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REGULAR ARTICLES

Silage or fresh by-product of peach palm as roughage in the feeding of lambs

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Abstract The objective of this study was to evaluate intake and apparent digestibility of agro-industrial by-product of peach palm in diets for lambs. Twenty castrated, crossbred Santa Ines lambs, with average age of 150 days and body weight of 22.4±3.4 kg, were distributed in a completely randomized design with four experimental diets composed of the following: fresh by-product of peach palm enriched with urea + ammonia sulfate (FU); fresh peach palm by-product + concentrate (FP); silage of peach palm by-product + concentrate (SP); and silage of peach palm by-product enriched with 15 % of cornmeal + concentrate (SPC). Intake was recorded daily, and the digestibility coefficients were estimated with the internal marker indigestible acid detergent fiber (iADF). Diet FU resulted in the lowest intake and digestibility of the nutrients evaluated. Animals receiving diet FP showed higher intakes of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), total digestible nutrients (TDN), and digestible energy (DE) in relation to animals fed diets SP and SPC. Diets SP and SPC showed higher coefficients of digestibility of DM, OM, CP, and NDF than diet FP. Diet SP reduced the intakes of DM, OM, ether extract (EE), non-fibrous carbohydrate (NFC), TDN, and DE and the digestibility coefficients of DM, OM, and NFC as compared with diet SPC. Feedlot lambs fed a diet with fresh peach palm by-product + concentrate (diet FP) have higher nutrient intake.

Keywords Alternative feedstuffs · Feedlot · Animal production · Ruminants

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Introduction

In the industrial production of the heart of peach palm (*Bactris gasipaes* Kunth.), approximately 350 kg of by-product is generated for every 300 kg of palm canned (Cabral et al. 2013). A large industry can generate up to 40 t of residue per day, which may cause environmental contamination if not properly managed. This by-product has a potential for use in the feeding of ruminants in its fresh form, right after extraction of the palm, or preserved as silage (Oliveira et al. 2010). However, the production of silage from this by-product requires the use of appropriate technologies, since it presents undesirable characteristics for ensilage, such as its average dry matter (DM) content of 140 g/kg of natural matter, which increases the risks of secondary fermentation. In this scenario, the use of additives such as cornmeal can improve the fermentation in the silo, because they elevate the dry matter content of the ensiled material (Andrade et al. 2012). In addition, the inclusion of cornmeal can increase the energy value of the silage.

Oliveira et al. (2010) found an average neutral detergent fiber (NDF) content of 723 g/kg DM and "in vitro" dry matter digestibility of 54,03 % in the fresh peach palm by-product. The dietary NDF content is negatively correlated to the dry matter intake (DMI) of animals fed roughage-based diets, and the voluntary ingestion of forage is a critical factor at the determination of animal performance.

The objective of this study was to evaluate intake and apparent digestibility of the diets containing the agro-industrial by-product of peach palm in its fresh form, in the form of silage, or silage enriched with 15 % of cornmeal, as roughage for feedlot lambs.

Material and methods

Location and animals

The experiment was conducted at the Laboratory of Research on Ruminant Nutrition and Feeding of the Department of Agricultural and Environmental Sciences of Universidade Estadual de Santa Cruz, located in the municipality of Ilhéus, BA, Brazil.

For the experiment, we utilized 20 castrated male crossbred Santa Ines lambs with body weight (BW) of 22.4±3.4 kg and aged 150 days, on average. The animals were identified, dewormed (albendazol—2.5 mg/kg BW) and confined in individual 0.96 m^2 pens with slatted floor provided with drinkers and feeders.

Experimental design and diets

The experimental design was completely randomized, with four experimental diets, which consisted of different forms of utilization of the by-product of peach palm: fresh by-product enriched with urea + ammonia sulfate (10:1 g/g) (FU); fresh by-product + concentrate (FP); silage of the by-product + concentrate (SP); and silage of the by-product enriched with 15 % cornmeal + concentrate (SPC). The roughage:concentrate ratio utilized in diets FP, SP, and SPC was 40:60, on the basis of the DM of the ingredients.

