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Performance and grazing behavior of growing goats supplemented with palm tree fruit

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ABSTRACT - This study aimed to evaluate the performance and ingestive behavior of growing goats grazing on Tanzania guinea grass and fed diets containing 40% carnauba or tucum fruits. Twenty-one male castrated goats were distributed into three groups, one exclusively on pasture and the other two on pasture and fed diet supplemented at the level of 1.5% body weight (BW) in a completely randomized design. The intake of the supplements was obtained by difference between the amount supplied and the leftovers, with weighing performed every seven days, while pasture intake was determined using titanium dioxide (TiO_2) as external indicator. Ingestive behavior was evaluated for three days. The supplement containing carnauba fruit resulted in a greater intake of neutral detergent fiber (0.137 kg NDF/day), with a reduction of 8.61% in the pasture dry matter (DM) intake of goats. Associated with the intake of pasture nutrients, the tucum fruit diet met the protein (0.103 kg CP/day) and energetic (0.547 kg TDN/day) requirements of goats with intake set at 0.124 kg CP/day and 0.572 kg TDN/day, with higher weight gain (0.111 kg/day) and larger loin eye area (12.76 cm^2). The supplementation with fruits influenced the grazing behavior of goats, increasing the idle time by 1 h in relation to animals not supplemented. The supplementation of growing goats grazing on Tanzania guinea grass pasture with a diet containing 40% tucum fruit, in the proportion of 1.5% BW, did not meet the nutritional requirements for gain of 150 g/day; however, it met requirements for maintenance and average gain of 111 g/day. Energy supplementation reduces the grazing time of goats; thus, it is necessary to consider the level and formulation of supplements, with the possibility of increasing the stocking rate and productivity per unit area.

Keywords: *Bactris setosa*, bite rate, *Copernicia prunifera*, pasture supplementation, weight gain

Introduction

Irrigated pastures in ruminant production systems improve animal productivity per unit area due to increased forage production and reduction of food deficit during drought periods, in addition to lower variation in its nutritional value (Johnson et al., 2010). However, the energy value and protein content of forage may not meet the high nutritional requirements of animals, which limits weight gain.

In this sense, the energetic-protein supplementation in pasture systems increases the availability of nutrients, besides improving the use of pasture by the animals by stimulating the synthesis of microbial protein in the rumen (Kawas et al., 2010), which together with the evaluation of the ingestive behavior allows adjusting the proportion of supplement per animal and the pasture stocking rate, with reduction in the physiological limitation of the intake and adequate ingestion of forage (Goetsch et al., 2010).

Among the ingredients conventionally used in animal supplementation, corn and soybean meal make up most of the diets, whose cost and demand for other purposes may limit their use for the production of goat meat. The use of native palm tree fruits from the Mid-North sub-region of Brazil is an alternative to these ingredients, given their availability during times of forage shortage, potential nutritional value, and intake by local herds of small ruminants.

Among the Arecaceae palm trees, carnauba (*Copernicia prunifera* (Mill.) H.E. Moore) and tucum (*Bactris setosa* Mart.) , which are native to the Northeast region, stand out with a higher occurrence in the states of Ceará, Piauí, and Rio Grande do Norte (Gomes et al., 2009). The main economic use of carnauba is the production of wax, and its fruits have a sweet flavor, very appreciated by animals (Lima et al., 2008). Tucum produces fruits with fleshy pulp, from November to January, being used for the extraction of oil rich in essential fatty acids (Monteiro and Fisch, 2005; Duarte et al., 2012).

The evaluation of the nutritive value of fruit and byproducts from palm trees can reduce deforestation of natural occurrence areas for pasture implantation, with less use of fire and herbicides, practices used due to disinformation of the forage value of these species (Albiero et al., 2007). The objective of this research was to evaluate the inclusion of carnauba and tucum fruits in supplementary diets for growing goats on Tanzania guinea grass (*Panicum maximum* cv. Tanzania) pasture in terms of nutrient intake, performance, and grazing behavior.

Material and Methods

The experiment was conducted in Teresina, state of Piauí, Brazil (latitude 05°05'21 S, longitude 42°48'07 W, and altitude 74.4 m), from April to June 2016. Animal research was conducted in accordance with the institutional committee on animal use under case number 141/16. During the experiment, mean values of temperature and relative humidity in the morning and in the afternoon were 27.56±3.6 °C and 78.2±9.2%, and 31.47±2.1 °C and 68.4±6.89%, respectively, with 0.7 mm rainfall and 1.1 m/s wind speed (INMET, 2015).

