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Nutrient metabolism and ingestive behavior of goats fed diets containing palm tree fruit[1]

Metabolismo de nutrientes e comportamento ingestivo de caprinos alimentados com rações contendo frutos de palmeira

Bruno Spindola Garcez[2]*, Arnaud Azevêdo Alves[3], Maria Elizabete de Oliveira[3], Miguel Arcanjo Moreira Filho[4], Danielle Maria Machado Ribeiro Azevêdo[5] and Marlúcia da Silva Bezerra Lacerda[6]

ABSTRACT - The objective was to evaluate the nutrient metabolism and ingestive behavior of goats fed diets containing fruits of Carnauba and Tucum palm trees, abundant in the Northeast region with fruiting in the dry season and use as alternative food for ruminants. For this end, 21 goats fed three diets, one control and two with carnauba or tucum fruits, in a completely randomized design. We determined nutrient intake through total collection of leftovers, faces and urine, as well as energy and nitrogen balance. Ingestive behavior was assessed by visual observations every 5 min for 24 h. There was a reduction in dry matter intake of 0.183 and 0.223 kg/day for diets containing tucum and carnauba fruits, respectively. The intake of digestible protein (78.04 gDP/day) and metabolizable energy (2.51 McalME/day) of the diet containing tucum fruits met the nutritional requirements of the animals, besides resulting in nitrogen balance above 60% and increase of 0.57 Mcal/kgDM of digestible energy of the diets. Diets containing fruits of carnauba required a longer rumination (453.65 min/day), associated with the higher fiber content in their composition. The inclusion of carnauba and tucum fruits in diets composed of corn, soybean and Tifton 85 hay for growing goats promotes a reduction in dry matter intake due to the low quality of the fiber of these fruits. However, the diets containing tucum fruits met the nutritional requirements of goats regarding digestible protein and metabolizable energy, suggesting the use of this alternative food for this category.

Key words: Alternative food. *Bactris setosa. Copernicia prunifera.* Nitrogen balance. Dry matter intake.

RESUMO - Objetivou-se avaliar o metabolismo de nutrientes e comportamento ingestivo de caprinos alimentados com rações contendo frutos das palmeiras Carnaúba e Tucum, abundantes na região Nordeste com frutificação no período seco e utilização como alimento alternativo para ruminantes. Foram utilizados 21 caprinos, alimentados com três rações, uma controle e duas contendo frutos de carnaúba ou tucum, em delineamento inteiramente casualizado. Determinou-se o consumo dos nutrientes através da coleta total de sobras, fezes e urina, além do balanço energético e nitrogenado. O comportamento ingestivo foi avaliado por observações visuais a cada 5 min, durante 24 h. Houve redução no consumo de matéria seca de 0,183 e 0,223 kg/dia para as rações contendo frutos de tucum e carnaúba, respectivamente. O consumo de proteína digestível (78,04 gPD/dia) e energia metabolizável (2,51 McalEM/dia) da ração contendo frutos de tucum atendeu as exigências nutricionais dos animais, além de resultar em balanço nitrogenado acima de 60% e aumento de 0,57 Mcal/kgMS da energia digestível das rações. As rações contendo frutos de carnaúba demandaram maior tempo em ruminação (453,65 min/dia), associado ao maior teor de fibra em sua composição. A inclusão de frutos de carnaúba e tucum em rações compostas por milho, soja e feno de capim-Tifton 85 para caprinos em crescimento promove redução no consumo de matéria seca, devido à baixa qualidade da fração fibrosa dos frutos. No entanto, as rações contendo frutos de tucum atenderam as exigências nutricionais dos caprinos quanto a proteína digestível e energia metabolizável, sugerindo o uso desse alimento alternativo para essa categoria.

Palavras-chave: Alimento alternativo. *Bactris setosa*. Balanço nitrogenado. Consumo de matéria seca. *Copernicia prunifera*.

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*Author for correspondence
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[1]Pesquisa parte de trabalho de Tese do Programa de Pós-Graduação em Ciência Animal, Universidade Federal do Piauí, Teresina-PI, Brasil
[2]Instituto Federal de Educação, Ciência e Tecnologia do Ceará/IFCE, *Campus* Crateús, Avenida Dr. Geraldo Barbosa Marques, 567, Venâncio, Crateús-CE, Brasil, 63.708-260, bruno.garcez@ifce.edu.br (ORCID ID 0000-0001-8920-6547)
[3]Programa de Pós-Graduação em Ciência Animal, Centro de Ciências Agrárias, Universidade Federal do Piauí/UFPI, *Campus* Universitário Ministro Petrônio Portella, Ininga, Teresina-PI, Brasil, arnaud@ufpi.edu.br (ORCID ID 0000-0002-0218-3213), maeliz@uol.com.br (ORCID ID 0000-0002-1867-7912)
[4]Universidade Federal do Piauí, *Campus* Cinobelina Elvas, BR 135, km 3, Planalto Horizonte, Bom Jesus-PI, Brasil, miguelarcanjo@agronomo.eng.br (ORCID ID 0000-0002-0137-2637)
[5]Embrapa Meio-Norte, Avenida Duque de Caxias, 5650, Buenos Aires, Teresina-PI, Brasil, danielle.azevedo@embrapa.br (ORCID ID 0000-0001-6541-2901)
[6]Instituto Federal de Educação, Ciência e Tecnologia do Ceará/IFCE, *Campus* Teresina Central, Rua Álvaro Mendes, 94, Centro (Sul), Teresina-PI, Brasil, marlucia.lacerda@ifpi.edu.br (ORCID ID 0000-0002-1455-7198)

INTRODUCTION

Feeding costs are still an obstacle to several small ruminant farming systems, especially when concentrate diets are used in periods of forage deficit, which despite the good nutritional value, make the system more expensive. In this sense, it is sought to know better the alternative ingredients for diets, mainly due to the high production of some native plant species in the dry period.

