

Forage intake process of goats on a Massai grass pasture with different sward heights¹

Processos de ingestão de forragem por caprinos em pastagem com capim-Massai com diferentes Alturas

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Abstract

The objective of this study was to evaluate the forage-intake process of goats feeding on Massai grass pastures with different heights (40, 50, 60, and 70 cm). The experimental design was completely randomized, with treatments corresponding to four sward heights with two replicates over time and space. Collected data were related to the forage-intake process and the chemical and morphological composition of the pasture. Grazing trials (45 min) were performed with four Anglo-Nubian crossbred goats. Total forage mass intake, bite mass, and intake rate were expressed in relation to animal weight. Pasture density, forage mass, and leaf blade increased as forage height increased. The chemical composition of forage at the evaluated heights was similar, except for reduced crude protein content at 70-cm height. Bite rate, intake rate, and time per bite had a quadratic relationship with increasing sward height. The greatest intake rate was observed at 54.7 cm of height, with $0.136 \text{ g DM min}^{-1} \text{ kg}^{-1} \text{ LW}$. Bite rate exhibited a linear and positive correlation with increase in intake. At the 50-cm height, goats harvested a mass of $3.65 \text{ g DM bite}^{-1} \text{ kg}^{-1} \text{ LW}$, when they performed 34.5 bites per minute. Adult goats had a greater forage intake on 50-cm high Massai grass pastures because they could obtain a greater bite mass in a shorter time per bite.

Key words: Bite mass. Bite rate. Intake rate. Intake.

Resumo

Objetivou-se avaliar os processos de ingestão de forragem por caprinos em pastagem com capim-Massai manejado sob diferentes alturas (40, 50, 60 e 70 cm). O delineamento adotado foi o inteiramente

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casualizado. Os tratamentos corresponderam a quatro alturas do dossel com duas repetições no tempo e no espaço. Os dados coletados foram relacionados aos processos de ingestão de forragem e composição química e morfológica do pasto. Foram realizados testes de pastejo de 45 minutos com quatro cabras mestiças da raça Anglonubiana. A massa de forragem total consumida, massa de bocados e a taxa de ingestão foram expressos em relação ao peso dos animais. Com o incremento da altura da forragem houve aumento na densidade do pasto, massa de forragem e lâmina foliar. A composição química da forragem nas alturas avaliadas foi semelhante, com exceção da redução do teor de proteína bruta aos 70 cm. A taxa de bocado, taxa de ingestão e tempo por bocado apresentou relação quadrática com o aumento da altura. A maior taxa de ingestão foi observada aos 54,7 cm de altura, com $0,136 \text{ g MS min}^{-1} \text{ kg}^{-1}$ de PC. A massa de bocado apresentou relação linear e positiva com o aumento da altura. Aos 50 cm as cabras colheram uma massa de $3,65 \text{ g MS bocado}^{-1} \text{ kg}^{-1}$ PC, quando realizavam 34,5 bocados por minuto. No pasto de capim-massai aos 50 cm ocorre maior consumo de forragem por cabras adultas, pois os animais conseguem obter uma massa maior do bocado em menor tempo por bocado.

Palavras-chave: Consumo. Massa do bocado. Taxa de ingestão. Taxa de bocado.

Introduction

The use of cultivated pasture for goats is a recent technique, because most goats feed on native pastures, especially in northeastern Brazil. An understanding of animal-pasture interactions for these small ruminants on a monoculture is of importance to the determination of management strategies that will provide greatest intake. Little information is available concerning how these small ruminants behave and feed on cultivated pastures with different structures. Understanding the behavior of these animals, classified as intermediate selectors (HOFFMAN, 1989), on cultivated pastures, will allow us to define a management practice that potentiates animal performance (ROMAN et al., 2007).

The vertical and horizontal structure of the pasture, expressed mainly by the available forage mass, height, and density of dry matter, has been studied regarding its influence on forage intake (PINTO et al., 2007). Among structural variables for pastures, height is one of the main tools for pasture management because it is associated with the available forage, as well as how the animals access food (SILVA et al., 2009).

