PRODUCCIÓN LÁCTEA, COMPORTAMIENTO EN PASTOREO Y CALIDAD DE BIOMASA EN PASTURAS NATIVAS TROPICALES A DIFERENTE CARGA ANIMAL DURANTE DOS AÑOS†

[MILK PRODUCTION, GRAZING BEHAVIOUR AND BIOMASS QUALITY IN NATIVE TROPICAL PASTURES GRAZED TO DIFFERENT STOCKING RATE DURING TWO YEARS]

Jesús Jarillo-Rodríguez[1], Epigmenio Castillo-Gallegos[1*], Luis Ramírez y Avilés[2], Braulio Valles de la Mora[1] and Eliazar Ocaña-Zavaleta[1].

[1]*Centro de Enseñanza, Investigación y Extensión en Ganadería Tropical de la FMVZ-UNAM. Facultad de Medicina Veterinaria y Zootecnia, Apartado Postal136, Martínez de la Torre C.P. 93600, Veracruz, México E-mail: jarillorj22@hotmail.com; pime11302002@yahoo.com.mx; braulio_36@hotmail.com; eocanazvel58@gmail.com*
[2]*Facultad de Medicina Veterinaria y Zootecnia de la Universidad Autónoma de Yucatán. Mérida, Yucatán, Km 15.5 Carretera Mérida-Xmatkuil. Mérida, México. E-mail: raviles@correo.uady.mx*
**Corresponding author*

SUMMARY

The objective of this study was to determine the effect of stocking rate (SR: 2, 3 and 4 cows/ha) upon standing dry matter variables, its quality and ingestive behavior of F1 Holstein x Zebu cows that grazed rotationally and considering the climatic seasons (S): Rainy, winter and dry in the north-central region of the State of Veracruz. A completely randomized design was used. The analysis of variance considered the fixed effects of SR, S and their interaction, being the season the repeated measurement and the experimental unit the subject. The standing dry matter (kg/ha) was affected by S (7140±637, 5341±524 and 4512±719, respectively), but not by SR. Grazing time (min/cow/d) was similar between 2 (428±71) and 4 (400±83) cows/ha, both different from 3 cows/ha (462±55). Ruminating time (min/cow/day) was affected by SR, averaging 372±104, 364±96, and 315±90 min/cow/d, respectively. *In situ* dry matter digestibility (%) went from 57.6±1.3 to 79.2±1.6 for leaves and from 62.6±2.0 to 78.8±0.5 for stems; either component increased their values as SR increased. Daily milk yield per cow was not affected by SR. It is concluded that que there is a significant effect of SR upon grazing and ruminating time, but these variables were not statistically related to pasture variables and individual milk yield, mostly due to the fact that forage availability never limited pasture intake in any of the three stocking rates utilized.
Palabras clave: Daily milk yield, biting rate, climatic period, standing dry matter, pasture management.

RESUMEN

El objetivo del estudio fue determinar el efecto de la carga animal (CA: 2, 3 y 4 vacas/ha) sobre el porcentaje de materia seca de gramas nativas, su calidad, y el comportamiento ingestivo de vacas F1 Holstein x Cebú, en pastoreo rotacional. en época (E) de lluvia, nortes y seca; en la zona centro norte del estado de Veracruz. Se empleó un diseño completamente al azar. Tanto las variables de pastura como de comportamiento animal y producción de leche, se analizaron con un modelo estadístico que consideró los efectos de CA, E, y sus interacciones; además de mediciones repetidas en la unidad experimental. La materia seca total en pie (kg/ha) fue afectada por E (7140±637, 5341±524 y 4512±719, respectivamente) pero no por CA. El tiempo de pastoreo (min/vaca/d) fue idéntico entre 2 (428±71) y 4 (400±83) vacas/ha, y diferentes de 3 vacas/ha (462±55). El tiempo de rumia fue afectado por CA (2, 3 y 4 vacas/ha), promediando: 372±104, 364±96, y 315±90 min/vaca/d, respectivamente. La digestibilidad *in situ* de la materia seca (%) para hojas fue de 57.6±1.3 a 79.2±1.6, y para tallos de 62.6±2.0 a 78.8±0.5, en ambos componentes el valor es mayor conforme se incrementó la CA. La producción láctea (8.1±2.5) no se afectó por CA. Se concluye que existe un efecto de CA sobre el tiempo de pastoreo y rumia; aunque no hubo una relación alta entre este comportamiento, las variables de la pastura y la producción láctea debido al rendimiento similar de forraje obtenido.
Palabras clave: producción láctea, tasa de bocados, periodo climático, rendimiento de materia seca, manejo de la pastura.

