



## Ingestive behavior of Girolando heifers in integrated crop, livestock (ICL), and forestry (ICLF) systems

[Comportamento ingestivo de novilhas Girolando mantidas em sistemas de integração lavoura-pecuária (ILP) e lavoura-pecuária-floresta (ILPF)]

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### ABSTRACT

Aiming to compare integrated crop, livestock (ICL) and forest (ICLF) systems in relation to ingestive behavior of dairy heifers, a 2 × 2 crossover trial was conducted with two periods and two systems. Eight Girolando (3/4holstein × 1/4 Gyr) heifers were evaluated in pasture of Xaraés palisade grass (*Urochloa brizantha* 'Xaraes' syn *Brachiaria brizantha*) managed with intermittent stocking. The ICLF system had eucalyptus trees planted in tiers with 65% crown cover. Ingestive behavior parameters were obtained using acoustic data collected with mP3 recorders for 48 hours. Statistical analysis was performed using the mixed procedure of SAS, and means were compared using the Tukey-Kramer test at 5% significance. The dry matter intake (DMI), number of daily grazing sessions, and the duration of the grazing sessions did not differ ( $P < 0.05$ ) between systems. A higher ( $P < 0.05$ ) bite rate and total daily bites and lower ( $P < 0.05$ ) bite mass was observed in the ICLF system in relation to ICL. Heifers in shaded pasture change their ingestive behavior in comparison with those in full-sun pasture.

Keywords: agrosilvo pastoral systems, dairy cattle, bite rate, natural shading

### RESUMO

Com o objetivo de comparar sistemas de integração lavoura-pecuária (ILP) e lavoura-pecuária-floresta (ILPF) em relação ao comportamento ingestivo de novilhas leiteiras, conduziu-se um ensaio em delineamento crossover 2 × 2, com dois períodos e dois sistemas. Oito novilhas Girolando foram mantidas em pastagens de capim-xaraés (*Urochloa brizantha* 'Xaraes' syn *Brachiaria brizantha*) manejadas com lotação intermitente. No sistema ILPF, havia renques de eucalipto com 65% de cobertura de copa. O comportamento ingestivo foi avaliado pela análise de áudios coletados com gravadores de Mp3, durante 48 horas. As análises estatísticas foram realizadas utilizando-se Proc mixed SAS. As médias foram comparadas pelo teste Tukey-Kramer, ao nível de 5% de significância. A ingestão de matéria seca (IMS), o número de sessões de pastejo por dia e a duração das sessões de pastejo não diferiram ( $P < 0,05$ ) entre os sistemas. As maiores ( $P < 0,05$ ) médias de taxa de bocado e de número de bocados por dia e a menor ( $P < 0,05$ ) média de massa de bocado foram observadas no ILPF quando comparado ao ILP. Novilhas em pastagem sombreada alteram seu comportamento ingestivo quando comparadas àquelas que são mantidas em pastagem a pleno sol.

Palavras-chave: agrossilvipastoral, bovinocultura leiteira, taxa de bocado, sombreamento natural

### INTRODUCTION

Grazing animals need to maintain constant forage intake throughout the day in order to meet their nutritional requirements. However, they have

faced the problem of obtaining these nutrients from a complex and heterogeneous environment, where the sward structure and accessibility as well as the quantity and quality of the nutrients are variable (Ferreira *et al.*, 2013). Forage

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consumption should be controlled by animal ingestive behavior (Sampaio *et al.*, 2016). For this reason, understanding the animal-plant relationship during grazing behavior is very important. This means to determine how animals adjust their ingestive behavior according to changes in sward structure and pasture environment, aiming to adjust feeding handling according to the maximum animal production potential (Costa *et al.*, 2011; Mezzalira *et al.*, 2011).

Bovine ingestive behavior can be evaluated by the variables grazing time, bite rate, and bite mass, which are influenced by the sward structure. In order to maintain constant dry matter intake and reach their daily nutritional requirements, animals undergo behavioral changes, such as increasing or decreasing grazing time, and changing the number of jaw movements for harvesting and processing fodder according to its height, density, leaf:stem ratio, and the spatial arrangement of sward leaves (Camargo *et al.*, 2012; Yayota *et al.*, 2015).