An area of 0.330 ha of irrigated pasture of *Panicum maximum* cv. Tanzania was divided into nine paddocks (330 m^2). Mechanized mowing was performed to standardize the pasture 24 days before the onset of the experiment, 30 cm in height (Ferreira et al., 2010), and after the last day of stocking to adjust the residual height after animals left the paddock. After mowing, topdressing was applied with 50 kg N/ha, 40 kg P_2O_5/ha, and 40 kg K_2O/ha as urea, single superphosphate, and potassium chloride, respectively. Pasture was irrigated by conventional spraying, with sprinklers spaced 12 m apart, with a flow rate of 7.3 mm/h and a four-day irrigation interval.

Twenty-one male castrated crossbred Anglo-Nubian goats of six months of age and 21.72±2.4 kg body weight were used. We adopted the grazing system under rotational stocking with a stocking rate [ratio between the number of animal units (AU) and the occupied area] of 4.53 AU/ha, three days of occupation, and 24 days of fallow, totaling a grazing cycle of 27 days, and allowing the expansion of 2.5 new leaves per tiller per day (Silva et al., 2007). Before the onset of the experiment, animals were weighed, clinically evaluated, dewormed, and assigned to three groups of seven animals each according to body weight, one group maintained on pasture without supplementation and two on pasture supplemented with diets containing 40% fruits of carnauba (*Copernicia prunifera* (Mill.) HE Moore) or tucum (*Bactris setosa* Mart.).

The forage biomass in the pre-grazing was measured by launching five frames with an area of 0.25 m^2 (0.5 × 0.5 m) at points representing the average height of the forage canopy in paddocks during the three grazing cycles, cutting the forage at a height of 30 cm from the ground (Ferreira et al., 2010). The dry matter (DM) yield of each paddock was estimated according to the formula: Forage production = sample DM (kg) × area/frame size (m^2) (Ferreira et al., 2010). Forage supply (%) was estimated by the relationship between forage production and stocking rate in each paddock.

Two representative aliquots of the collected samples were taken, one for the determination of forage DM production and another for the fractionation of morphological components (leaf, stem, and dead material), which were converted into kg of DM/ha, with determination of the leaf:stem ratio, as well as grazing simulation sample goats to determine the forage chemical composition (Table 1). In the pre- and post-grazing, the sward height in paddocks was determined with the aid of a graduated ruler.

The chemical composition of the ingredients, supplements, and forage was determined according to methodologies of AOAC (2012) for DM, crude protein (CP), mineral matter (MM), and ether extract (EE). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (LIG) were obtained according to the methodology described by Mertens et al. (1997) and adapted to autoclave (105 °C/60 min) (Barbosa et al., 2015) using 4×5 cm non-woven fabric bags (TNT) with 100 μm porosity (Valente et al., 2011).

The proportion of non-fiber carbohydrates (NFC) was estimated according to Hall et al. (2000): %NFC = 100 – (%CP + %NDFcp + %MM + %EE). Neutral detergent fiber and ADF fractions were corrected for ash, after incineration of the bags in a muffle furnace (AOAC, 2012), and for protein, after determination of the nitrogen fractions of the residues (Licitra et al., 1996).

It was considered to formulate the diets the requirements for growing goats with 20 kg body weight (BW) and gain of 150 g/day, consuming 3.24% BW (0.103 g crude protein/day and 0.570 kg total digestible nutrients (TDN)/day), according to NRC (2007) (Table 2). The supplementation was carried out in the proportion of 1.5% body weight, with the feed being formulated to meet approximately 40% requirements of animals and supplied daily 8 h before releasing the animals to pasture, with quantities adjusted accordingly with weighing, every seven days.

The experiment lasted 72 days, with the first 12 days for adaptation of the animals to management and diets, and 60 days for data collection. All animals remained on pasture from 9:00 to 17:00 h, with free

Table 1 - Chemical composition of ingredients, supplements, and Tanzania guinea grass at 24 days of regrowth (g kg^{-1} dry matter)