Different pasture heights cause variation in the performance of an animal, resulting from a greater or lesser ability to ingest the forage (CARVALHO et al., 2007). Increased pasture height should

mean a greater amount of food could be ingested, because, in theory, the taller the pasture, the greater the opportunity an animal has to meet its intake requirements. This is especially true when the pasture has morphological characteristics that contribute to adequate forage harvesting, such as a large number of leaves, which are the most digestible and preferred part by animals. However, lower grazing heights may lead animals to reduce their intake, because the depth of their bite is lower, and consequently, the bite mass captured will also be smaller, which will affect the forage intake rate of the animals (DECROYENAERE et al., 2009).

Components of ingestive behavior, such as bite rate, bite mass, and forage-intake rate of animals, can change when animals are subjected to different vegetative structures (GONG et al., 1996; OLIVEIRA NETO et al., 2013). Animals change the parameters of their ingestive process in an attempt to meet their intake requirements, because variables such as bite mass and forage-intake rate differ according to pasture structure, especially height. Changes in pasture height might affect the time required to grasp and chew the food, which consequently alters intake of forage (MACEDO et al., 2015).

It is necessary to determine the pasture structures that provide adequate intake by goats. The goals would be to optimize available forage

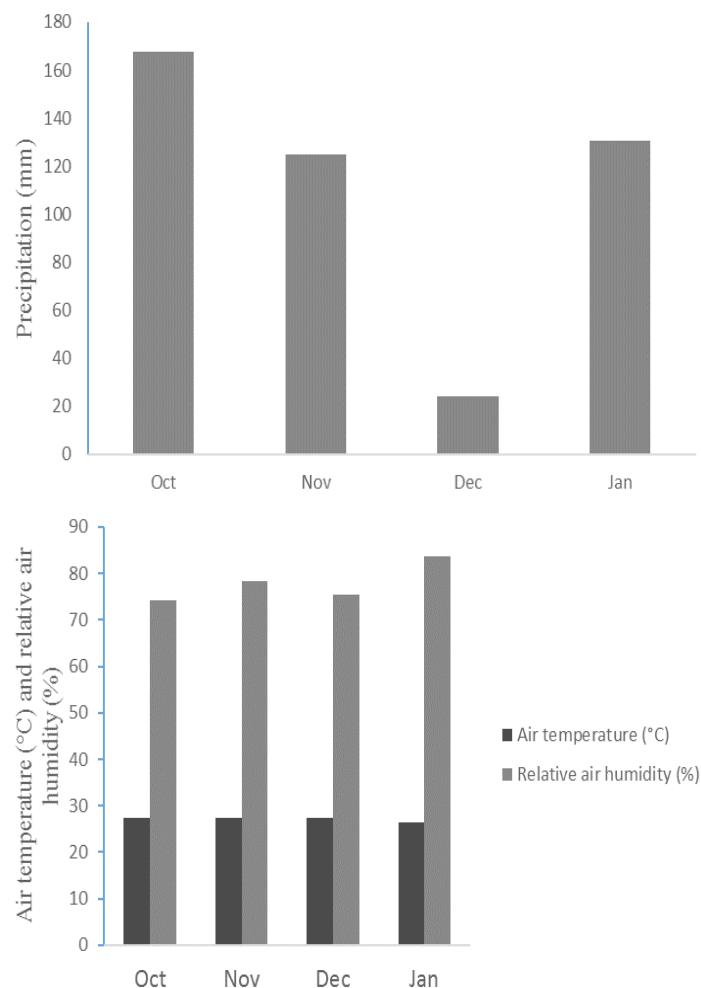
and avoid losses caused by rejection of undesirable parts by animals (e.g., stems) or by reduction of intake because of increased time taken during the manipulation process, and ultimately to achieve good animal performance. Therefore, the objective of this study was to evaluate the forage-intake process in goats on Massai grass pastures with different sward heights.