The integrated crop-livestock-forest (ICLF) production system integrates crop, livestock, and forest components in rotation, combination, or succession in the same area. It has been applied to improve the soil use, to diversify agricultural production, to restore soil quality and pasture areas, and to contribute to cattle ranching, especially in terms of animal welfare (Balbino *et al.*, 2011; Freitas *et al.*, 2013; Lima *et al.*, 2018). However, due to shading from trees in the pasture area, changes in the forage morphophysiology are observed, such as an increase in leaf area, accompanied by a decrease in leaf blade thickness, which result in higher values of specific leaf area in shaded environments (Lopes *et al.*, 2017).

Because of changes in plant morphophysiology, the patterns of bovine ingestive behavior may be affected, such as the bite size, the number of bites per unit time, grazing time, and animal consumption and performance (Gobbi *et al.*, 2009; Yayota *et al.*, 2015; Santos *et al.*, 2018). The hypothesis of this study is that Girolando heifers modify their ingestive behavior according to differences in pasture structure within integrated crop-livestock (ICL) and integrated crop-livestock-forest (ICLF) systems.

## MATERIAL AND METHODS

The Ethics Committee for Animal Utilization of Brazilian Agricultural Research Corporation (Embrapa Rondônia) approved all the management practices applied to experimental animals (process number 06-2015). Trials were carried out in the experimental field of Embrapa, Porto Velho, Rondônia, Brazil (8°48'03.89" S and 63°50'53.08" W) from September 10<sup>th</sup> to November 11<sup>th</sup>, 2015. The predominant climate in this region is Am according to the Köppen classification actualized by Alvares *et al.* (2014). This is characterized by a dry season (from May to September) and a rainy season (from October to April). The means of annual air temperature and annual rainfall are 26°C and 2095mm, respectively.

Eight 25 ± 6.8 month-old Girolando (¾ Holstein × ¼ Gyr) heifers with an initial live weight (LW) of 268 ± 83kg were used. They were distributed in a 2 × 2 crossover design between two ICLF and ICL systems. There were two 30-day experimental periods (period 1 and period 2), 10 days for adaptation, and 20 days for data collection, with a total of 60-days of experimental period. An area of 10ha was divided into two 5-ha areas for each of the ICL and ICLF systems. In each area, the pasture of Xaraés palisade grass (*Urochloa brizantha* 'Xaraes' syn *Brachiaria brizantha*) was divided into four paddocks of 1.25ha and managed by intermittent grazing (10 days of occupation and 30 days of resting periods) at a stocking rate of 2.5 animal unit (AU) per ha. In the center of each pasture system, there was a place for offering water and mineral salt mix *ad libitum*.

The ICLF system had seven tiers of four rows each of eucalyptus trees planted in March 2013 at a 3 × 3m plant spacing. At the beginning of the trial, the trees had an average diameter at breast height of 11.9 ± 2.7cm, total height 13.8 ± 2.5cm, and crown cover 65%. To estimate the forage allowance, the forage was sampled in 1m<sup>2</sup> plots randomly placed in different areas of the paddock before the occupation period. The sward height was measured with a 100-cm (1mm scale) graduated ruler just before cutting (10cm height) and weighing with a portable digital dynamometer (DD2000 Instrutherm®, São Paulo, Brazil). Grass samples were oven-dried at 65°C to

constant weight to determine the dry matter (DM) content.

The forage bulk density (FBD) was estimated according to Lopes *et al.* (2017):

$$\text{FBD (DMkg.ha}^{-1}\text{.cm}^{-1}) = \text{FA} \times \text{height}^{-1}$$

Where:

FA = forage allowance within sward (kg DM.ha<sup>-1</sup>)

Height = height of forage sward (cm)

Forage dry matter intake (DMI) was estimated using the equation:

$$\text{Forage DMI (kg DM.day}^{-1}) = \text{TFP} \times (1 - \text{IVDMD})^{-1}$$

Where:

TFP = total fecal production (kg fecal DM.day<sup>-1</sup>)

IVDMD = *in vitro* DM digestibility (%)

Total fecal production was estimated using the external digestive marker LIPE® (Produtos de Pesquisas Simões e Saliba, Belo Horizonte, MG, Brazil). One dose (500mg) per animal was provided each morning for seven days, following the manufacturer's recommendations. From the third day, feces were collected directly from the

animal's rectum. Then, feces samples were oven-dried at 65°C until a constant weight was achieved, and dried 1-mm samples were sent to the laboratory for analysis (Machado *et al.*, 2011).