Among the native species to the Mid-North sub-region, stand out carnauba *Copernicia prunifera* (Mill.) H.E. Moore) and tucum (*Bactris setosa* Mart.) palm trees, whose fruits are commonly consumed by herds of small ruminants in an area of natural occurrence of these palms, with empirical reports of good acceptance and contribution to maintaining the weight of the animals.

Carnauba is a palm tree of the family *Aracaceae*, native to the Northeast of Brazil, with a higher occurrence in the States of Ceará, Piauí and Rio Grande do Norte (SOUSA *et al*., 2015). Its main economic use is by cutting the leaves for wax production, besides that fruits are used for animal feeding in extensive systems in the areas of occurrence of the plants, which should occur soon after ripening, due to the rapid decomposition of the pericarp after the fruit falls on the ground.

Tucum has stems and leaves covered by aculeus and produces fleshy fruits, in the months of November to January, very resistant and rich in oil composed of essential fatty acids, besides having protein content close to 7% (DUARTE *et al.*, 2012), which may make its use feasible as a concentrate ingredient in ruminant diets.

In addition to the chemical composition, the consumption and metabolism of nutrients in ruminants should be considered in the evaluation of feed containing palm tree fruit. Besides that, it is very important to know the ingestive behavior, because it allows adjustments in feeding management for better productive performance of the animals (RICE *et al.*, 2016). Thus, the goal of this study was to evaluate the nutritive value of feed containing fruits of carnauba and tucum palm trees, in terms of nutrient intake and digestibility, energy-nitrogen balance and ingestive behavior of goats.

MATERIAL AND METHODS

This research was carried out at the Animal Sciences Department, Agricultural Sciences Center (CCA), Federal University of Piauí, Teresina, State of Piauí. Twenty-one female Anglo-Nubian goat females, aged approximately two years and weighing 28.21 ± 6.65 kg, in good health and nutritional conditions, were kept in metabolism cages, with water and mineral mix *ad libitum*. Three diets were evaluated, being a control diet and two with inclusion of carnauba or tucum fruits. This was a completely randomized experimental design with three treatments (experimental diets) and seven replicates (goats) per treatment.

The chemical composition of the ingredients (Table 1) was determined according to Association of Official Analytical Chemists International (2012) methodologies for dry matter (DM), protein (CP), ash (CZ) and ether extract (EE). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (LIG) were obtained according to the methodology described by Mertens (1997) adapted for autoclave (105 °C/60 min) (BARBOSA *et al.*, 2015) using 4 x 5 cm non-woven fabric bags (TNT) with 100 μm porosity (VALENTE *et al.*, 2011).

The TDN content of the ingredients was estimated by the formula %TDN = 83.79 - 0.4171*NDF and of the diets by the formula %TDN = 1.02 x MOD (CAPPELLE *et al.*, 2001). NDF and ADF fractions were corrected for ash after incineration of the bags post-digestion in a muffle furnace (ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTIS INTERNATIONAL, 2012) and for protein, after determination of the nitrogen fractions of the residues (ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTIS INTERNATIONAL, 2012).

The diets were prepared based on the requirements established by the National Research Council (2007) for growing goats with 30 kg body weight and DM intake of 3.41% BW (11.53% CP and 60.47% TDN), with forage: concentrate ratio of 38.6: 61.4, provided in two daily meals at 8 and 16 hours, with 15% of leftovers established during adaptation (Table 2). Before the experiment, the animals were weighed and dewormed.

The experiment lasted 22 days, including 15 days used for adaptation of the animals, five days for data collection and two days for evaluation of ingestive behavior. The nutrient intake was determined by weighing the leftovers, and 20% aliquots were taken and stored at -5 to -10 °C for further determination of the chemical composition. The dry matter and nutrient intake, in g/animal/day, %BW and g/UTM, was calculated by the difference between the feed provided and the daily leftovers.

Feces and urine were totally collected, taking aliquots of 20% of total excreted, which were packed in plastic bags and bottles, respectively, and stored at -5 to -10 °C and then pre-dried for analysis of chemical composition. Urine collection vessel contained 10 mL of 1: 1 HCl (6.0 N) to avoid volatilization of Nitrogen. The apparent digestibility coefficients (DC) of DM, OM, CP, NDF, ADF, EE and GE were obtained by the formula:

CD(%) = [(ingested nutrient - nutrient in the feces)/ ingested nutrient]x100

In order to evaluate the balance of nitrogen compounds, the total amount of Nitrogen ingested was quantified by the ratio of this nutrient in the diet and in the leftovers. The total N content of feces, leftovers and urine was determined by the Kjeldahl method (ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS INTERNATIONAL, 2012). Nitrogen retention (gN/day) was calculated by the formula: *Nretained = Ningested - (Nfeces + Nurine)* and the percentage of apparently retained N*ingested* (Nitrogen balance), was estimated according to Moreno *et al.* (2010): *NB (%) = [Ningested - (Nfeces + Nurine)]/Ningested X 100*. N*absorbed* was calculated as *:Nabsorbed = (Nsupplied - Nleftovers) - Nfeces, while Ningested = Nsupplied - Nleftovers* (MORENO *et al.*, 2010).