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

Diet FU was enriched with urea + ammonia sulfate 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 of CP.

The by-product of peach palm consisted of its inner bark (sheath), end of stems, and stems inappropriate for processing.

The animals were fed twice daily (8:00 a.m. and 4:00 p.m.), and the amount supplied was adjusted daily according to the amount of orts from the previous day, so that there was a surplus of about 10 % of the total provided, in order to promote a voluntary ingestion.

Experimental period and data collection

Animals went through 20 days of adaptation to diets. After adapting two periods of 21 days each, totaling 42 days were used for data collection, when the orts were collected and weighed every day for the determination of intake (total supplied—orts). Samples of the feed were supplied, and orts were collected and stored in a freezer.

There were two periods for collection of feces, with five collection days in each. Feces were collected directly from the rectum of animals and placed in plastic bags that were identified and stored in a freezer.

Laboratory analyses

At the end of the trial, the samples of the feed supplied, orts and feces, were thawed at room temperature, pre-dried in a forced-ventilation oven at 60±5 °C for 72 h, and ground in a Wiley mill with a 1-mm screen sieve for the chemical analyses and with a 2-mm screen sieve for in situ incubation.

Contents of DM, CP, organic matter (OM), ether extract (EE), and acid detergent fiber (ADF) were determined according to the methods of AOAC (1990).

In the analyses of NDF, the samples were treated with thermostable alpha-amylase, without the use of sodium sulfite, and corrected for the residual ash (Mertens 2002). The correction of NDF for the nitrogen compounds was done according to Licitra et al. (1996).

The non-fibrous carbohydrate (NFC) content of the feeds was calculated according to Hall (2000): NFC=100 (NDFap+CP+EE+MM), where NDFap=NDF corrected for residual ash and protein.

The digestibility of the components of the diet was determined from the internal marker indigestible acid detergent fiber (iADF), according to the methodology described by Casali et al. (2008).

To determine the fecal dry matter production (FDMP), with the use of internal marker, the following formula was utilized: FDMP (g/day)=marker consumed (g/day)/concentration of the marker in the feces (g/g).

The digestibility coefficient (DC) of each nutrient was calculated as follows: DC=(nutrient consumed−nutrient excreted)/nutrient consumed×100.

The total digestible nutrients (TDN) and the digestible energy (DE) were calculated according to the equations adopted

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 + ammonia sulfate (10:1)				10	3	3	–
Mineral mixture[a]				10	10	10	10
	By-product forms						
	Fresh	Silage	Silage enriched with 15 % corn meal				
Nutrients (g/kg DM)							
Dry matter[b]	123	142	256	143	568	575	621
Organic matter	934	932	956	925	944	943	954
Crude protein	79	63	81	109	163	157	154
Ether extract	63	65	108	61	78	79	106
Neutral detergent fiber[c]	622	687	402	608	400	426	312
Acid detergent fiber[c]	469	544	243	458	225	255	131
Non-fibrous carbohydrates	169	116	364	147	303	282	383
Total digestible nutrients	–	–	–	605	754	789	891

FU fresh by-product enriched with urea + ammonia sulfate, *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—1200 mg/kg, Se—15 mg/kg, Zn—2600 mg, Mo—180 mg

[b] g/kg as fed

[c] Corrected to ash and protein

by the NRC (2001): TDN=digestibleCP+digestibleNDF+digestibleNFC+(2.25×digestibleEE) and DE (Mcal/kg)=(digestibleCP/100×5.6+digestibleEE/100×9.4+digestibleNFC/100×4.2+digestibleNDF/100×4.2)×100.