Material and Methods

The experiment was conducted from November 2011 to February 2012, in the experimental area of Embrapa Meio-Norte, located in the

municipality of Teresina/PI, Brazil ($5^{\circ}6'18''$ latitude, $42^{\circ}48'12''$ longitude). The soil was a yellow Latisol, according to the Embrapa (2006) classification, with the following chemical properties: pH in water 6.3, Ca + Mg 2.5 cmol_c dm⁻³, K 0.11 cmol_c dm⁻³, sum of bases 2.5 cmol_c dm⁻³, CEC at pH 7 7.1 cmol_c dm⁻³, base saturation 41%, and OM 16.60 g kg⁻¹. According to the Köppen classification, the climate in Teresina was tropical rainy Aw' (megathermal), with dry winters and rainy summers. Maximum, minimum, and average daily temperatures were 34.2, 22.9, and 34°C, respectively. The relative air humidity varied from 75 to 83%, and the accumulated rainfall during the period was 446.5 mm (Figure 1).

Figure 1. Precipitation (mm), temperature (°C), and relative air humidity (%) during experimental period



The Massai grass pasture was planted in a 0.34 ha area in 2010. The soil was analyzed before the establishment of the pasture, and based on the results fertilization was applied only once, with 100-120-50 kg of N-P-K ha⁻¹.

Eight 170-m² paddocks were used. A plot-leveling cut was initially made at 20 cm above the soil, and evaluations were conducted when the pastures reached heights of 40, 50, 60, and 70 cm. The time of the evaluations was determined by the average of 30 measurements of height taken in the pasture every two days, using a graded ruler. The average was allowed to vary within 5% of the defined values.

Grazing trials (45 min) were performed with four Anglo-Nubian goats. Dry goats with an average live weight of \pm 30 kg (0.42) were used. The forage allowance during the experimental period was 9.9, 9.6, 10.7, and 16.8% for the heights of 40, 50, 60, and 70 cm, respectively.

The forage mass pre-grazing was measured by casting two 0.50 m² frames randomly over each paddock and cutting the forage within the frame at 20 cm above the soil level. Pasture height was measured using a graduated ruler and 30 readings were taken per paddock.

A representative aliquot of the harvested samples was collected to determine the pre-grazing forage mass for evaluation of the morphological components of the pasture. This aliquot was separated into the leaf blade, pseudostem (stem + sheath), and dead-material fractions, which were weighed and dried in a forced air-circulation oven at 65°C for 72 h. The green forage mass was expressed in kg DM ha⁻¹.

The chemical composition of the pasture was obtained from samples simulating the grazing activity of the animals. The crude protein (CP) and mineral matter (MM) contents were determined using the methodology proposed by the AOAC (2012). The NDF and ADF contents were determined following the method of Van Soest et al. (1991). The

total digestible nutrient (TDN) level was estimated according to Capelle et al. (2001). *In vitro* dry matter digestibility was determined according to the technique of Tilley and Terry (1963) in an *in vitro* incubator developed by Tecnal.

The ingestion processes were determined by double sampling during 45-min grazing tests, according to Penning and Hooper (1985). The night before the evaluations, goats were gathered and deprived of solids and liquids. Prior to the beginning of data collection, the goats were equipped with feces and urine collectors, weighed, and taken to the paddocks. The goats were grouped in two pairs. The first pair (animals A and B) remained contained near the paddock and unable to consume water or feed, to allow the evaluation of metabolic losses, which were determined by variation in weight during 45 min. The second pair (animals C and D) was subjected to a 45-min grazing trial, monitored by four evaluators that worked in pairs. Each pair evaluated one animal on the pasture and recorded the number of bites and feeding time using counters and stopwatches.

At the end of the 45 min, animals C and D were weighed (holding the feces and urine collectors) to determine the weight difference between the time they entered and exited the pasture. Animals A and B, which were on standby, were also weighed and moved to the second grazing session, during which the same procedures were repeated while animals C and D were contained.

Forage intake (I) was calculated by the equation $I = (W_2 + F + U + MWL) - W_1$, where W_1 and W_2 = weight of the animals before and after grazing, respectively, F = weight of feces, U = weight of urine, and MWL = metabolic-weight loss.