As for energy balance, urine GE was determined in an adiabatic calorimeter (ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS INTERNATIONAL, 2012) using polyethylene capsules and the loss of energy as methane was estimated by the equation proposed by Blaxter and Clapperton (1965): *Cm = 3.67 + 0.062D*, where: *Cm* = methane production (kcal/100 kcal energy consumed) and *D* = apparent digestibility of GE. Metabolizable energy (ME) was estimated by difference between digestible energy (DE) and energy losses in the urine and as methane. From the GE and ME values of the diets, the energy metabolizability (*q*) was calculated by the relation *q* = ME/GE. The utilization efficiency of ME for maintenance (*km*) was estimated from the equation proposed by Blaxter and Clapperton (1965): Km = 0.503 + 0,35qm.

The ingestive behavior of goats was evaluated in the last two days of the experiment by the scan sampling method, with visual observations every 5 min for 24 h (JOHNSON; COMBS, 1991), recording the time spent on feeding, rumination, idle and other activities (mineral salt and water intake, defecation and urination). The number of cud chews per cud (CC_{nb}) and time of cud chews per cud (CC_{tb}) were obtained by visual observation of the animals from 8 to 10 h, 14 to 16 h and from 18 to 20 hours.

Information regarding ingestive behavior was recorded in spreadsheets by seven trained observers, and the parameters were determined as described by Bürger *et al.* (2000): TCT = FT + TT; FEDM = DMI/FT; FENDF = NDFI/FT; REDM = DMI/RT; ERFDN = NDFI/TR; NC = RT/CCtb; CCtb = NC X CCnb; MDMbr = DMI/NC and MNDFbr = NDFI/NC, where: TCT = total chewing time (min/day); TA = feeding time; RT = rumination time;

Table 1 - Chemical composition of ingredients of the diets

Constituents[1]	Ingredient				
	Ground corn grain	Soybean meal	Carnauba fruit	Tucum fruit	Tifton 85 hay
Dry matter	87.61	87.09	87.50	88.57	92.95
			%DM		
Organic matter	86.35	82.51	83.43	85.11	88.13
Crude protein	9.41	50.11	6.54	7.16	10.96
Ether extract	4.11	1.26	5.49	18.96	1.37
NDFcp	11.42	13.76	70.37	53.27	75.84
ADFcp	4.92	11.17	45.75	31.33	38.88
Lignin	0.95	1.39	4.75	2.17	4.31
Hemicellulose	6.50	2.59	24.62	21.94	36.96
Cellulose	3.97	9.78	41.00	29.16	34.57
NFC	73.80	28.58	13.53	17.15	7.01
TDN	79.02	78.05	54.43	61.57	50.60
GE (Mcal/kg)	4.03	4.01	3.52	5.29	3.12
			%TN		
NDIN	3.75	5.50	29.14	26.25	44.28
ADNI	1.51	2.43	14.30	14.77	30.21

[1]NDFcp = neutral detergent fiber corrected for ash and protein; ADFcp = acid detergent fiber corrected for ash and protein; NFC = non-fiber carbohydrates; TDN = total digestible nutrients; GE = Gross energy; NIDN = neutral detergent insoluble nitrogen; NIDA = acid detergent insoluble nitrogen

Table 2 - Proximate and chemical composition of the diets

Ingredient/nutrient[1]	Diets		
	Control	Carnauba fruit	Tucum fruit
Proximate composition			
Tifton 85 hay	38.59	38.62	38.69
Ground corn grain	54.35	32.91	33.02
Soybean meal	7.06	6.50	6.45
Tucum fruit	0.00	0.00	22.84
Carnauba fruit	0.00	21.97	0.00
Chemical composition			
Dry matter (%NM)	89.63	89.61	89.85
% DM			
Organic matter	86.60	86.20	86.55
Crude protein	12.88	12.02	12.00
Ether extract	2.85	3.16	6.11
NDFcp	36.44	49.40	45.63
ADFcp	18.47	27.41	24.22
Lignin	2.27	3.11	2.54
Hemicellulose	17.97	21.99	21.41
Cellulose	16.20	24.30	21.68
Non-fiber carbohydrates	45.00	32.01	32.96
TDN[2]	68.02	60.93	69.18
GE (Mcal/kg)	3.77	3.45	3.98
% total N			
NIDN	19.51	25.09	24.45
AIDN	12.65	15.46	15.57

[1]NDFcp = neutral detergent fiber corrected for ash and protein; ADFcp = acid detergent fiber corrected for ash and protein; TDN = total digestible nutrients; NIDN = neutral detergent insoluble nitrogen; NIDA = acid detergent insoluble nitrogen; [2]Cappelle *et al.* (2001): 1.02 x MOD

FEDM = feed efficiency of dry matter (gDM/h); FENDF = feed efficiency of neutral detergent fiber (gNDF/h); REDM = rumination efficiency of dry matter (gDM/h); RENDF = rumination efficiency of neutral detergent fiber (gNDF/h); NC = number of cuds (cuds/day); CCnb = number of cud chews per cud (CC/cud); CCnt = total number of cud chews (CC/day); CCtb = time of cud chews per cud (sec/cud); MDMbr = mass of dry matter per cud (gDM/cud); MNDFbr = mass of neutral detergent fiber per cud (gNDF/cud).

The initial weights were adopted as covariate to estimate the means of the parameters evaluated, in order to adjust their effects and to reduce the experimental error. Significant means were compared using the Tukey's test at 5% probability, according to procedures for linear models (PROC GLM) of the statistical software Statistical Analysis System (2000).

