ca—82 g/kg, S—11.7 g/kg, P—60 g/kg, Mg—13 g/kg, Na—132 g/kg, Cu—350 mg/kg, Co—30 mg/kg, Cr—11.7 mg/kg, Fe—700 mg/kg, F—600 mg/kg, I—50 mg/kg, Mn—1,200 mg/kg, Se—15 mg/kg, Zn—2,600 mg, Mo—180 mg

[b]In gram per kilogram as fed

[c]Corrected to ash and protein

contrasts (Table 2). The contrast (A) was performed to evaluate the effect of TMR in relation to the diet without concentrate. The contrasts designated by letters B and C allowed for evaluating the effect of the form of supply of roughage (fresh×silage) and the type of silage (without× with additive), respectively. Statistical procedures were conducted using the GLM procedure (Proc GLM; SAS, Version 9.2, 2008), adopting 0.05 as the critical level of probability for type I error.

Results

Lambs that received FU diet showed lower ($P<0.05$) FBW, TWG, ADG, and DMI values compared with those that received the TMR (Table 3). Among the animals that received the TMR, the group that was fed with FP diet showed higher ($P<0.05$) FBW, TWG, ADG, and DMI and better FC in relation to the groups that consumed peach-palm in the form of silage. Greater DMI and better FC ($P<0.05$) were observed for the lambs that consumed enriched silage in comparison with those that consumed the non-enriched silage.

The animals that received FU diet presented ($P<0.05$) values lesser for the carcass characteristics (Table 4) in relation to those fed with TMR, regardless of the form of utilization of the peach-palm by-product. Among the lambs that received the TMR, there was no difference ($P>0.05$) for these characteristics regardless of the form of utilization of roughage (Table 4).

As to the linear measures (Table 5), the carcasses of lambs which consumed the FU diet showed lower values ($P<0.05$) for ECL, RC, RW, CD, ICL, LEA, and BFT. The carcasses of the animals that received SPC diet presented greater BFT in comparison with those that received SP diet ($P<0.05$).

The carcasses of the lambs fed with FU diet were lighter ($P<0.05$) for all the cuts assessed (Table 6) in comparison with the carcasses of those receiving TMR. In the percentages concerning the half-carcass, there was difference ($P<0.05$) for the values of anterior arm, posterior arm, and chop.

Regarding the non-carcass components (Table 7), the group that received FU diet showed lower ($P<0.05$) weights for all components evaluated in relation to the groups fed

Table 2 Distribution of coefficients in the orthogonal contrasts employed in the decomposition of the sum of squares for treatments

Contrast[a]	Experimental diet			
	FU	FP	SP	SPC
A	+3	−1	−1	−1
B	0	+2	−1	−1
C	0	0	+1	−1

FU fresh by-product enriched with urea, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate

[a] Contrasts: A=FU×FP+SP+SPC, B=FP×SP+SPC, C=SP×SPC

Table 3 Initial body weight (IBW), final body weight (FBW), total weight gain (TWG), average daily gain (ADG), dry matter intake (DMI), and feed conversion (FC) according to experimental diets

Variable	Experimental diet				Mean	SEM	Contrast[a]		
	FU	FP	SP	SPC			A	B	C
IBW (kg)	20.56	23.26	22.72	23.04	22.40	–	–	–	–
FBW (kg)[b]	22.74	30.70	28.29	29.86	27.90	1.10	**	*	ns
TWG (kg)[b]	0.34	8.31	5.89	7.46	5.50	0.73	**	*	ns
GDA (kg/day)[b]	0.008	0.198	0.139	0.174	0.131	0.02	**	*	ns
DMI (kg/day)	0.445	1.002	0.764	0.889	0.775	0.04	**	**	**
DMI (g/kg BW)	21.63	35.16	29.29	32.68	29.69	0.77	**	**	**
FC (kg/kg)	54.79	5.06	5.51	5.10	17.63	4.92	**	**	**

ns not significant ($P>0.05$), *FU* fresh by-product enriched with urea, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate

*$P<0.05$; **$P<0.01$

[a] Contrasts: A=FU×FP+SP+SPC, B=FP×SP+SPC, C=SP×SPC

[b] Adjusted means by covariance

with TMR. No difference ($P>0.05$) was observed for the percentage of non-carcass components in relation to empty body weight.