Constituent	Ingredient				Supplement		Tanzania guinea grass
	Ground corn grain	Soybean meal	Carnauba fruit	Tucum fruit	40% carnauba fruit	40% tucum fruit	
DM	876	870	875	886	876	880	925
OM	863	825	834	851	846	853	872
CP	94	502	65	72	142	149	109
EE	41	13	55	189	42	96	13
NDFcp	114	138	704	533	354	283	620
ADFcp	49	112	457	313	221	164	338
LIG	11	14	47	22	25	15	50
HEM	65	26	246	219	132	145	282
CEL	40	98	410	292	196	149	287
NFC	738	296	135	171	421	438	205
TDN[1]	790	780	544	616	690	719	559
NDIN (g kg^{-1} TN)	38	55	291	262	144	132	456
ADIN (g kg^{-1} TN)	15	24	143	148	69	71	162

DM - dry matter; OM - organic matter; CP - crude protein; EE - ether extract; NDFcp - neutral detergent fiber corrected for ash and protein; ADFcp - acid detergent fiber corrected for ash and protein; LIG - lignin; HEM - hemicellulose; CEL - cellulose; NFC - non-fiber carbohydrates; TDN - total digestible nutrients; TN - total nitrogen; NDIN - neutral detergent insoluble nitrogen; ADIN - acid detergent insoluble nitrogen.
[1] Estimated according to Cappelle et al. (2001): %TDN = 83.79 – 0.4171 × NDF (R^2 = 0.83).

Table 2 - Proximate composition of supplements containing 40% fruits of carnauba or tucum (g kg^{-1} dry matter)

Ingredient	Supplement	
	40% carnauba fruit	40% tucum fruit
Ground corn grain	454	444
Soybean meal	146	156
Carnauba fruit	400	-
Tucum fruit	-	400
Total	1000	1000

access to water, mineral salt, and shade cloth installed in the paddock, being gathered during the night in a fold attached to the area.

The individual intake of supplement was quantified during the period of collection, subtracting the leftovers from the amount supplied. The nutrient intake (INT_{nut}) of the supplement was obtained based on the intake of DM: $INT_{nut(g)} = gNUT_{forn} - gNUT_{leftovers}$. The daily weight gain (DWG) of animals was calculated by the difference between initial (IW) and final weight (FW), and the relation between the total weight gain and days of supplementation: DWG = WGt/supplementation days (Oliveira et al., 2007).

The estimation of forage intake by non-supplemented animals was performed using the external indicator titanium dioxide (TiO_2), provided to animals for 13 days, at three grazing cycles, with ten days for adaptation and three days for fecal collection. Feces were collected directly from the rectal ampulla and stored at −4 °C. Determination of TiO_2 was performed as described by Myers et al. (2004), in visible UV spectrophotometer, at 410 nm wavelength.

Fecal production (Pf) was estimated according to Berchielli et al. (2006): Pf (kg/day) = I_i/I_f, in which I_i = indicator ingested and I_f = indicator in the feces (g/g DM). From the fecal production, DM intake was estimated according to Berchielli et al. (2000): DMI (kg) = $P_f/(1 - IVDDM)$, in which DMI = DM intake (kg); P_f = fecal output (kg), estimated by TiO_2; and IVDDM = *in vitro* digestibility of DM.

The estimate of DMI by the supplemented animals was obtained as proposed by Madsen et al. (1997), using the degradation parameters NDF and rumen passage rate to estimate the rumen fill, as follows: rumen fill = $[((1 - a - b)/k) + (b/(c + k))]/24$; NDFC (kg/day) = rumen capacity (kgNDF)/rumen fill; DMI = (1/NDF(%DM) × NDFC), in which a = soluble fraction, b = potentially degradable insoluble fraction, c = degradation rate (%/hour), and k = passage rate (%/hour). To estimate rumen capacity, we used the NDF content of Tanzania guinea grass and the proportional intake at 1.2% BW, adopting the average weight of each group (Madsen et al., 1997).

The measurements of the loin eye area (LEA) and loin eye depth were taken at ¾ of the ventral length of the muscle, between the 12th and 13th ribs. Ultrasound images and measurements of carcass characteristics were obtained with Aloka SSD500 (Corometrics Medical System, Wallingford, CT), equipped with a 3.5 MHz linear transducer, according to Figueiredo Filho et al. (2012).

The grazing behavior of goats was quantified from 9:00 to 17:00 h, in the three grazing cycles, during three consecutive days by using instantaneous focal animal sampling at a 10-min fixed interval (Martin and Bateson, 1993). The visual observation of the behavior of goats was carried out by three trained evaluators, who used a digital stopwatch, located on the sides of the paddock at a distance that did not interfere with the natural behavior of the animals but allowed their visualization. Each evaluator observed a group of seven animals, with sheets containing numbering and coat characteristics.