RESULTS AND DISCUSSION

The inclusion of fruit of the carnauba and tucum palm trees in the diets resulted in a reduction ($P<0.05$) in DM intake (DMI) by 0.23 and 0.18 kg/day, respectively, in relation to the control diet (Table 3). The DMI of the diets containing fruit was lower than that recommended for goats by the National Research Council (2007), 1.02 kgDM/day, which is associated with the higher fiber content of these diets. The diet containing carnauba fruit resulted in higher intake of NDF (NDFI) (0.41 kg / day) and ADF (ADFI) (0.29 kg/day), due to the higher proportion of fiber in fruits (70.37% NDF and 45.75% ADF) (Table 2).

The NFCI represented 33.67 and 35.96% of DM intake for the diets containing carnauba or tucum fruit, respectively, which was associated to the low proportion

Table 3 - Nutrient intake by goats fed diets containing carnauba or tucum fruit

Intake[1]	Diets[2]			SEM[3]
	Control	Carnauba fruit	Tucum fruit	
DM (kg/day)	1.12 a	0.89 b	0.94 b	0.51
DM (%BW)	4.03 a	3.36 b	3.65 ab	0.19
DM (g/UTM)	92.44 a	75.79 b	81.27 ab	4.23
NDF (kg/day)	0.33 b	0.41 a	0.36 b	0.03
NDF (%BW)	1.29 b	1.46 a	1.33 b	0.06
ADF (kg/day)	0.18 b	0.29 a	0.21 b	0.02
CEL (kg/day)	0.15 a	0.26 b	0.18 ab	0.04
CP (kg/day)	0.17 a	0.13 b	0.12 b	0.09
DP (kg/day)	0.112 a	0.085 b	0.078 b	3.21
EE (kg/day)	0.02 b	0.02 b	0.05 a	0.00
NFC (kg/day)	0.55 a	0.30 b	0.34 b	0.03
TDN (kg/day)	0.76 a	0.54 c	0.65 b	0.05

[1]DM = dry matter, NDF = neutral detergent fiber, ADF = acid detergent fiber, CEL = cellulose, CP = crude protein, DP = digestible protein, EE = ether extract, NFC = non-fiber carbohydrates, TDN = total digestible nutrients; [2]Mean values followed by different letters, in the same row, are significantly different by Tukey's test a 5%; [3]SEM = standard error of the mean

of this constituent in the diets (31.98 and 32.78%) and to the low intake by goats (0.30 and 0.34 kg/day) led to a reduction in DM intake. The CNDF of diets containing tucum fruits (1.33% BW) was similar to the control diet (1.29% BW), which is associated with the selection of concentrates of this diet, and suggests less acceptance of tucum fruits by goats, which left a higher proportion of them in the leftovers.

The inclusion of fruit in the concentrate fraction (62%) of the diets also contributed to the reduction in nutrient intake, since it promoted an increase of 39.2 and 26.1% in the proportion of total NDF in diets containing fruits of carnauba and tucum (49.19% and 47.51%), due to the increase of fiber carbohydrates incorporated in the diet.

The diets met the requirements of crude protein (CP) (118.00 g/day and 9.21 g/BW$^{0.75}$) and digestible protein (63 gDP/day) established by the NRC (2007) for goats of the category, with intake of 112.14; 85.01 and 78.14 gDP/day, for the control and diets with inclusion of carnauba and tucum fruit, respectively. The highest protein intake by goats in the control group is associated with the selection of concentrate by the animals, with a higher proportion of fiber in leftovers, mainly from hay.

Goats are classified as selective ruminants and even in feedlot systems, they express this characteristic and spend most of their time to the search and selection of food (RIBEIRO *et al*., 2009), confirming the effect obtained for diets tested herein. In diets with forage and concentrate fractions, there may be segregation of the mixture due to the animals action in turning the feed in the trough with the muzzle to facilitate the selective intake, which influences both the quality and quantity of the feed consumed, besides the chemical composition of leftovers, causing variation in the intake of nutrients by the animals.

Although the energy value of the diets was adjusted, the TDN intake (TDNI) was higher (P <0.05) in animals fed the control diet, due to the higher proportion of corn in the diet (54.35%) in relation to diets containing carnauba and tucum fruit (32.91 and 33.12%, respectively). Only the control diet met the requirements of goats, 0.680 kgTDN/day and 2.26%BW, presenting consumption of 0.763 kgTDN/day and 2.49% BW.

Although the TDNI for goats fed diets containing carnauba fruit was lower than the requirements for growth with a gain of 150 g/day, it was higher than the TDN requirements for maintenance (0.490 kgTDN/day and 1.63% BW), which suggests the use of this diet for goats of less demanding categories in periods of forage shortage.

The inclusion of tucum fruit in the diet resulted in intake of 0.65 kg TDN/day, higher than that obtained by Urge *et al*. (2014) for goats with weight gain of 170 g/day and fed diets containing 50% (0.449 kgTDN/day) and 75% (0.465 kgTDN/day) of concentrate. However, the lower proportion of NFC reduced by 31.4% TDNI in the diets containing carnauba fruit.

The diet containing carnauba fruit resulted in lower DM digestibility (DMD) ($P < 0.05$), which is related to the higher proportion of fiber constituents and to their low digestibility (NDFD = 38.79% and ADFD = 35.45%) (Table 4). The proportion of cellulose in carnauba fruit corresponds to 45.75% NDF of the fruit, with low digestibility (36.75%), contributing to a decline in the DMD.