The ingestive behavior of the grazing goats was determined by the methodology of Palhano et al. (2007), according to the 45-min-grazing testing protocol, in which bite rate (bites min⁻¹), time per bite (s bite⁻¹), total forage-mass intake (g DM kg⁻¹ LW), bite mass (mg DM bite⁻¹ kg⁻¹ LW), and intake

rate ($\text{g DM}^{-1} \text{ min}^{-1} \text{ kg LW}$) were evaluated. The total forage-mass intake, bite mass, and intake rate were expressed in relation to the weight of the goats.

Total forage mass intake was calculated as the difference in the weight of each animal between the two weighing sessions, plus the respective metabolic losses. The bite mass was the ratio between forage-mass intake and the number of bites during the grazing periods. Intake rate was the ratio between forage-mass intake per live weight and the effective time for intake.

The statistical design was completely randomized, with four pasture heights and two replicates over time and space. Linear regressions were used in the analysis of pasture characteristics, whereas for analyses of ingestive processes, linear and polynomial regressions to the second degree and Pearson's correlation analyses were performed using the SAS (2002) statistical software.

Results and Discussion

The pasture heights of 40, 50, 60, and 70 cm corresponded to the 18, 22, 30, and 48 days of regrowth and influenced the forage mass and pasture structure (Table 1). The greatest forage and leaf-blade masses and pasture and leaf-blade densities were observed in the 70-cm pasture (3,152.6 and 2,400.4 kg DM ha^{-1} ; 44.59 and 33.95 $\text{kg DM}^{-1} \text{ cm}^{-1} \text{ ha}$, respectively). Leaf mass predominated and an absence of stem was detected in the pastures with 40 and 60 cm heights. At 70 cm, stem was present, but the leaf:stem ratio of 2.1 indicated a high proportion of the leaf component in the pasture. Ribeiro et al. (2012), under similar environmental conditions, did not observe the presence of stem and senescent material in Tanzania grass, which is in the same genus as Massai grass, at 30 to 50 cm height. This was similar to the characteristics observed in Massai grass at 40 to 60 cm.

Table 1. Structural and chemical characteristics of the Massai grass pasture with different sward heights.

Sward structural and chemical characteristics	Sward height (cm)				Regression equation	R^2
	40	50	60	70		
Actual entry height (cm)	39.9	49.3	57.7	70.7		
Actual exit height (cm)	31.8	39.0	43.2	55.9		
Forage mass (kg DM ha^{-1})	701.7	1,189.4	1,774.1	3,152.6	$\hat{Y} = -2661 + 79.37*x$	0.93
Leaf blade mass (kg DM ha^{-1})	701.7	1,189.4	1,774.1	2,400.4	$\hat{y} = -1608 + 56.80*x$	0.99
Pasture density ($\text{kg DM}^{-1} \text{ cm}^{-1} \text{ ha}$)	17.58	24.12	30.74	44.59	$\hat{y} = -18.95 + 0.87*x$	0.96
Leaf blade density ($\text{kg DM}^{-1} \text{ cm}^{-1} \text{ ha}$)	17.58	24.12	30.74	33.95	$\hat{y} = -4.05 + 0.55*x$	0.97
Leaf/stem ratio	-	-	-	2.1		
CP (%)	10.5	12.2	10.4	7.5	$\hat{y} = -16.4327 + 1.1272*x - 0.0112*x^2$	0.97
NDF (%)	74.5	75.0	72.9	74.2	$\bar{y} = 74.15$	-
ADF (%)	39.4	37.5	38.1	39.0	$\bar{y} = 38.50$	0.89
IVOMD (%)	58.06	57.27	56.72	56.17	$\hat{y} = 60.47 - 0.0622*x$	0.99
TDN * (%)	53.39	53.07	52.42	53.12	$\bar{y} = 53.00$	-

*Values estimated by the formula of Cappele et al. (2001).