---

† S*ubmitted May 23, 2016 – Accepted July 05, 2018.* This work is licensed under a CC-BY 4.0 International License

INTRODUCTION

The objective of pasture management in animal production systems is to optimize the proportion of available forage consumed by the grazing animal (Dillon *et al*., 2005). To reach this objective, it is necessary to understand climate, animal and pasture factors that affect dry matter intake during grazing. Management of stocking rate (SR) aims to manipulate pasture structural components (through numbers of grazing animals) in order to strike a balance between animal product per animal and per hectare. By manipulating pasture structure and dry matter yield, a high dry matter intake can be obtained, resulting in a high level of individual animal performance (Ungar and Noy-Meir, 1988).

Under tropical conditions, some pasture structural components, such as plant height, are related to animal ingestive behavior (Stobbs, 1973; Silva and Carvalho, 2005), and are altered when stocking rate is modified (Kennedy *et al*., 2007). In general, a high stocking rate reduces dry matter yield by reducing regrowth capacity, and also alters botanical composition, since survival of pasture plant species is affected by stocking rate. Eventually, pasture structural modifications occur that modify animal ingestive behavior (Gibb, 2006), resulting in decreased pasture intake and animal performance (Langer, 1979).

In the humid tropics of Mexico, native gramma pastures are the main source of feed (Amendola *et al*., 2005) for grazing cattle (Ocaña, 2003), but very little research has been conducted on pasture production and animal performance. Even less effort has been devoted to studying changes in pasture structure and its effect on ingestive behaviour of grazing cattle (Castillo, 2003), some studies indicate that ingestive behavior can be modified by plant structure (Orantes-Zebadúa *et al*., 2014) and time in erect pasture (Ortega *et al*., 2009); for example, more leafy plant structure decreases grazing time and increases the quantity of dry matter intake (Nochebuena *et al*., 1994). The present study was designed to measure the effects of stocking rate on pasture forage production and nutritional quality, and on animal grazing behaviour.

MATERIALS AND METHODS

The study was conducted from September 1, 2005 to July 30, 2007, and was divided into two periods: 2005-2006 and 2006-2007. The study area was located at the Centre for Teaching, Research and Extension in Tropical Animal Husbandry (CEIEGT), of the Faculty of Veterinary Medicine, at the National University of Mexico (20° 02'N, 97° 06'W; 112 masl), in the municipality of Tlapacoyan, Veracruz, Mexico.

Climate and soils

The study was conducted over two periods (2005-2006 and 2006-2007), each one beginning in the rainy season (September and October), continued in the winter season (January and February), and ending in the dry season (May and June). Total annual rainfall was 1211 mm and 1811 mm for the first and second periods, respectively (Table 1). The soil in the area is classified as an acid Ultisol (pH 4.5-5.2), with a clay-lime texture, low N (0.032%) and P (2.32 ppm, Bray II) content, low cation exchange capacity and no Al toxicity (23.18%).

Table 1. Temperature and rainfall for the three seasons during two experimental periods.

Period	Season	Temperature (°C)			Rainfall
		Mean	Max	Min	(mm)
Year 1	Rainy	25.9	38.4	16.8	557
	Windy	20.0	33.2	8.2	314
	Dry	25.6	40.2	12.5	340
Year 2	Rainy	26.4	31.8	21.3	1118
	Windy	21.1	25.3	16.8	377
	Dry	27.8	33.7	22.1	316

Year 1= 2005-2006, Year 2= 2006-2007

Animals, pastures and treatments

Thirty multiparous F1 (Holstein x Cebu) cows were divided into 3 groups of 10 animals (489.9±67.5 kg live weight), balanced according to parity, milk yield in the previous lactation and live weight, and assigned randomly to graze 3 stocking rate treatments.