The inclusion of tucum fruits in the diet had no influence on digestibility of DM, OM and CP, with a reduction in DNDF (47.28%), DFDA (41.70%), DCEL (43.14%) and DHEM (53, 06%). The higher digestibility of the control diet is associated with the selection and intake of concentrate ingredients by goats, which present high DDM.

The high DDM of the diets containing tucum fruits (65.85%) is associated with the effect of the high EE content of the fruit, increasing the energy content provided by the diet and the quality of the fiber fraction, with higher digestibility of hemicellulose (53.06%) and cellulose (43.14%) compared to carnauba fruits (36.75 and 42.71% for CEL and HEM, respectively). However, there was a reduction in the digestibility of cell wall components of diets containing tucum fruits in relation to the control diet, which may be associated with lower quality of fruit fiber along with hay, which presented high NDF (75.84%) and ADF (38.88%) contents.

The inclusion of tucum fruits in the diet resulted in lower ($P<0.05$) intake, absorption and retention of N (19.20, 14.67 and 11.55 gN/day, respectively), and lower fecal (4.53 gN/day) and urinary (3.12 gN/day) excretion relative to the control diet, although equivalent to the diet containing carnauba fruit (Table 5). The highest intake of N when fed the control diet, with a higher proportion of corn (9.67% CP) and soybean (50.11% CP), in relation to the less protein fruits, is justified by the selection of ingredients by goats.

Table 4 - Nutrient digestibility of diets containing carnauba or tucum fruits for goats

Digestibility (%)[1]	Diets[2]			SEM[3]
	Control	Carnauba fruit	Tucum fruit	
DM	65.44 a	56.55b	65.85 a	2.17
OM	66.69 a	59.74 b	67.83 a	1.46
CP	65.91 a	61.30 a	66.38 a	3.37
EE	75.08 b	76.62 b	84.26 a	1.46
NDF	55.07 a	39.79 c	47.28 b	3.30
ADF	48.76 a	34.45 c	41.70 b	2.11
CEL	51.02 a	36.75 c	43.14 b	3.93
HEM	60.66 a	42.71 c	53.06 b	4.09

[1]DM = dry matter, OM = organic matter, CP = crude protein, EE = ether extract, NDF = neutral detergent fiber, ADF = acid detergent fiber, CEL = cellulose, HEM = hemicellulose; [2]Mean values followed by different letters, in the same row, are significantly different by Tukey's test a 5%; [3]SEM = standard error of the mean

Table 5 - Balance of nitrogen compounds from diets containing carnauba or tucum fruits for goats

Variables[1]	Diets			SEM[3]
	Control	Carnauba fruit	Tucum fruit	
$N_{ingested}$ (N_i, g/day)	27.21 a	20.80 b	19.20 b	1.45
N_{feces} (N_f, g/day)	6.14 a	4.84 ab	4.53 b	0.22
N_{urine} (N_u, g/day)	3.51 a	3.23 ab	3.12 b	0.19
N_{feces}/N_{urine} (g/g)	1.74 a	1.49 b	1.45 b	0.10
$N_{absorbed}$ (g/day)	21.07 a	15.96 b	14.67 b	0.94
$N_{retained}$ (g/day)	17.56 a	12.66 b	11.55 b	0.94
Nitrogen balance (%N_i)	64.53 a	60.86 a	60.15 a	1.80

[1]Mean values followed by different letters, in the same row, are significantly different by Tukey's test a 5%; [2]SEM = standard error of the mean

Goats fed the diet containing tucum fruit both ingested less (P<0.05) N in relation to the control diet and excreted less (P<0.05) fecal and urinary N. N absorption and retention were lower (P<0.05) with the inclusion of tucum or carnauba fruit in the diets, justified by lower intake of N by the goats fed these feed and associated to the lower intake of DM (0.89 and 0.94 kg DM/day) and CP (0.13 and 0.12 kgCP/day) relative to the control diet.

The use of N by the ruminal microbiota is directly related to the energy available in this environment, which influences the synthesis of microbial protein, with an increase in the supply of nitrogen compounds to the other segments of the gastrointestinal tract, besides increasing the retention and absorption of this compound by the ruminant animal and optimizing its recycling (CHANJULA *et al.*, 2014), consistent with the results obtained for the control diet, which provided higher intake of NFC (0.55 kg/day).

As for nitrogen balance, goats fed diets containing carnauba or tucum fruits retained approximately 60% N ingested, which, according to Van Soest (1994), avoids mobilization of N from the animal body reserves and reduces urinary excretion of nitrogen compounds, as well as lower metabolic energy costs due to energy expenditure for hepatic conversion of excess ammonia to urea (CALSAMIGLIA *et al*., 2010).

The inclusion of fruits of carnauba or tucum in the diets did not influence (P>0.05) the gross energy digestibility (GED), energy metabolizability (*q*) (Mcal/kgDM) and the efficiency in the use of metabolizable energy (EfiME) (Table 6). However, the inclusion of tucum fruits increased (P <0.05) DE (3.65 Mcal/kgDM) in relation to the other diets, which is related to their EE content (18.96%), which increased the caloric value of the diet as to GE (3.98 Mcal/kg).

The low DGE of the diets containing carnauba fruit (65.42%) results from the influence of the NDF of the palm tree fruits on the energetic value of the diets, in addition to the lower quality of the diets, with a high proportion of the lignocellulosic fraction. The inclusion of fruits of carnauba and tucum in the diets reduces the proportion of NFC in the diets, which associated with the percentage of insoluble nitrogen (INDA) of fruits (Table 1), provides less energy and N for the synthesis of microbial protein in the rumen with negative impact on digestibility.