The CP contents displayed quadratic behavior ($P < 0.05$) (Table 1). From 40 to 60 cm of height, the pasture exhibited an average of 11% CP (Table 1), corresponding to 78.2 kg CP ha⁻¹. Leaf blade mass at 70 cm, provided lower protein intake, but higher yield, and resulted in 180.0 kg CP ha⁻¹. The quadratic behavior of CP can be explained by the composition of the pasture. At 40 cm of height, the pasture had greener leaves, which expanded after the plot-leveling mowing, unlike that observed at 50 cm, at which time the pasture had younger leaves from the regrowth of basal tillers. New leaves have a greater crude protein level than older leaves (SANTOS et al., 2009).

The NDF and ADF levels of the Massai grass did not conform to the equation (Table 1), with mean values of $\bar{y} = 74.15$ and $\bar{y} = 38.50\%$, respectively. This was because the samples collected for the pasture for chemical analyses were obtained by evaluators, who simulated animal grazing, and were composed only of leaves from the upper part of the pasture. They did not contain stems even at the greatest pasture height (70 cm). The total digestible nutrients (TDN) of the Massai grass between 40 and 70 cm did not differ ($P > 0.05$) (Table 1). The *in vitro* OM digestibility values were similar to those reported in the literature for tropical forage grasses, between 40 and 60%. These results occurred because of non-limiting FDA levels and variations in PB (PACIULLO et al., 2007; VARGAS JÚNIOR et al., 2013). The average TDN level of 53% (Table 1) is in agreement with values obtained from other tropical grasses (BENETT et al., 2008; OLMEDO et al., 2011). Although the NDF and ADF contents did not differ and the cell wall provides energy to the ruminants, the amount of energy available at the different heights did not limit intake because the Massai grass pastures with 40 to 70 cm of height exhibited similar TDN.

The bite rate exhibited a quadratic behavior ($P < 0.05$) according to the pasture sward height (Figure 2a). The estimated bite rate increased up to 48.9 cm, with 34.5 bites min⁻¹, and then decreased as the

sward height increased. From 40 to 48.9 cm, there was a bite rate increase of 1.3 bites min⁻¹. At the lowest heights, the animals tried to compensate for the lower leaf-blade mass (Table 1) and lower bite depth by increasing their bite rate. This behavior was also observed by Camargo et al. (2012), who evaluated the bite rate of lambs on ryegrass pastures.

Time per bite (Figure 2b), which is the inverse of the bite rate, exhibited a decrease up to 51.7 cm, approximate to the greatest bite rate (48.9 cm). From this point, it increased with sward height. This may be a result of the greater forage mass ingested per bite (Figure 2c) with increased sward height. Thus, the animal took longer to form and manipulate the bite when on taller pastures.

Bite mass increased ($P < 0.02275$) with increasing pasture height (Figure 2d), which resulted in a longer time per bite (Figure 2b). When the sward height and leaf-blade mass were lower, bite mass was reduced (Figure 2d); thus, animals required a longer time for chewing, which led to a greater bite rate to compensate for forage intake. Lower bite rates by goats grazing tussock grasses were observed by some authors (RIBEIRO et al., 2012; RODRIGUES et al., 2013; VELOSO FILHO et al., 2013), indicating that this growth habit limits the forage-intake process by these animals.