The grazing behavior activities of each animal were classified as grazing time (time for apprehension, chewing, and swallowing of forage), rumination time (when there is rechewing of the cud, but without apprehension of new forage), displacement time (time for the displacement and exploratory behavior in the paddocks), and idle time (animals lying or standing in shaded areas without ruminating).

The bite rate, as a measure of the ingestive behavior, was determined during the grazing behavior evaluation at 9:00, 11:00, 13:00, 15:00, and 17:00 h, by visualization of each animal in the group, noting the time spent to perform 20 bites (Forbes and Hodgson, 1985) using a stopwatch for time determination.

During evaluation of the behavior, temperature and relative humidity data were obtained every hour using thermo-hygrometers positioned at two locations inside the paddock. From the data, we calculated the temperature and humidity index (THI) using the equation proposed by Thom (1959): THI = 0.8 × TA + (% RH/100) × [(AT – 14.4) + 46.4], in which AT = air temperature (°C) and RH = relative humidity (%).

The experiment was performed in a completely randomized design, with the animals representing experimental units (replicates), in a split plot arrangement being the treatments (animals exclusively on pasture or supplemented with diets containing 40% of carnauba or tucum fruits) assigned to the plots, and the three grazing cycles, to the split plots. To adjust the dependent variables: intake of DM and nutrients, weight gain, LEA, and grazing behavior, the initial weight of the animals was used as covariate. In the evaluation of forage production and structural characteristics of the pasture, the grazing cycles represented the treatments with five repetitions (paddocks/cycle).

The dependent variables (intake of DM and nutrients, weight gain, LEA, and grazing behavior) were evaluated under the effect of supplementation or not with carnauba or tucum fruits, and F-test was applied using the SLICE option of LSMEANS of the SAS (Statistical Analysis System, version 9.0). For grazing behavior, the supplementation or not of goats and grazing cycles were considered as fixed effects. Given a significant effect of supplementation on a certain variable, the means of the treatments were compared by Tukey's test (P<0.05). Mean values of forage production and sward structure were analyzed according to PROC GLM procedure of SAS, and when significant, they were compared by Tukey's test (P<0.05).

The mathematical model used to analyze the effect of supplementation on the dependent variables was:

$$yijk = \mu + \alpha i + \beta j + eij + (\alpha\beta)ij + \varepsilon ijk,$$

in which $yijk$ = dependent variable, μ = overall effect of the mean, αi = effect of supplementation (carnauba or tucum fruits), βj = effect of grazing cycle, eij = error associated with plot, $(\alpha\beta)ij$ = effect of interaction between supplementation and grazing cycle, and εijk = overall residue.

Results

Pasture height did not vary during grazing cycles, with a mean of 64.17 cm in height when the animals entered. The highest biomass production occurred in the first grazing cycle (P<0.05), with 3935.05 kg DM/ha, in which the proportion of leaves corresponded to 91% of total forage mass (Table 3). The leaf:stem ratio was high in the first grazing cycle (13.78), with a downward trend during the experiment.

Table 3 - Structural characteristics of Tanzania guinea grass pasture at 24 days of regrowth

Characteristic	Grazing cycle[1]			SEM
	1	2	3	
Pre-grazing height (cm)	64.61a	63.54a	64.37a	0.86
Post-grazing height (cm)	30.21b	31.99b	34.52a	2.16
Forage biomass (kg DM/ha)	3935.05a	3726.80b	3634.72b	96.13
Leaf biomass (kg DM/ha)	3668.94a	3382.96b	3316.51b	83.26
Stem biomass (kg DM/ha)	266.11b	343.84a	318.21a	32.65
Leaf:stem ratio	13.78a	9.83b	10.42b	1.57

DM - dry matter; SEM - standard error of the mean.
[1] Mean values followed by different letters in the same row are significantly different by Tukey's test at 5%.

Dry matter intake of the supplements was not influenced (P>0.05) by type of palm tree fruit used; however, there was higher intake of NDF (NDFI; 0.137 kg NDF/day) and ADF (NDFI; 0.083 kg ADF/day) for supplements composed of carnauba fruit (Table 4). The nutritional requirements for CP and TDN were met only for goats supplemented with diets containing tucum fruit (0.127 kg CP/day and 0.574 kg TDN/day).