The availability of ME (Mcal/kgDM) of the control diets and those containing tucum fruit provided a consumption of 2.49 and 2.55 McalME/day, meeting that set by National Research Council (2007) for goats (2.47 Mcal/day), while the diet containing carnauba fruit had a lower value (2.31 Mcal/day). Energy availability is related to the amount of fermentable substrates in dry matter, being NFC the first source of carbon skeletons for rumen microorganisms (ZHOU *et al*., 2015). In this sense, low contents of NFC, as observed for carnauba (13.53%) and tucum (17.15%) fruits, may impar protein synthesis and microbial fermentation by providing less fermentable energy for NH_3-N fixation, limiting growth and negatively affecting DDM (MIRANDA *et al*., 2015).

The energy metabolizability indicates that the inclusion of tucum and carnauba fruits to the diet positively influences the metabolism of GE into ME (0.42 and 0.44 Mcal/kgDM), providing more energy for the metabolism of the animal, being its use dependent on the nutritive value of the food and the efficiency in reducing the heat losses by the organic reactions (URGE *et al*., 2004).

The inclusion of carnauba and tucum fruits in the diets did not influence the efficiency of EM use, 33.09 and 35.12%, respectively. However, it denotes low endogenous use of energy from diets, associated with higher content (49.40 and 45.63%) and lower digestibility of the NDF fraction (39.79 and 47.28% for diets containing carnauba and tucum, respectively). The efficiency of DM use correlates negatively with the proportion and quality of dietary fiber, due to the type of rumen fermentation and

Table 6 - Energy balance of diets containing carnauba or tucum fruits for goats

Variables[1]	Diets[2]			SEM[3]
	Control	Carnauba fruit	Tucum fruit	
GED (%)	66.06 a	65.42 a	68.65 a	2.41
DE (Mcal/kgDM)	3.08 b	3.15 b	3.65 a	0.27
ME (Mcal/KgDM)	2.49 a	2.31 b	2.55 a	0.33
q (Mcal/KgDM)	0.40 a	0.42 a	0.44 a	0.06
Efficiency ME (%)	32.01 a	33.09 a	35.12 a	3.21

[1]GED = gross energy digestibility (GE), DE = digestible energy, ME = metabolizable energy, *q* = metabolizability of GE, EficME = efficiency in the use of ME; [2]Mean values followed by different letters, in the same row, are significantly different by Tukey's test a 5%; [3]SEM = standard error of the mean

the final products formed, with greater energy loss as heat and methane (EL-MECCAWI *et al*., 2009).

The control diet resulted in lower (P<0.05) feeding time (336.37 min/day) by goats, indicating higher selectivity of concentrate and lower intake of remaining hay, with higher (P<0.05) time in idle (668.96 min/day) (Table 7).

The high RT spent by goats fed diets containing carnauba fruit (453.65 min/day) is related to the higher proportion of NDF of this diet, since this constituent represents more than 70% of the total DM of the carnauba fruit, which resulted in higher NDFI (0.41 g/day) and ADFI (0.27 g/day), also increasing chewing time (CT) by 186.38 min/day in relation to the control diet.

The proportion of NDF in the diets directly influences the ingestive behavior of ruminants due to its interference with food intake, influencing the filling, fermentation and rumen function, as well as reducing the rate of passage, with longer digesta retention time and reduced DM intake, being directly correlated with rumination time (GOETSCH *et al*., 2010).

The mean time spent in idle was 668.96; 565.90 and 620.87 min/day for the control diet and those included with fruits of carnauba and tucum, respectively. According to Barreto *et al.* (2011), the higher the proportion of concentrate in the diet, the shorter the rumination time and the longer the time spent in idle, associated with both the physiological energy limitation and the rejection of less nutritive portions of the feed left by the animals after selecting the concentrate.

The inclusion of carnauba and tucum fruits reduced (P<0.05) the feeding efficiency of DM (FEDM), with a mean of 149.68 gDM/h, and improved (P <0.05) the efficiency of feeding NDF (FENDF) of the diet with carnauba fruit (65.16 gNDF/h), reflecting an increase in NDF intake, even with lower DM intake.

There was an increase in the number of cuds (NC) (22.79 cuds/day), number of cud chews per cud (72.31 CC/cud) and total number of cud chews (1,554.41 CC/day) (P <0.05) for diets with carnauba fruits, associated to both the higher proportion of NDF and the lower digestibility of this fraction (39.79%),

Table 7 - Ingestive behavior of goats fed diets containing carnauba or tucum fruits

Variables[1]	Diets[2]			SEM[3]
	Control	Carnauba fruit	Tucum fruit	
FT (min)	336.37 b	382.83 a	383.65 a	35.57
RT (min)	353.73 b	453.65 a	355.47 b	24.99
IT (min)	668.96 a	565.90 c	620.87 b	46.22
TOA (min)	80.94 a	37.62 b	80.01 a	15.50
TCT (min)	660.10 b	846.48 a	759.12 ab	44.45
FEDM (g/h)	199.06 a	144.48 b	154.89 b	18.50
FENDF (g/h)	55.29 b	65.16 a	59.10 b	8.01
ERDM (g/h)	242.03 a	131.96 b	153.60 b	20.66
ERNDF (g/h)	56.67 b	69.59 a	58.57 b	6.88
NC (cud/day)	17.58 b	22.79 a	19.27 ab	1.44
CC_{np} (CC/cud)	64.71 b	72.31 a	65.97 b	2.86
CC_{nt} (CC/day)	1165.80 b	1534.51 a	1458.99 a	82.73
CC_{tb} (sec/cud)	54.28 ab	60.68 a	50.95 b	2.40
GDMc (g/cud)	64.82 a	45.58 b	45.32 b	4.32
GNDFc (g/cud)	20.15 a	19.22 ab	17.57 b	1.92