In pastures of both systems, Xaraés palisade grass samples were taken by hand-plucking (Prohmann *et al.*, 2012) during four consecutive days (from the 3<sup>rd</sup> to 6<sup>th</sup> day of the paddock occupation period). The samples were oven-dried at 65°C until a constant weight was achieved. Dried 1-mm samples were analyzed for DM, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (LIG) following the methodologies of the National Institute of Science and Technology of Animal Science (INCT-CA) reported by Detmann *et al.* (2012). The determination of *in vitro* DM digestibility (IVDMD) of the diet was adapted from ANKOM (2017). The chemical composition and digestibility of Xaraés palisade grass, as well as the forage allowance in pastures of both systems are shown in Table 1. The forage bulk density (FBD) and sward height of Xaraés palisade grass are shown in Table 2.

Table 1. Forage allowance, chemical composition, and digestibility of Xaraés palisade grass in integrated crop livestock (ICL) and integrated crop livestock forestry (ICLF) systems

System	Forage allowance (kg DM.100kg BW <sup>-1</sup> )	DM (%)	% DM				IVDMD (%)
			CP	NDF	ADF	LIG	
ICL	41.9	30.6	9.5	59.9	27.5	2.2	75.64
ICLF	32.3	25.9	12.5	60.2	28.8	2.5	72.83

DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; LIG, lignin; BW, body weight, IVDMD, *in vitro* dry matter digestibility.

Table 2. Forage bulk density (FBD) and sward height of Xaraés palisade grass in integrated crop livestock (ICL) and integrated crop livestock forestry (ICLF) systems

System	FBD (DMkg.ha <sup>-1</sup> .cm <sup>-1</sup> )	Height (cm)
ICL	68.3	76.6
ICLF	55.9	97.0

DM – Dry matter.

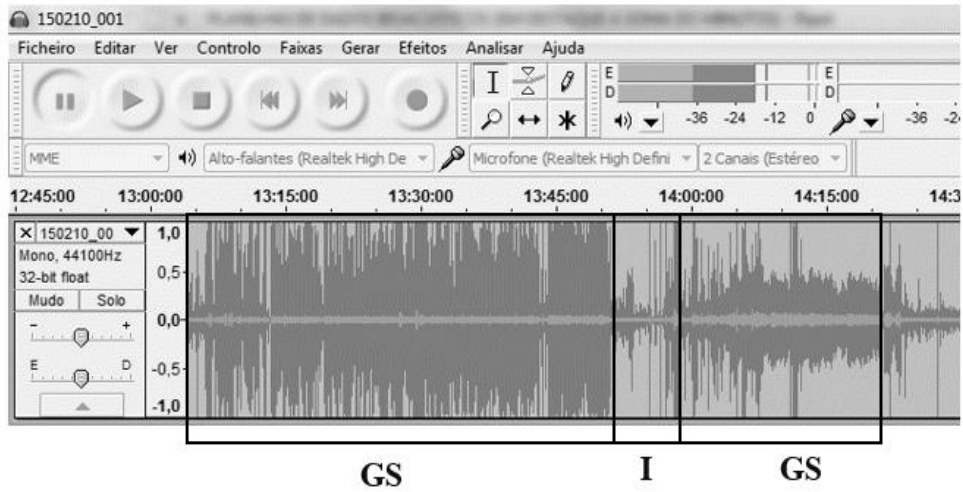
Grazing behavior was observed from 14<sup>th</sup> to 16<sup>th</sup> day of the experimental period using acoustic data (Veit *et al.*, 2018). Audios were captured by mP3 recorders (model PX240, Sony® Corporation, Japan) tied to the heifer's halters for continuously registering the grazing sounds during 48h. Audios were reproduced using Audacity® software.

Following Throuw *et al.* (2009), the number of grazing sessions throughout the day and their duration were identified, considering a grazing period to be more than five minutes and not interrupted for more than five minutes by another activity (Figure 1A).

The bite rate (BR) was determined during the grazing activity of each animal, considering bites to be characterized by sounds of prehension and breaking the leaves by the animal, which had a greater intensity than chewing sounds (Figure

1B). From these data, a stopwatch was used to measure the time (minutes) spent by the animal to produce 20 bites, which was then converted to bites per minute (Jamieson and Hodgson, 1979).