Statistical analyses

The comparison between the diets was performed by decomposing the sum of squares, which is related to this source by orthogonal contrasts (Table 2). The contrast (A) was performed to evaluate the effect of the use of peach palm by-product as a diet with concentrate in relation to the diet with peach palm by-product without concentrate. The contrasts represented by letters B and C made it possible to evaluate the effect of the form of supply of the roughage (fresh × silage) and the type of silage (without additive×with additive), respectively. The statistical procedures were performed with the aid

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 + ammonia sulfate, *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 Intakes of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), non-fibrous carbohydrates (NFC), ether extract (EE), total digestible nutrients (TDN), and digestible energy (DE) according to the experimental diets

Variable	Experimental diet				Mean	SEM	Contrast[a]		
	FU	FP	SP	SPC			A	B	C
DM (g/day)	445.8	1002.2	773.6	911.8	783.4	29.5	**	**	**
DM (g/kg BW)	21.6	35.2	29.3	32.7	29.7	0.7	**	**	**
DM (g/kg $BW^{0.75}$)	46.0	81.2	66.3	74.9	67.1	1.9	**	**	**
OM (g/day)	417.1	949.5	732.3	874.6	743.4	28.4	**	**	**
CP (g/day)	34.4	174.6	129.9	130.2	117.3	6.9	**	**	ns
NDF (g/day)	254.6	351.7	290.0	261.4	289.4	8.1	**	**	ns
NDF (g/kg BW)	12.3	12.3	11.0	9.4	11.2	0.3	*	**	*
NFC (g/day)	99.5	340.5	248.2	385.6	268.5	15.1	**	ns	**
EE (g/day)	28.5	82.7	64.3	97.3	68.2	3.8	**	ns	**
TDN (g/day)	269.0	750.9	600.5	787.2	601.9	34.5	**	*	**
DE (Mcal/day)	1.16	3.31	2.65	3.44	2.64	0.15	**	*	**

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

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

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

of a software SAS (2008), adopting 0.05 as the critical level of probability for type I error.

Results

The animals that had not been fed concentrate supplementation showed lower intake ($P<0.05$) of all the nutrients evaluated in relation to those fed with concentrate (Table 3). When the diets with concentrate were compared, it was observed that the lambs fed the fresh peach palm showed higher intakes ($P<0.05$) of DM, OM, CP, NDF, TDN, and DE in relation to the animals fed the silage of the peach palm.

Comparing the diets with silage, the diet with enriched silage resulted in higher intakes ($P<0.05$) of DM, OM, EE, NFC, TDN, and DE in relation to the diet with silage without additives.

The use of concentrate in the diet, regardless of the form of supply of the by-product, promoted increase ($P<0.05$) in the digestibility coefficients of DM, OM, CP, NDF, and EE (Table 4). Diets with ensiled peach palm by-product increased ($P<0.05$) the digestibility coefficients of DM, OM, CP, and NDF in relation to diet with the fresh peach palm by-product + concentrate, but no differences were observed ($P>0.05$) for the digestibility of NDF and EE. The apparent digestibility coefficients of DM, OM, and NFC increased ($P<0.05$) in the diet with peach palm silage with 15 % cornmeal in relation to the silage of peach palm without additive, but there was no difference ($P>0.05$) in the digestibility coefficients of CP, NDF, and EE in this comparison.

Table 4 Apparent digestibility coefficients of the nutrients of the experimental diets

Digestibility (%)	Experimental diet				Mean	SEM	Contrast[a]		
	FU	FP	SP	SPC			A	B	C
Dry Matter	59.4	71.8	74.7	81.9	71.9	1.6	**	**	*
Organic Matter	60.3	73.0	76.2	82.6	73.0	1.6	**	**	*
Crude Protein	56.6	69.2	74.5	78.2	69.6	1.8	**	*	ns
NFC	83.4	73.2	76.3	87.9	80.2	1.6	ns	*	**
Ether Extract	56.3	77.6	79.8	83.8	74.4	2.1	**	ns	ns
NDF	49.3	63.9	66.6	71.9	62.9	1.9	**	ns	ns

FU fresh by-product enriched with urea + ammonia sulfate, *FP* fresh by-product + concentrate, *SP* silage of the by-product + concentrate, *SPC* silage of the by-product enriched with 15 % corn meal + concentrate, *NFC* non-fibrous carbohydrates, *NDF* neutral detergent fiber, *ns* not significant ($P>0.05$)

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

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

Discussion

The NRC (2007) estimates a DMI of 0.590 kg/day, or 29.7 g/kg BW, for animals of this category. Considering the intake in kg/day, all the diets containing concentrate achieved the estimated DMI. Considering the intake in g/kg of BW, only diets FP (35.2 g/kg BW) and SPC (32.7 g/kg BW) provided the intake estimated by the NRC (2007).