Ether extract intake was high (0.037 kg EE/day) for supplements containing tucum fruit, due to the higher proportion of this component in the DM of this fruit (189 g kg^{-1} DM). There was a reduction of 8.61% (0.052 kg DM/day) (P<0.05) in the pasture DMI of goats supplemented with diets containing carnauba (0.543 kg DM/day) or tucum (0.550 kg DM/day) fruits in relation to non-supplemented animals (0.598 kg DM/day) (Table 5).

Table 4 - Intake of nutrients from supplements containing 40% carnauba or tucum fruits by goats on Tanzania guinea grass pasture

Intake	Supplement[1]		SEM
	40% carnauba fruit	40% tucum fruit	
DM (kg/day)	0.350a	0.368a	0.015
DM (%BW)	1.441a	1.413a	0.590
DM (g/UTM)	117.354a	124.570a	7.150
OM (kg/day)	0.311a	0.319a	0.031
OM (%BW)	1.352a	1.363a	0.120
NDF (kg/day)	0.137a	0.104b	0.007
ADF (kg/day)	0.083a	0.056b	0.008
CEL (kg/day)	0.074a	0.051b	0.012
HEM (kg/day)	0.054a	0.048a	0.003
LIG (kg/day)	0.009a	0.005a	0.001
CP (kg/day)	0.060a	0.064a	0.018
EE (kg/day)	0.016b	0.037a	0.004
NFC (kg/day)	0.081a	0.092a	0.031
TDN (kg/day)	0.228a	0.267a	0.011
TDN (%BW)	1.112a	1.182a	0.041
TDN (g/UTM)	24.383a	25.452a	1.460

DM - dry matter; OM - organic matter; CP - crude protein; NDF - neutral detergent fiber; ADF - acid detergent fiber; EE - ether extract; NFC - non-fiber carbohydrates; TDN - total digestible nutrients; UTM - unit of metabolic size; BW - body weight; SEM - standard error of the mean.
[1] Mean values followed by different letters in the same row are significantly different by Tukey's test at 5%.

Table 5 - Nutrient intake of Tanzania guinea grass forage by goats supplemented with feed containing 40% fruits of carnauba or tucum

Intake	Non-supplemented	Supplemented[2]		SEM
		40% carnauba fruit	40% tucum fruit	
DM (kg/day)[1]	0.598a	0.543b	0.550b	0.023
DM (%BW)	3.012a	2.243b	2.382b	0.161
OM (kg/day)	0.521a	0.473b	0.479b	0.045
CP (kg/day)	0.065a	0.058a	0.063a	0.004
NDF (kg/day)	0.371a	0.336b	0.341b	0.052
ADF (kg/day)	0.204a	0.183a	0.185a	0.019
CEL (kg/day)	0.172a	0.222b	0.160b	0.045
HEM (kg/day)	0.167a	0.137b	0.156a	0.021
NFC (kg/day)	0.123a	0.111a	0.113a	0.012
TDN (kg/day)	0.334a	0.302b	0.307b	0.042

DM - dry matter; OM - organic matter; CP - crude protein; NDF - neutral detergent fiber; ADF - acid detergent fiber; CEL - cellulose; HEM - hemicellulose; NFC - non-fiber carbohydrates; TDN - total digestible nutrients; BW - body weight; SEM - standard error of the mean.
[1] Mean values followed by different letters in the same row are significantly different by Tukey's test at 5%.
[2] Pasture DM intake, estimated according to Madsen et al. (1997).

Supplemented goats showed an increase of 32.12 g/day and 55.30 g/day in body weight gain for diets containing carnauba and tucum fruits, respectively, but did not reach the predicted gain for the category (150 g/day) (Table 6). The greater weight gain of the supplemented goats resulted in a larger LEA, especially the diets containing tucum fruits (12.76 cm^2).

There was a reduction of 1.2 h ($P<0.05$) in the grazing time of animals receiving supplementation, which increased in 1 h the time they remained in idle, besides a longer displacement time in the area (+ 0.3 h) for animals kept exclusively on pasture. There was no influence of supplementation on rumination period, with a mean of 0.69 h during the observation period (8 h) (Table 7). The bite rate was not affected by supplementation, with an average of 18 bites/min (Figure 1).

Table 6 - Performance and loin eye area of goats on Tanzania guinea grass pasture supplemented with feed containing fruits of carnauba or tucum

Parameter	Non-supplemented	Supplemented[1]		SEM
		40% carnauba fruit	40% tucum fruit	
Initial weight (kg)	20.75	22.33	22.07	-
Final weight (kg)	24.12	27.63	28.74	-
Days of supplementation	-	60	60	-
Average daily gain (g/day)	56.11c	88.23b	111.41a	9.23
Supplement intake (kg/day)	-	0.40	0.42	-
Loin eye area (cm^2)	7.19c	10.41b	12.76a	1.14

SEM - standard error of the mean.
[1] Mean values followed by different letters in the same row are significantly different by Tukey's test at 5%.