[1]FT = feeding time, RT = rumination time, IT = idle time, TOA = time in other activities, TCT = total chewing time, FEDM = feed efficiency of dry matter (DM), FENDF = feed efficiency of neutral detergent fiber (NDF), ERDM = rumination efficiency of DM, ERNDF = rumination efficiency of NDF, NC = number of cuds, CC_{np} = number of cud chews per cud, CC_{nt} = number of cud chews per day, CC_{tb} = time of cud chews, GDMc = grams DM per cud, GNDFc = grams NDF per cud; [2]Mean values followed by different letters, in the same row, are significantly different by Tukey's test a 5%; [3]SEM = standard error of the mean

as well as the low quality, with only 36.75% cellulose digestibility.

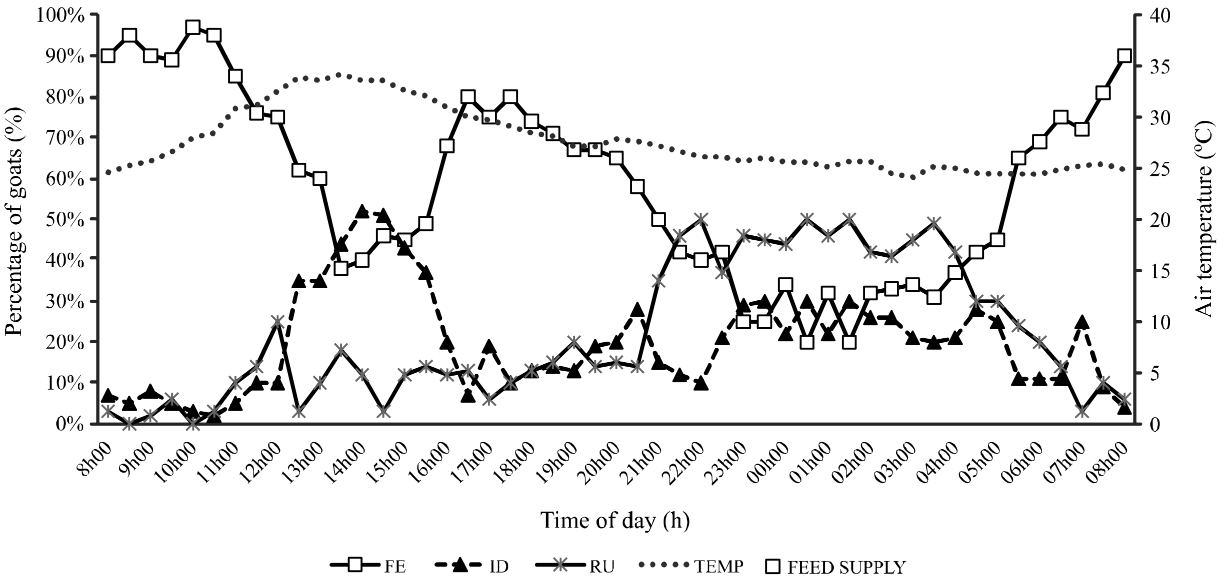
The proportion of NDF in the cud (gNDFc) of goats was lower (P<0.05) when fed diets containing tucum fruits (17.57 g/cud) in relation to the control diet, due to the higher solubility of the concentrate ingredients (corn and soybean meal) in the ruminal environment, being rapidly degraded by the microbiota, leaving a digesta with a higher proportion of NDF to be ruminated, with an increase in the proportion of DM (64.82 gDM) and NDF (20.15 gNDF/cud) in the cud from the remaining fiber fraction.

During the experiment, the mean temperature and relative humidity in the morning and afternoon were 27.3 °C and 72.9% and 34.6 °C and 63.4%, respectively. In the afternoon, the goats were outside the thermal comfort zone, established by Alves *et al.* (2014) at 75 to 80% humidity and 20 to 30 °C, with a critical temperature above 34 °C, which, together with physical limitation, due to the higher proportion of NDF in diets containing palm tree fruits, resulted in a lower number of animals in feeding during the period from 12h00 to 14h30, when the air temperature was higher (34.9 to 35.7 °C) (Figure 1).

Goats outside the thermal comfort zone tend to trigger thermoregulatory mechanisms, with a reduction in DM intake during hotter hours, and an increase in idle time and water intake (ALVES *et al.*, 2014). Increased intake by animals after 16 hours is associated with both rumen emptying, with a reduced regulatory effect on intake, and new supply of diet at this time. There is also a gradual reduction in air temperature after this time, with values close to 29 °C up to 17 hours, which may have provided greater thermal comfort to animals and stimulated consumption.

From 19 h 00 to late dawn, there was an increase in the proportion of animals in idle and rumination, with two peaks of rumination, one from 20 h 00 to 22 h 00, and another at dawn, after 03 h 00. This characteristic is a reflection of the adaptability process of goats to the environment, since to survive the action of predators they did not graze at night, adapting to rumination and rest (VAN SOEST, 1994).

Figure 1 - Frequency of feeding (FE), rumination (RU) and idle (ID) of goats fed diets containing carnauba and tucum fruits



CONCLUSION

The inclusion of carnauba and tucum fruits in diets composed of corn, soybean and Tifton 85 hay for growing goats promotes a reduction in dry matter intake due to the lower quality of the fiber of these fruits. However, the diets containing tucum fruits met the nutritional requirements of goats regarding digestible protein and metabolizable energy, suggesting the use of this alternative food for this category.