Discussion

For a gain of 200 g/day in this animal category, the NRC (2007) estimates DMI of 0.590 kg/day or 29.7 g/kg BW. Considering the intake in kilogram per day, all TMR promoted the estimated DMI. For intake in gram per kilogram BW, however, only FP and SPC diets promoted the intake value estimated by the NRC (2007).

Research studies (Hubner et al. 2007; Lazzarini et al. 2009) have demonstrated high negative correlation between DMI and the neutral detergent fiber (NDF) content of the diet, associating this factor with the lower digestibility of the fibrous fraction in relation to the other dietary components, which may result in longer permanence of the digesta in the rumen–reticulum and consequently longer time for rumen fill. Hübner et al. (2007) observed that levels above 430 g/kg DM of NDF limited DMI in sheep. The concentration of 608 g/kg DM of NDF of the diet FU (Table 1) might have been what limited DMI. Also, the lowest concentration and source of CP, and the lack of synchronization between the CP and carbohydrate in FU diet, should have provided lower availability of nutrients and thus reducing weight gain in the lambs that received this diet.

Among the animals that received TMR, FP diet promoted higher DMI compared with the diets with silage, which

Table 4 Slaughter weight (SW), empty body weight (EBW), hot carcass weight (HCW), cold carcass weight (CCW), hot carcass dressing (HCD), cold carcass dressing (CCD), true dressing (TD), and cooling loss (CL) according to experimental diets

Variable	Experimental diet				Mean	SEM	Contrast[a]		
	FU	FP	SP	SPC			A	B	C
SW (kg)	20.02	29.92	26.94	29.02	26.48	1.09	**	ns	ns
EBW (kg)	15.22	25.55	22.01	24.30	21.77	1.07	**	ns	ns
HCW (kg)	8.04	14.30	12.29	13.77	12.10	0.68	**	ns	ns
CCW (kg)	7.75	14.01	12.01	13.47	11.81	0.68	**	ns	ns
HCD (%BW)	40.02	47.66	45.56	47.29	45.13	0.85	**	ns	ns
CCD (%BW)	38.59	46.69	44.52	46.25	44.01	0.88	**	ns	ns
TD (%BW)	52.60	55.86	55.73	56.54	55.18	0.55	**	ns	ns
CL (%HCW)	3.56	2.04	2.28	2.22	2.52	0.17	**	ns	ns

ns not significant ($P>0.05$), *FU* fresh by-product enriched with urea, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate

**$P<0.01$

[a] Contrasts: A=FU×FP+SP+SPC, B=FP×SP+SPC, C=SP×SPC

Table 5 Internal carcass length (ICL), external carcass length (ECL), leg length (LL), chest depth (CD), rump width (RW), rump circumference (RC), loin eye are (LEA), backfat thickness (BFT), and carcass compactness index (CI) according to experimental diets

Variable	Experimental diet				Mean	SEM	Contrast[a]		
	FU	FP	SP	SPC			A	B	C
ICL (cm)	55.44	58.46	59.90	59.14	58.24	0.99	ns	ns	ns
ECL (cm)	48.84	54.94	54.02	53.24	52.76	0.77	**	ns	ns
LL (cm)	45.16	48.06	43.98	48.12	46.33	1.04	ns	ns	ns
CD (cm)	22.78	25.46	25.40	25.76	24.85	0.41	**	ns	ns
RW (cm)	16.08	17.94	17.80	18.64	17.62	0.33	**	ns	ns
RC (cm)	49.00	57.32	54.92	58.06	54.83	1.02	**	ns	ns
LEA (cm^2)	5.94	12.24	10.54	12.27	10.25	0.71	**	ns	ns
BFT (cm)	0.02	1.61	1.15	2.42	1.30	0.23	**	ns	**
CI (kg/cm)	0.14	0.24	0.20	0.23	0.20	0.01	**	ns	ns

ns not significant ($P>0.05$), *FU* fresh by-product enriched with urea, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate

**$P<0.01$

[a] Contrasts: A=FU×FP+SP+SPC, B=FP×SP+SPC, C=SP×SPC

reflected in greater CCW, TWG, ADG, and better FC of the former in relation to the latter animals (Table 3). Studies with similar animal categories have found FC of 6.40 with bermudagrass hay (Fernandes et al. 2011), 5.38 with elephant grass hay (Lima et al. 2012), and 5.99 with pea straw (Ommer et al. 2010).

Table 6 Weights and proportions of cuts of lambs fed the agro-industrial by-product of peach-palm in different forms

Cut	Experimental diet				Mean	SEM	Contrast[a]		
	FU	FP	SP	SPC			A	B	C
Weight (kg)									
One half carcass	3.81	6.79	5.84	6.58	5.76	0.32	**	ns	ns
Neck	0.26	0.35	0.39	0.37	0.34	0.03	**	ns	ns
Shoulder	0.55	0.93	0.89	0.90	0.82	0.04	**	ns	ns
Chop	0.57	1.18	0.95	1.17	0.97	0.07	**	ns	ns
Leg	1.10	1.91	1.64	1.82	1.62	0.09	**	ns	ns
Anterior arm	0.20	0.28	0.27	0.29	0.26	0.01	**	ns	ns
Rib/flank	0.61	1.29	0.99	1.21	1.02	0.08	**	ns	ns
Posterior arm	0.23	0.33	0.27	0.32	0.29	0.01	**	ns	ns
Loin	0.26	0.45	0.39	0.43	0.38	0.02	**	ns	ns
Proportion (% half-carcass)									
Neck	7.02	5.11	6.68	5.81	6.16	0.28	ns	ns	ns
Shoulder	14.32	13.85	15.20	13.79	14.29	0.31	ns	ns	ns
Chop	14.97	17.37	16.23	17.80	16.59	0.45	*	ns	ns
Leg	28.79	28.04	28.10	27.87	28.20	0.30	ns	ns	ns
Anterior arm	5.19	4.16	4.67	4.37	4.60	0.12	**	ns	ns
Rib/flank	16.08	18.84	16.85	17.88	17.41	0.64	ns	ns	ns
Posterior arm	5.98	4.97	4.65	4.94	5.14	0.21	*	ns	ns
Loin	6.86	6.59	6.69	6.51	6.66	0.16	ns	ns	ns

ns not significant ($P>0.05$), *FU* fresh by-product enriched with urea, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate

*$P<0.05$; **$P<0.01$

[a] Contrasts: A=FU×FP+SP+SPC, B=FP×SP+SPC, C=SP×SPC

Table 7 Average weights of the non-carcass parts of lambs fed the agro-industrial by-product of peach-palm in different forms

Component	Experimental diet				Mean	SEM	Contrast[a]		
	FU	FP	SP	SPC			A	B	C
Weight (kg)									
Blood	0.80	1.39	1.20	1.16	1.14	0.060	**	ns	ns
Skin	1.66	2.72	2.30	2.58	2.32	0.125	**	ns	ns
Head	1.03	1.33	1.23	1.20	1.20	0.036	**	ns	ns
Paws	0.56	0.74	0.73	0.73	0.69	0.023	**	ns	ns
Tail	0.04	0.08	0.07	0.07	0.06	0.005	**	ns	ns
Heart	0.10	0.13	0.12	0.14	0.12	0.005	*	ns	ns
Kidneys	0.05	0.08	0.08	0.09	0.07	0.004	**	ns	ns
Spleen	0.04	0.06	0.06	0.08	0.06	0.005	**	ns	ns
Lung	0.17	0.30	0.29	0.33	0.27	0.020	**	ns	ns
GIT empty	0.59	0.80	0.78	0.80	0.75	0.027	**	ns	ns
Tongue	0.08	0.08	0.08	0.09	0.08	0.003	ns	ns	ns
Internal fat	0.28	1.15	0.83	1.02	0.82	0.092	**	ns	ns
Total NCC (%EBW)[b]	35.47	34.77	35.41	34.14	34.95	0.357	ns	ns	ns