Table 7 - Grazing behavior and bite rate of goats grazing on Tanzania guinea grass pasture and supplemented with feed containing fruits of carnauba or tucum

Activity (h)	Non-supplemented	Supplemented[1]		SEM
		40% carnauba fruit	40% tucum fruit	
Grazing	5.59a	4.36b	4.46b	0.124
Rumination	0.68a	0.64a	0.77a	0.014
Displacement	0.26b	0.44a	0.50a	0.021
Idle	1.45b	2.53a	2.33a	0.067
Bite rate (bite/min)	18.16a	17.59a	18.50a	2.431

SEM - standard error of the mean.
[1] Mean values followed by different letters in the same row are significantly different by Tukey's test at 5%.

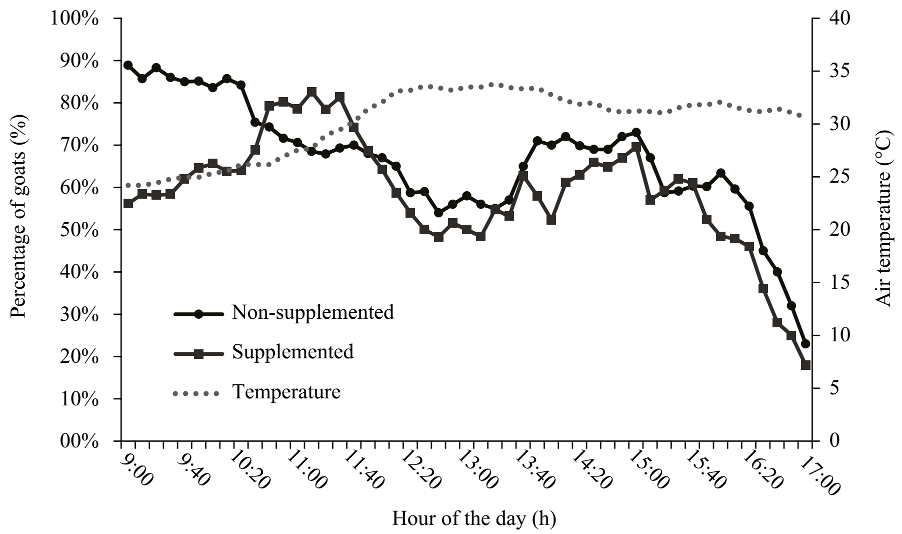

Figure 1 - Grazing frequency (%) of supplemented and non-supplemented goats on Tanzania guinea grass pasture in relation to the hour of day and the ambient temperature.

Mean values of temperature, relative humidity, and temperature and humidity index (THI) during the observation of animal behavior in the morning was 26.6 °C, 83.6%, and 70.2, and in the afternoon, 31.8 °C, 73.1%, and 72.1, respectively (Figure 1). Grazing was concentrated in the first morning hours (between 9:00 and 10:20 h) for non-supplemented animals, in which 90% of the animals performed this activity, compared with the supplemented goats, which started grazing after 10:30 h. There was a reduction in grazing in the period between 12:00 and 14:00 h, when the animals were looking for the shade cloths present in the area.

Discussion

The high leaf biomass (kg DM/ha) obtained for grazing cycles (91.8%) indicates good pasture quality; however, there was a reduction (P<0.05) after the first grazing cycle, associated with the decapitation of tillers and elimination of the apical meristem, besides the effect of animal trampling (Araújo et al., 2015), since with the decrease in forage of better quality during the occupation, the animals moved in the area to meet their requirements.

Forage biomass in the grazing cycles was superior to that obtained by Rufino et al. (2012) for Tanzania guinea grass at 27 days of regrowth (3,292.10 kg DM/ha) and by Ribeiro et al. (2012) for Tanzania guinea grass with pre-grazing height of 50-70 cm (2,320.92 kg DM/ha) under similar conditions of management. Forage biomass resulted in an offer of 8.25 kg DM/100 kg BW. According to Rodrigues et al. (2013), in the same area of the present study, the intake of Tanzania guinea grass by grazing goats is approximately 2.75% BW; therefore, the forage supply was sufficient to meet this demand.