REFERENCES

ALVES, A. S. *et al*. Determination of physiological parameters and thermal gradients of Anglo-nubian goatling in Brazilian semiarid. **Journal of Animal Behaviour and Biometeorology**, v. 2, n. 3, p. 90-94, 2014.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS INTERNATIONAL. **Official Methods of Analysis**. Arlington: AOAC, 2012. 474 p.

BARBOSA, M. M. *et al.* Evaluation of laboratory procedures to quantify the neutral detergent fiber content in forage, concentrate, and ruminant feces. **Journal of AOAC International**, v. 98, n. 4, p. 883-889, 2015.

BARRETO, L. M. G. *et al.* Ingestive behaviour of Moxoto and Caninde goats fed diets with two energy levels in feedlot. **Revista Brasileira de Zootecnia**, v. 40, n. 4, p. 834-842, 2011.

BLAXTER, K. L.; CLAPPERTON, J. L. Prediction of the amount of methane produced by ruminants. **British Journal of Nutrition**, v. 19, n. 7, p. 511-522, 1965.

BÜRGER, P. J. *et al.* Ingestive behavior in Holstein calves fed diets with different concentrate levels. **Revista Brasileira de Zootecnia**, v. 29, n. 1, p. 236-242, 2000.

CALSAMIGLIA, S. *et al.* Strategies for optimizing nitrogen use by ruminants. **Animal,** v. 4, n. 7, p. 1184-1196, 2010.

CAPPELLE, E. R. *et al.* Estimates of the energy value from chemical characteristics of the feedstuffs. **Revista Brasileira de Zootecnia**, v. 30, n. 6, p. 1837-1856, 2001.

CHANJULA, P. *et al.* Effects of dietary crude glycerin supplementation on nutrient digestibility, ruminal fermentation, blood metabolites, and nitrogen balance of goats. **Asian-Australasian Journal of Animal Sciences**, v. 23, n. 3, p. 365-374, 2014.

DUARTE, A. Y. S. *et al.* Ethnobotany of Natural Fibres - *Bactris setosa* (tucum) in a Traditional Rural Community. **Fibres & Textiles in Eastern Europe**, v. 20, n. 2, p. 18-20, 2012.

EL-MECCAWI, S. *et al*. Energy intake, heat production and energy and nitrogen balances of sheep and goats fed wheat straw as a sole diet. **Livestock Science**, v. 125, n. 1, p. 88-91, 2009.

GOETSCH, A. L. *et al.* Feeding behavior of goats: invited review. **Journal of Animal Science,** v. 88, n. 1, p. 361-373, 2010.

JOHNSON, T. R.; COMBS, D. K. Effects of prepartum diet, inert rumen bulk, and dietary polyethylene glycol on dry matter intake of lactating dairy cows. **Journal of Dairy Science**, v. 74, n. 3, p. 933-944, 1991.

MERTENS, D. R. Creating a system for meeting the fiber requirements of dairy cows. **Journal of Dairy Science**, v. 80, n. 7, p. 1463-1481, 1997.

MIRANDA, P. A. B. *et al*. Consumo, degradabilidade in situ e cinética ruminal em bovinos suplementados com diferentes proteinados. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 67, n. 2, p. 573-582, 2015.

MORENO, G. M. B. *et al.* Performance, digestibility and nitrogen balance of lambs fed corn silage or sugar cane based diets with two levels of concentrate. **Revista Brasileira de Zootecnia**, v. 39, n. 4, p. 853-860, 2010.

NATIONAL RESEARCH COUNCIL. **Nutrient requirements of small ruminants**: sheep, goats, cervids, and new world camelids. Washington: National Academy of Science, 2007. 347 p.

RIBEIRO, V. L. *et al.* Seletividade e composição da dieta ingerida por caprinos recebendo alimentação à vontade e restrita. **Revista Brasileira de Ciências Agrárias**, v. 4, n. 1, p. 91-94, 2009.

RICE, E. M. *et al*. Relationships between temperament, feeding behavior, social interactions, and stress in lambs adapting to a feedlot environment. **Applied Animal Behavior Science**, v. 183, n. 1, p. 42-50, 2016.

SOUSA, R. F. *et al.* Etnoecologia e etnobotânica da palmeira Carnaúba no Semiárido Brasileiro. **Revista CERNE**, v. 21, n. 4, p. 587-594, 2015.

STATISTICAL ANALYSIS SYSTEM. SAS/STAT user’s guide. Cary: SAS Institute, 2000.

URGE, M. *et al.* Growth performance by Alpine, Angora, Boer and Spanish weather goats consuming 50 or 75% concentrate diets. **Small Ruminant Research**, v. 55, n. 1/3, p. 149-158, 2004.

VALENTE, T. V. P. *et al.* Avaliação dos teores de fibra em detergente neutro em forragens, concentrados e fezes bovinas moídas em diferentes tamanhos e em sacos de diferentes tecidos. **Revista Brasileira de Zootecnia**, v. 40, n. 5, p. 148-1154, 2011.

VAN SOEST, P. J. **Nutritional ecology of the ruminant**. 2. ed. New York: Cornell University, 1994. 476 p.

ZHOU, X. Q. *et al*. Effect of dietary energy source and level on nutrient digestibility, rumen microbial protein synthesis, and milk performance in lactating dairy cows. **Journal of Dairy Science**, v. 98, n. 10, p. 7209-7217, 2015.