In a 10.8 ha area of native pasture, three stocking rate treatments were established: 2 (low), 3 (medium) and 4 (high) cows ha^{-1}. A 3-day grazing/27-day recovering rotational grazing cycle was established, and during the study twenty four grazing cycles were performed. There were ten paddocks per stocking rate, on areas of 5.0, 3.3 and 2.5 ha, respectively. Prior to initiating the study, the main botanical component was native grasses (86.9%), primarily *Paspalum notatum* Fluegge) and *Axonopus compressus* (Swartz) Beauv) and introduced grasses (*Cynodon nlemfuensis* Vanderyst, *Brachiaria arrecta* (Hack. ex T. Durand & Schinz) Stent and *Brachiaria mutica* (Forsk.) Stapf

Ten different cows grazed on each stocking rate treatment during the experimental periods. Two paddocks in each stocking rate treatment were randomly chosen and used for performing measurements, in two continuous grazing cycles at the end of each season. These paddocks were grazed on successive 3-day periods. Cows were not supplemented during the rainy and dry seasons, but received 1.14 kg of concentrate (14% crude protein) per cow per day during the windy season.

Pasture measurements and ingestive behaviour

On the second day of the three day grazing period, the herbage mass present (HMP) before and after grazing was assessed using the comparative yield method (Hendricksen and Minson, 1980; Haydock and Shaw, 1975), with 5 double-sampling quadrats (50 x 50 cm) and 100 visual comparison quadrats. During the second period (2006 – 2007) duplicate measurements were made in each paddock, by dividing it into 2 sections of equal size. Ten subsamples from the total HMP before (BG) and after grazing (AG) were separated into leaf blades (LF), stems (ST: leaf sheath + true stem) and dead material (DM). From these data the percentage of use (USE) of LF and ST was calculated as:

$$USE = [(LFBG - LFAG)/(LFBG)] \times 100 \qquad (1)$$

Where: LFBG = Leaves before grazing; LFAG = Leaves after grazing

Botanical composition (BC) was estimated before and after grazing in the last two grazing cycles during each season, using the dry-weight-rank method (Mannetje and Haydock, 1963) on one hundred quadrats per paddock. Data for native and introduced grasses are shown, as these components represent more than 90% of the forage available in the pastures. Samples of HMP were analyzed for crude protein (CP; N x 6.25) using the Kjeldahl method (AOAC, 1980) neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin (LIG) (Van Soest, 1991), using an ANKOM digester and 48-h *in situ* ruminal dry matter (DM) degradability (ISDMD; Orskov and McDonald, 1979).

Observations of ingestive behavior were made on the second day of the 3-day grazing period. At 10-minute intervals over 21 h, "sweeping" visual observations were performed (Gary *et al*., 1970) and recorded as to whether each cow was grazing, ruminating or engaged in other activities. From these data, the total number of times of each activity per cow was computed and the result multiplied by 10, which provides an estimate of the number of minutes per day that each cow was engaged in each activity (Gary *et al*., 1970).

Biting rate was estimated using "focal" visual observations (Gary *et al*., 1970) during the last 10 minutes of each hour, when the time for each cow to take 20 bites was recorded. Data were converted to bites per minute (Penning and Rutter, 2004). The cows were not observed from 08:00 h to 11:00 h when they were in the milking shed.

Treatment design and statistical analyses

A completely randomized design was applied and the experimental unit for pasture variables was a paddock (two paddocks in each stocking rate treatment). For the case of ingestive behaviour variables, individual animals were the experimental units (Jamieson and Hodgson, 1979), with 10 cows per treatment. A grazing animal can be considered as an independent random effect if its individual behavior does not differ from that of the herd (Rook and Penning, 1991) thus the data were analyzed under this assumption.

There were twenty four 30-day grazing cycles performed throughout the experiment, and of those, twelve were chosen to sample the randomly selected paddocks with respect to HMP and its components. In the 2005-2006 period: Grazing cycles 1 and 2, 5 and 6, and 9 and 10, for the rainy, windy and dry seasons, respectively. In the 2006-2007 period: Grazing cycles 13 and 14, 17 and 18, and 21 and 22 for the same seasons. In the first period, there was a single sampling on each stocking rate x paddock x grazing cycle combination, while in the second period, each paddock was divided in two equal sections where two simultaneous samplings were done. The grazing cycle was considered the repeated measurement on the paddock.