The DMI of the supplements was not influenced by the type of palm tree fruit used, because we set the proportion of the supplement in the diet at 1.5% BW, and the higher intake of NDF and ADF obtained for the supplementation with carnauba fruits occurred due to the greater proportion of these constituents in this supplement (354 g NDF and 221 g ADF) than in the supplement containing tucum fruit (283 g NDF and 164 g ADF).

The DMI of supplements containing carnauba or tucum fruit corresponded to 53.84 and 55.07%, respectively, of the requirements established by the NRC (2007) for growing goats with gain of 150 g/day (0.648 kg DM/day and 3.24% BW). The intake of CP and TDN of the supplement containing carnauba fruit corresponded to 60.19 and 40.02% and the supplement containing tucum fruit corresponded to 62.13 and 43.31%, respectively, in relation to the requirements of goats (0.103 kg CP/day and 0.570 kg TDN/day).

The nutrient supply from the concentrate supplementation should not completely meet the requirements of animals, thus avoiding physiological energetic limitation by the chemostatic effect in the medial hypothalamus (satiety center), and the pasture should meet other needs (Ferdous et al., 2012). Setting the supplement at 1.5% BW is compatible with the research carried out with goats supplemented in the proportion of 1 to 1.5% BW with corn and soybean meal in pasture systems (Bezerra et al., 2010; Adami et al., 2013).

The percentage of EE in the supplement with tucum fruit was above the range of 6-7%, a critical limit (Palmquist and Jenkins, 1980; Mir et al., 2001) for inclusion of lipids in diets for ruminant; however, it did not reduce the DMI of the animals, since due to the pasture intake, there was a reduction in the lipid content of the total diet (pasture + supplement) to 4.23%.

The reduction in forage intake by supplemented animals is related to both total supplement intake (energy regulation) and the proportion of nutrients in the ingredients, such as NDF of carnauba fruit (704 g kg^{-1} DM) or EE of tucum fruit (18.96%). This reduction in intake resulted in a surplus of forage in the area, verified by the increase in the residual height in the paddocks from the first grazing cycle (Table 3), which indicates a possibility of increasing the stocking rate.

The percentage of substitution of forage for concentrate, estimated by Hodgson (1990), was 13.4%, which may be considered low in relation to that obtained by Adami et al. (2013) (16.72%) for goats supplemented in the proportion of 1.5% BW with diets composed of corn and soybean meal. When the energy availability of supplements with high digestibility approaches the requirements of ruminants, they start to regulate the intake by energy demand, which is due to metabolic factors such as high levels of circulating glucose (Goetsch et al., 2010).

The intake of CP (0.127 kg/day) and TDN (0.574 kg/day) of goats on pasture supplemented with concentrate containing tucum fruit met the nutritional requirements established by the NRC (2007), 0.103 kg CP/day and 0.570 kg TDN/day. However, the diets containing carnauba fruit met only the requirements of CP (0.125 kg/day), with a lower TDN intake (0.530 kg/day), which is associated with a higher proportion of cellulose (41%) of fruits, which, associated with pasture NDF, increased the intake of this constituent in the diet (0.296 g/day) in relation to the tucum fruits (0.211 g/day).

Forage supply [relationship between the amount of forage DM per unit area and number of animal units (stocking rate)] corresponded to 8.25 kg/100 kg BW (approximately 1.79 kg forage/animal/day), 3.25 times higher than the average intake of the animals in this study (2.54% BW). According to Hodgson (1984), intake is maximized when the supply of forage corresponds to three to four times the capacity of DMI of the ruminant. In this sense, there was no limitation of pasture intake by the animals, which, together with the good nutritive value of the pasture (109 g kg^{-1} CP), relates the low weight gain of the non-supplemented goats to the high nutritional requirements, which was not met by the forage nutrients only.

The highest weight gain of goats supplemented with feed containing tucum fruit (111.41 g BW/day) is due to the greater energetic availability of fruits and the fulfillment of nutritional requirements by the combination of the supplement with pasture (Table 6). The high potential degradation of DM (68.91%) and the fast lag time (1.05 h) of tucum fruit (Garcez et al., 2015) favor the energetic contribution in the rumen environment, microbial metabolism, and propionate:acetate ratio.

Goats did not reach the predicted weight gain (150 g BW/day), which result is similar to that obtained by Adami et al. (2013) (0.110 kg BW/day) for goats of the same category supplemented with diets containing corn, soybean, and wheat meal in the proportion of 1.5% BW. Thus, supplementation with tucum fruit can be adopted for less demanding animal categories or for reducing the diet costs, considering the proportion of NDF and EE of the fruits.