A)



B)

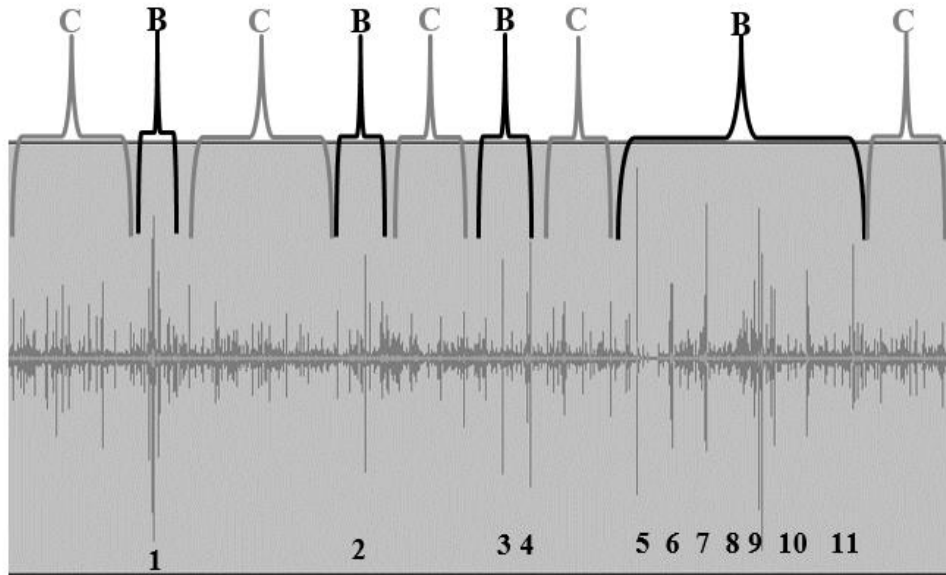


Figure 1. Screenshot of Audacity® during the reproduction of soundtracks: A is an oscillogram of sound of two grazing sessions (GS) with an interval (I) between them; and B is an oscillogram of a sequence of sounds of bites (B) and chewing (C); the numbers 1 to 11 is the counting of bites (peak of sounds). Source: Audacity® (2018).

The number of daily total bites (TB) was obtained according to Baggio *et al.* (2009):

$$TB \text{ (n.day}^{-1}\text{)} = BR \times GT^{-1}$$

Where:

BR = bite rate (bites.min<sup>-1</sup>);

GT = grazing time (min)

The bite mass (BM) was estimated according to the method of Jamieson and Hodgson (1979):

$$BM \text{ (g DM.bite}^{-1}\text{)} = DMI \times TB^{-1}$$

Where:

BM = bite mass;

DMI = dry matter intake (kg DM.day<sup>-1</sup>);

TB = daily total bites (n.day<sup>-1</sup>).

Statistical analysis of the data was performed using SAS (Statistical Analysis System Institute Inc., Cary, NC) MIXED procedure model:

$$Y_{ijkl} = \mu + S_{ij} + P_k + T_l + e_{ijkl}$$

Where:

$Y_{ijkl}$ : is the observation  $ijkl$ ;

$\mu$ : is the overall mean.

S: is the effect of animal  $i$  (1 to 8) within the sequence  $j$  (1 or 2)

P: is the fixed effect of period  $k$  (1 or 2)

T: is the fixed effect of production system  $l$  (ICL or ICLF)

$e_{ijkl}$  is the random error.

Means were compared using the Tukey-Kramer test at the 5% significance level.

## RESULTS AND DISCUSSION

The bite rate (BR) and daily total bite (TB) of Girolando heifers were different ( $P < 0.05$ ) between the systems, with higher values being found within the ICLF than in the ICL (Table 3). Generally, the BR is related to the height of the forage sward. Under conditions of greater sward

height, animals tend to decrease the BR and grazing time due to the higher bite mass (BM), which causes changes in the TB, since this is the product of the BR and grazing time (Rocha *et al.*, 2016; Sampaio *et al.*, 2016). Despite the greater height of Xaraés palisade grass in the ICLF system than in the ICL (Table 3), there was no decrease in the BR of animals grazing in the ICLF. This may be related to the volumetric density of the forage, which was greater in the ICL system (Table 2), which resulted in a greater BM (Table 3). Consequently, a lower BR was found in the ICL system because animals take longer to swallow a bite with higher volume because the chewing time per bite is longer (Hirata *et al.*, 2010; Teixeira *et al.*, 2010; Galli *et al.*, 2018).