Failure to use the concentrate in the diet FU resulted in lower DMI in animals fed this diet. The type of CP ingested (non-protein nitrogen) generated incompatibility between energy and protein sources necessary for the development of ruminal microorganisms thus impairing ruminal digestibility of DM and hence reducing the intake.

Among the diets with concentrate, the diet FP resulted in a 29.5 and 9.9 % higher DMI ($P<0.05$) than diets SP and SPC, respectively.

According to Charmley (2001), silage intake is 27 % lower than that of the original forage which did not undergo the fermentation process. There are three hypotheses associated with the reduction in silage intake: presence of toxic substances such as amines produced during the fermentation process; a high content of acids in the extensively fermented silages, causing reduction in the acceptability; and decrease in the concentration of soluble carbohydrates and, consequently, in the availability of energy for the growth of the rumen. Other factors such as smell and taste can cause reduction in silage intake by ruminants (Gerlach et al. 2014).

Comparing the diets with silage, there was a difference ($P<0.05$) between the DMI of the enriched silage and that of the silage without additives (Table 3). Inclusion of cornmeal increased the DM content of the silage and, consequently, of diet SPC, thereby increasing the DMI of the animals on that treatment. Besides, the improvement in the fermentation process of the enriched silage might have reduced the undesirable fermentations, resulting in higher acceptability by the animals.

The diets with concentrate met the CP requirement estimated by the NRC (2007), which is 116 g/day. Diet FP resulted in higher CP intake ($P<0.05$) than the diets with silage because of the higher DMI.

The proportion of CP consumed in relation to the DMI (Table 3) accounted for 7.7 % of the total consumed by the animals which received diet FU. Lazzarini et al. (2009) affirmed that 7 % DM of CP is the minimum for an appropriate rumen fermentation to occur; however, the nitrogen source used (urea) has rapid rate of degradation having thus incompatibility with carbohydrate degradation and damage to ruminal fermentation.

Even with a higher concentration of NDF in its composition (Table 1), diet FU caused a lower NDF intake than the observed in other diets (Table 3). This was so because of the lower DMI observed in the animals that had been fed this diet. Comparing the diets with concentrate, the diet which contained fresh peach palm by-product showed higher NDF intake (351.7 g/day) in relation to those with silage, as a response to the higher DMI caused by the diet. Among the diets with silage, even with higher DMI, SPC (261.4 g/day) did not cause significant differences ($P>0.05$) in NDF intake as compared with SP (290 g/day), because the NDF content of SPC was lower in relation to SP, equaling the NDF intake of the diets.

No difference was observed ($P>0.05$) in the intakes of NFC and EE when the diet FP was compared with SP and SPC, because even though it caused a lower DMI, diet SPC had a higher concentration of these two nutrients in its composition, due to the addition of cornmeal to the silage, equaling the intakes of these nutrients. When the diets containing silage were compared, higher NFC and EE intake was observed in diet SPC as compared with SP, due to the higher DMI and concentration of these nutrients in the former. Diet FU, however, showed lower NFC and EE intakes because in addition to presenting lower DMI, it had a lower concentration of these nutrients in its composition, since it did not receive the concentrate feed, as opposed to FP, SP, and SPC.