The LEA obtained in this study was higher than that obtained by Sousa et al. (2009), 9.8 cm^2, for goats supplemented with feed with 157 g kg^{-1} CP and 670 g kg^{-1} TDN, and by Souza et al. (2015), 6.98 cm^2, for goats supplemented with a diet composed of corn and soybean in the proportion of 1.5% BW. The LEA measurement is a good indicator of carcass conformation, with a positive correlation of LEA with the percentage and distribution of the muscular biomasses (Mora et al., 2015). Late-maturing muscles, such as *Longissimus dorsi*, are the most used in this evaluation for easy measurement by ultrasound and for providing more reliable indices of muscle tissue development and size (Hashimoto et al., 2012).

The lower LEA obtained for goats supplemented with carnauba fruits is related to their lower TDN intake (0.530 g/day), affecting the muscle deposition, by reducing the production of propionate in the rumen (Silva et al., 2010). The low proportion of TDN in fruits, associated with the high content of fiber carbohydrates, which have slow ruminal degradation, results in low energy availability for muscle tissue synthesis, with a negative influence on LEA.

The reduction in grazing time of goats on pasture supplemented with feed containing fruits of carnauba and tucum is justified by the effect of energy supplementation on intake, with effect on the regulation of forage intake, favoring a reduction in grazing time and demand of nutrients from the pasture (Adami et al., 2013).

The time spent on grazing of goats kept exclusively on Tanzania guinea grass pasture (5.59 h) was higher than that obtained for goats grazing this grass at 37 days of regrowth (4.52 h), by Rodrigues et al. (2013), and at 28 days of regrowth (5.30 h), by Ribeiro et al. (2012), indicating that the regrowth age and the structural and nutritional characteristics (NDF content) of the pasture influence forage intake of the animals.

As for rumination, it was expected that supplementation would have a negative effect on the time used in this activity, since it reduced the intake of pasture NDF of goats, which did not occur, and may be related to the increase in the intake of this fraction from supplements. The short rumination time observed during the evaluation time (9-17 h) is associated with this activity occurring preferably at night. This characteristic reflects the adaptability 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).

The shortest displacement time for non-supplemented goats is also related to the characteristics of the pasture, because, according to Gonçalves et al. (2009), grazing animals in a monoculture grass area activate less complex decision-making mechanisms for forage selection than in areas where the selectivity of the diet is necessary, reducing the distances traveled in the area. The time spent in displacement by the supplemented goats was higher, due to the physiological energy regulation provided by the supplement and its effect in making the animals more selective in the choice of the grazing site, searching for areas with better-quality forage (Silveira et al., 2015).

Bite rate was not influenced by supplementation ($P>0.05$), on average 18 bites/min, due to the adequate supply of forage (8.25%) and similar characteristics of the pasture in the three grazing cycles. One of the determining factors for the variation in this rate is the forage supply, which must exceed the daily needs of the animal to allow adequate DMI (Hodgson, 1984). When forage supply is limiting to ingestion, there is a change in the proportion of plant tissues in the diet, with a higher proportion of stems and lignified tissues, increasing ADF intake (Decruyenaere et al., 2009), which was not observed in this study.

The delay for the supplemented goats to start grazing occurred due to the metabolic limitation on forage intake promoted by the energy-protein supplement, with a higher frequency of animals in idle and in displacement in the pasture soon after intake of the supplement. All the goats reduced the grazing frequency after 16:00 h, with a higher proportion of non-supplemented animals on grazing than those supplemented in that period (less than 40% performing this activity). The supplementation with palm tree fruits in the morning allowed goats to reach a level of intake compatible with their nutritional requirements in a shorter period (Silveira et al., 2015) and to supply the fiber demand from the pasture faster than the non-supplemented goats.

Conclusions

The supplementation of growing goats on Tanzania guinea grass pasture with concentrate containing 40% of tucum fruits, in the proportion of 1.5% body weight, does not meet the nutritional requirements of 150 g/day gain. However, it is able to meet requirements for maintenance and average gain of 111 g/day, providing greater weight gain than the diet containing 40% carnauba fruits.

Energy supplementation reduces the grazing time of goats and raises the period for the beginning of pasture intake; thus, the level and formulation of the supplements should be considered, with the possibility of increasing stocking rate and meat yield of goats per unit area.

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