ns not significant ($P>0.05$), *FU* fresh by-product enriched with urea, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate, *GIT* gastrointestinal tract

*$P<0.05$; **$P<0.01$

[a] Contrasts: A=FU×FP+SP+SPC, B=FP×SP+SPC, C=SP×SPC

[b] Total non-carcass components, in percent empty body weight

The greater nutrient uptake of the TMR promoted higher values for SW, EBW, HCW, CCW, HCD, CCD, and TD (Table 4). The greater CL observed in the carcass of animals that received FU diet was a result of the lower ($P<0.05$) BFT observed in these carcasses (Table 5), since fat works as a thermal insulator, acting mostly against dehydration, hardening, and darkening of the meat in the carcass.

The difference in fat thickness was due to the lower DMI and total digestible nutrients content of the diets, observed in the animals fed with the diet without concentrate, in comparison with the others, and in those that received silage without additive, in comparison with those that consumed the enriched silages, as demonstrated by Chay-Canul et al. (2011).

The lower value of the measures observed on the carcasses of lambs that received FU diet is a consequence of the lower development of these animals due to nutritional restriction. Among the variables observed, CI is the most expressive, since it indicates the deposition of tissue per unit of length. The CI of lambs that received the FU diet was lower ($P<0.05$) than the average presented by those fed with TMR (Table 6). The groups which received TMR did not present differences for CI, which had an average value close to those observed by Costa et al. (2011) with lambs fed with different levels of melon scraps in replacement of ground corn (0.22) and by Cartaxo et al. (2011) with lambs of different genotypes receiving two levels of energy in the diet (0.24).

The weight of cuts reflects the half-carcass weight; hence, why the lowest values were verified for the animals that received FU diet in comparison with those that received TMR (Table 6). Similar results were observed by Xenofonte et al. (2009), who verified lower weight for the cuts of the lighter carcasses.

The analysis of the proportions of cuts in relation to the half-carcass weight corroborates such discussion, since no differences were verified ($P>0.05$) in the percentages of cuts in relation to the half-carcass except for the proportions of anterior arm, posterior arm, and chop, which were different ($P<0.05$) between the group that received FU diet and the others. Heavier animals showed greater development in the flank region in relation to the limbs (Furusho-Garcia et al. 2004). Carvalho and Medeiros (2010) observed that the lambs which received diets with higher energy levels showed higher proportion of sidecut (chop + rib). The animals that received FP, SP, and SPC diets had better development of the central part of the carcass ($P<0.05$), especially chop, reducing the proportion of limbs in relation to half-carcass and thus differing in these variables in relation to the animals that received FU diet.

The lower weight of the non-carcass components of the lambs fed with FU diet (Table 7) indicates the lower overall development of the animals within this group. The absence of difference ($P>0.05$) in the proportion of total non-carcass components contributes to this hypothesis, since this value is obtained in relation to EBW. The average proportion of non-carcass components was similar to the average value found by Safari et al. (2011) in growing lambs.

Conclusion

The by-product of peach-palm with urea is capable of meeting only the requirements for maintenance and propitiates carcass characteristics of low quality. Santa Ines lambs fed with total mixed rations utilizing fresh peach-palm by-product as roughage show greater dry matter intake and average daily gain compared with those fed with total mixed rations utilizing the silage of the by-product; however, this difference is not observed when the carcass characteristics of lambs are evaluated.

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