The intakes of TDN and DE showed differences ($P<0.05$) as a response to the different DMI and nutrient content of the diets. Lambs fed diet FU had the lowest TDN and DE intakes among the experimental diets. Diet FP resulted in higher TDN and DE intake, due to the higher DMI, in comparison with the diets with silage. Diet SPC, however, provided higher TDN and DE intakes than SP, both because of the higher DMI and the higher TDN content of this diet.

The high NDF content of diet FU (608 g/kg DM) in relation to the other dietary components might have influenced the lower DM digestibility, since the NDF fraction is less digestible than the other nutrients like NFC and CP.

The CP source and the low concentration consumed (7.7 %DM) might have resulted in lower digestibility of the nutrients in diet FU. According to Hristov et al. (2005), the rates of release of energy, originated from carbohydrates, and of nitrogen, originated from the protein degradation and from non-protein-nitrogen sources, should be proportional, so that the microbial production and consequently the ruminal fermentation are maximized. The origin of the N utilized in diet FU was urea, which has a high rumen-degradation rate. The main source of carbohydrates, however, was NDF, which presents a slow degradation rate. The lack of synchrony between the degradation of the nitrogen compounds and carbohydrates might have reduced the microbial growth, which resulted in lower digestibility of the nutrients in this diet.

The ensilage process increased ($P<0.05$) the apparent digestibility of DM and OM in relation to the diet with fresh by-product (71.8 and 73.0 %, respectively). Compared with fresh feeds, those in the form of silage have a higher content of ammonia (Charmley 2001). Because the ammonia in the rumen is promptly used by the microorganisms, the digestibility of the CP was higher in the diets with silage, thereby increasing the digestibility of DM and OM.

Among the diets with concentrate that used the silage, SPC (81.9 %) showed higher apparent DM digestibility ($P<0.05$) than SP (74.7 %). This was so because with inclusion of cornmeal as additive, in diet SPC, the concentration of NFC increased and NDF decreased. Because the NFCs are more digestible than the NDF, there was a higher apparent DM digestibility in this diet. This behavior was also observed by Oliveira et al. (2010), who observed in vitro DM digestibility coefficients of peach palm by-product of 47.9 and 54.5 % in the silages without additive and enriched with 10 % of cornmeal, respectively.

The diets with concentrate presented similar apparent DM digestibility to the values observed in diets with the same roughage:concentrate proportion using corn silage (Moreno et al. 2010)—78.7 %; Elephant grass hay (Lima et al. 2012)—80.1 %; and fresh Elephant grass (Aragão et al. 2012), with 81.8 % of digestibility. Diet FU, which did not have concentrate feeds, showed an apparent DM digestibility close to the values observed by Bringel et al. (2011) and Miotto et al. (2012)—59.4 and 51.3 %, respectively—in diets with Elephant grass silage only.

The concentration of EE in the roughage, besides the concentrate feed, provided a high concentration of EE in the experimental diets (Table 1). It is known that a high EE concentration in the diet reduces the fiber digestibility; it can be reduced by up to 50 % when the EE concentration is 10 % (Jenkins 1993). However, in our study, this behavior was not observed, because the diets that showed higher EE content (FP, SP, and SPC) presented higher NDF digestibility coefficients (Table 4). This fact can be explained by the form this EE was present in the diet, bound to the fiber of the roughage or the particles of concentrate, because none of the diets received sources of fats or supplemental oils, thereby working as a "protected" source of EE.

Some other studies utilizing the same roughage:concentrate ratio have found NDF digestibilities of 56.6 % in a diet with Tifton 85 hay (Costa et al. 2012) and 78.7 % in a diet with fresh Elephant grass (Aragão et al. 2012), which demonstrates compatibility of the values found in the present experiment with those found in the literature.

Conclusions

The peach palm by-product, either silage or fresh form can be used in diets in confinement, since associated with concentrate, enabling higher intake and digestibility, although the fresh form is the most indicated for providing higher TDN intake. Evaluating the costs of these diets should be considered in order to certify their viability. Supplying peach palm by-product without the use of concentrates results in low nutrient intake.

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Conflict of interest The authors declare that they have no conflict of interest.

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