The smaller BM of animals in the ICLF system (Table 3) may be related to the integration between the forest component and pasture. Shading forage changes its morphophysiological characteristics, such as decreased tillering and number of leaves per tiller and tends to have higher leaves as an adaptation for reaching the light (Geremia *et al.*, 2018), which explains the lower forage density and greater sward height in this system when compared to the ICL system (Table 2). The BR verified in both systems (ICL and ICLF) (Table 3) were similar to the value of 26.85 bite.min<sup>-1</sup> reported by Souza *et al.* (2011) for beef heifers in different grazing situations. However, they are below the range of 40-70 bites.min<sup>-1</sup> reported for growing cattle (Delagarde *et al.*, 2001). The daily TB (Table 3) was similar to the values of 9,865 to 11,159 bites found by Suárez *et al.* (2014) in beef steers grazing hybrid grass *B. ruziziensis* × *B. decumbens* × *B. brizantha* mulato II (CIAT 36087) in a tropical region of Colombia. These values are considered low, since cattle can perform more than 35,000 prehension actions during the day (Carvalho *et al.*, 2001; Werner *et al.*, 2019).

Table 3. Mean bite rate (BR), daily total bite (TB), bite mass (BM), number of grazing sessions, and duration of grazing sessions for Girolando heifers in integrated crop-livestock (ICL) and integrated crop-livestock-forest (ICLF) systems

Variables	Systems		P
	ICL	ICLF	
BR (bite.min <sup>-1</sup> )	23.57 b	28.52 a	0.0491
DTB (n.day <sup>-1</sup> )	9.124 b	12.304 a	0.0220
BM (g DM.bite <sup>-1</sup> )	1.11 a	0.7 b	0.0083
Grazing sessions (n.day <sup>-1</sup> )	9	8	0.3196
Duration of grazing session (min)	44.72	49.04	0.6501

Means followed by different letters in rows are different by the Tukey-Kramer test at 5% significance.

The low values of BR and TB can be related to the BM (Table 3), which depends on the sward height. Despite the numerical differences in bulk density and height between the ICL and ICLF systems (Table 2), animals took bites with a large volume of forage per bite, so they were able to show similar daily DMI (9.96 and 8.18kg DM.day<sup>-1</sup> in ICL and ICLF, respectively). The BM values observed in both systems (Table 3) are in accordance with a range of 0.7-1.1. g DM.bite<sup>-1</sup> reported for adult cattle grazing temperate pasture of alfalfa and fescue at different heights (Galli *et al.*, 2018). It is likely that cattle BM is related to pasture height (Galli *et al.*, 2018) and forage bulk density (Geremia *et al.*, 2018).

Previously, Souza *et al.* (2019) observed that heifers in ICLF spent more time grazing than those in ICL during the day (from 6:00 to 18:00h). This fact seems to be related to the thermal comfort offered by the trees' shade, since the number of daily grazing sessions and the duration of the grazing sessions did not differ ( $P < 0.05$ ) between systems (ICL vs. ICLF) (Table 3). The number of grazing sessions in both systems (9 and 8 in ICL and ICLF, respectively) are similar to the range 6-8 observed for adult cattle (Teixeira *et al.*, 2010). In general, the duration of a grazing session is approximately 40minutes (Teixeira *et al.*, 2010), which is close to those observed here (44.72 and 49.04minutes in ICL and ICLF, respectively).

The grazing number and duration are related to forage allowance, which was similar between the two systems (Table 1). In general, these variables are affected by the limitation of forage allowance. In this case, the number of grazing sessions increased in order to compensate for the lower rumen fill and satiety (Melo *et al.*, 2016; Baggio *et al.*, 2008). In this study, animals in both systems had no limitation on the forage allowance (Table 1), which was above the threshold of 12kg DM.100kg BW<sup>-1</sup> (Hodgson, 1990). Other factors related to these variables are the chemical characteristics of the grass (Maggioni *et al.*, 2009), which were similar between the systems (Table 1) and explained the similarity in number and duration of grazing sessions.

## CONCLUSION

Girolando heifers grazing Xaraés palisade grass have lower bite mass and higher bite rate and daily total bite number in the ICLF system than the ICL system.

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