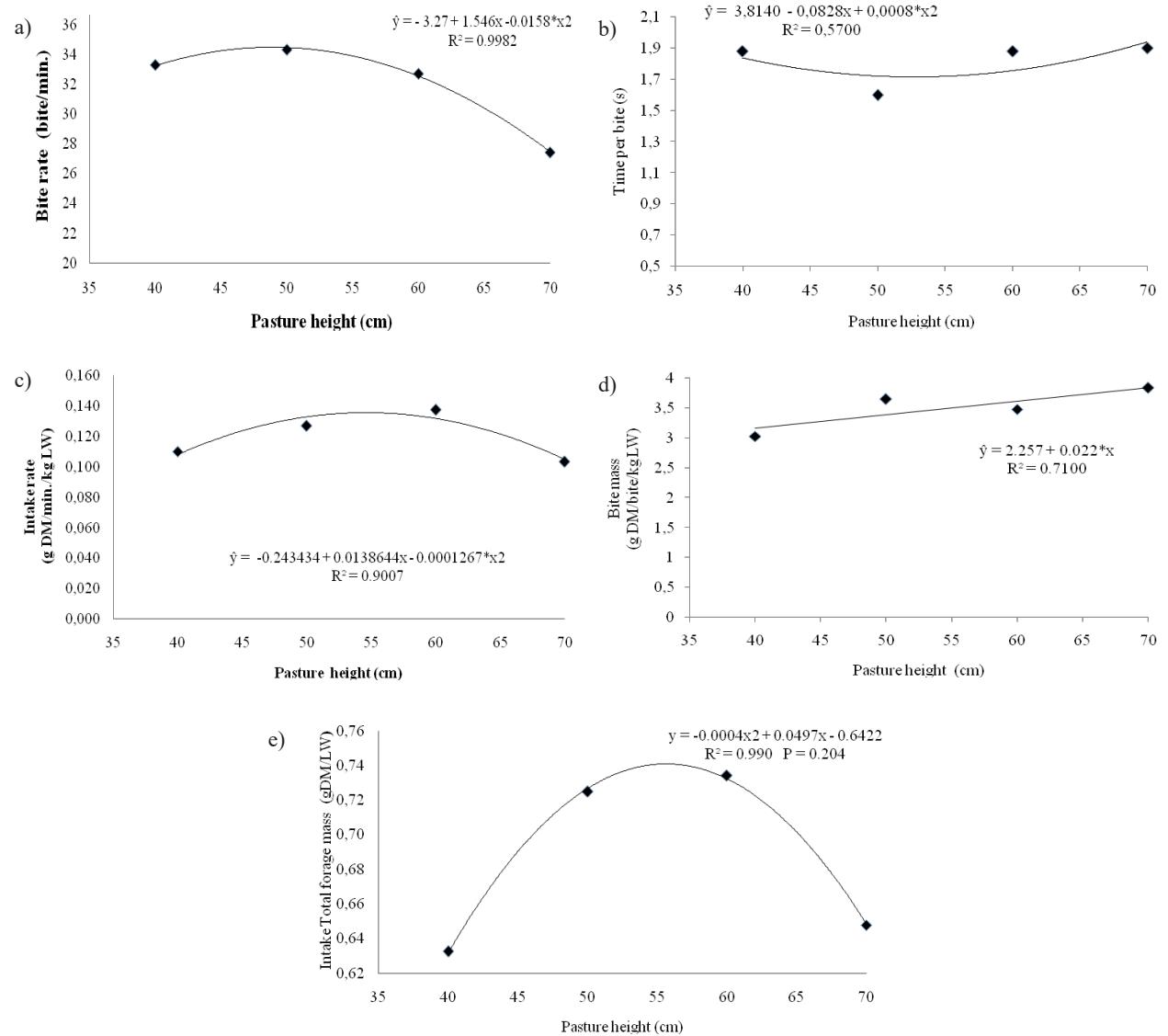
The ratio between bite mass (Figure 2d) and sward height ($P < 0.0275$) varied from 3.03 g DM bite⁻¹ kg⁻¹ LW (or 0.091 g DM bite⁻¹ animal⁻¹) to 3.84 g DM bite⁻¹ kg⁻¹ LW (or 0.116 g DM animal⁻¹) from the lowest to highest evaluated heights, respectively. Greater bite masses were obtained at the greatest height, indicating greater forage and leaf-blade masses (Table 1).

Height was a decisive factor in bite mass (Figure 2d). Positive responses were observed in bite mass and bite time at the greatest sward heights (Figure 2b), with a consequent reduction in bite rate (Figure 2a). This fact points to a growing deficiency of forage grasping with increase in sward structure. However, there was an increase in intake rate (Figure 2c) and

in the total forage mass intake (Figure 2e) for the heights of 54.7 and 52.5 cm, respectively, with later

reduction, probably because of the difficulty in manipulating the bite as pasture height increased.

Figure 2. a) bite rate (bites min^{-1}), b) time per bite (s), c) intake rate ($\text{g DM min}^{-1} \text{kg}^{-1} \text{LW}$), d) bite mass ($\text{g DM bite}^{-1} \text{kg}^{-1} \text{LW}$), and e) total forage-mass intake ($\text{g DM kg}^{-1} \text{LW}$) by goats on Massai grass pastures with different sward heights.



The quadratic behavior between intake and pasture height, with maximum intake of $0.136 \text{ g DM min}^{-1} \text{kg}^{-1} \text{LW}$ (Figure 2c), was likely influenced by the chemical composition of the pasture because the maximum CP content (11.9%) occurred at 50.3 cm of height (Table 1). The decrease in intake rate

at heights greater than 54.7 cm was likely caused by the greater pasture height, which resulted in more time spent per bite (Figure 2b).

Forage grasping (time per bite) influenced the reduction of forage intake speed by Anglo-Nubian goats. Intake rate is related to grasping and chewing

of forage (WOODWARD, 1997), considering that the increase in chewing time is linked to dietary fiber content, which in the current study did not differ among pasture heights. In taller pastures, longer leaves are difficult grasp by goats. In addition, they promote larger bites, which require longer chewing time for better swallowing. In this situation, more time for the manipulative process consequently reduced intake rate.

The relationship between forage intake and pasture height was quadratic. The estimated maximum intake of $0.70 \text{ g DM kg}^{-1} \text{ LW}$ was reached at 52.5 cm (Figure 2e). At this height, the pasture was composed of leaf blades only (Table 1), which demonstrated that the factor with the greatest contribution to increased intake was pasture height. At the heights of 40 and 70 cm, lower forage mass intake was observed (Figure 2c). In the two cases, height was most likely the main limiting factor. At 40 cm, it negatively affected bite depth, and at 70 cm, the higher forage allowed the animals to seeking new grazing sites instead of deepening their bite.

The results obtained for other variables of the ingestive process, intake rate, bite rate, and bite mass, indicated that the intake by goats on Massai grass pasture with 52.5 cm of height is conditioned by the combination between height and density. A similar behavior at 50 cm ($28 \text{ g DM kg}^{-1} \text{ LW}$) was obtained in a study conducted with goats in a sub-humid region (RIBEIRO et al., 2012), wherein the lowest intake ($18 \text{ g DM kg}^{-1} \text{ LW}$) was found at 30 cm and the greatest ($23 \text{ g DM kg}^{-1} \text{ LW}$) at 90 cm.

Bite mass exhibited a positive correlation with intake rate (0.81) and with the forage-mass intake (0.82). That is, at 52.5 cm of height, the pasture structure provided an appropriate bite mass for goats and also allowed a greater intake rate ($54.7 \text{ g DM min}^{-1} \text{ kg}^{-1} \text{ LW}$) with less time spent per bite (1.67 s bite⁻¹).

An increase in bite mass with the increase in the pasture height provided an elevation in the intake rate until 60 cm. From this point onwards, bite mass

continued to increase linearly, whereas the intake rate and bite rate began to decrease. This behavior can be explained by the increase in pasture height, where the animal attempts to increase its bite mass to compensate for the reduction of forage intake and bite rate (Figures 2c and 2a), probably caused by the difficulty in grasping forage and manipulating bites. With the increase in pasture height, the goats increased the bite mass and time per bite (Figures 2d and 2b)

The greatest estimated intake occurred at the height of 52.5 cm; however, there was no correlation between intake and bite rate ($P = 0.2643$) even though the greatest bite rate occurred at 48.9 cm of height. The change in the sward structure with the increase in the masses of forage ($P = 0.1189$) and leaf blade ($P = 0.1207$) also did not affect bite rate among the heights. However, the time per bite was negatively correlated (-0.72; $P = 0.0002$) with bite rate. When the pasture was taller, the goats reduced their bite rate and increased the time per bite by increasing the time spent grasping and chewing.

Conclusions

The height of Massai grass pastures determined the ingestive-behavior patterns of Anglo-Nubian goats.

The greatest forage intake was observed at approximately 50 cm of height because goats obtain an appropriate bite mass with less time spent per bite, resulting in greater forage intake.

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