The herbage mass present and its components were analyzed with a model that considered the fixed effects of stocking rate and grazing cycle and the random effect of paddock. Grazing cycle was used as a continuous variable, so the model included its linear, quadratic and cubic single effects as well as interactions of these effects with stocking rate in order to test if HMP behavior was similar between stocking rates, as grazing cycles advanced in time. The PROC MIXED of SAS for repeated measurements was used. Of the covariance structures tested (CS, AR(1), ARH(1), ARMA(1,1), HF, TOEP, TOEPH and UN) only CS, AR(1) and ARMA(1,1) converged, and of these three, AR(1) was the one with the lowest AIC_C value, indicating it was the most suitable to the data (Littell *et al*., 1998).

Animal behavior variables were analyzed with models that considered the fixed effects of stocking rate, season and their interactions; the individual animal, on which repeated measurements were taken was the replicate, considered a random effect, and the repeated measurement was each of the six combinations of growth cycle (2005-2006 and 2006-2007) by season (rainy, winter and dry). The procedure PROC MIXED in SAS for repeated measurements was used. The autoregressive [AR(1)] covariance structure~~s~~ was the most appropriate for ingestive behavior variables (Littell *et al*., 1998). Model effects and differences between least squares means were considered significant if P<0.05.

RESULTS AND DISCUSSION

Available dry matter and pasture nutritional value indicators

Stocking rate did not affect HMP (leaves, stems and total DM) for any season during 2005-2006. As well, there was no interaction between stocking rate and seasons (Table 2). Yet, in 2006-2007, during the rainy season, all variables were higher at 3 cows ha^{-1} than at the other stocking rates. During the windy season, all values appeared to decline as stocking rate increased, although stocking rates with 3 and 4 cows ha^{-1} were statistically similar; no differences were detected during the dry season. During 2005-2006, the variable "leaves" was different (P<0.0009) for the windy and dry seasons (P<0.02). For "stems", the windy season was different in comparison to the rainy (P<0.005) and dry seasons (P<0.008). During 2006-2007, the variables leaves, stems and total dry matter were statistically different (P<0.0001).

Pasture use showed no statistical differences between stocking rate and seasons, yet in 2005-2006 it was slightly more than 40% at 4 cows ha^{-1} (Table 3). During the rainy season, there was little difference in the use of leaves and stems, but as the year progressed, the preference for leaves over stems became more pronounced. This was more obvious at the lightest stocking rate. In 2006-2007, the response to stocking rate was not so obvious (Table 3), but the preference for leaves over stems remained.

During both experimental periods, the contribution of native (*Paspalum notatum* Fluegge and *Axonopus compressus* (Swartz) Beauv) and introduced grasses (*Cynodon nlemfuensis* Vanderyst, *Brachiaria arrecta* (Hack. ex T. Durand & Schinz) Stent and *Brachiaria mutica* (Forsk.) Stapf to herbage mass was affected by stocking rate. The proportion of native grasses increased, while introduced grasses decreased with increasing stocking rate (Table 4). The greatest change occurred with the increase from 2 to 3 cows ha^{-1} (around 17%), compared to 4% when going from 3 to 4 cows ha^{-1}.

Table 2. Dry matter (LSM and ± s.e.) of leaves, stems (true stem + leaf sheath) and total standing DM (kg ha^{-1}) of native grass-based pastures stocked at 2, 3 and 4 cows ha^{-1} during the rainy, windy and dry seasons during two consecutive grazing periods.

Component	2005-2006			2006-2007		
	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}
Leaves, stems and total standing DM						
Rainy season						
Leaves	3190±260[a1]	2901±75[a]	3007±540[a]	2517±89[a]	3514±196[b]	2630±257[ab]
Stems	2076±161[a]	2234±102[a]	2491±454[a]	2919±221[a]	3821±327[b]	2291±310[ac]
Dead material	2328±491[a]	1159±194[a]	1605±542[a]	1495±365[a]	1520±201[a]	1147±270[a]
Total	7594±793[a]	6294±184[a]	7103±1501[a]	6931±498[a]	8855±384[b]	6068±461[ac]
Winter season						
Leaves	1935±263[a]	2184±465[a]	1232±33[a]	2422±214[a]	2384±287[ab]	1467±197[b]
Stems	1520±219[a]	1732±476[a]	1119±161[a]	1976±218[a]	1478±206[ab]	820±64[b]
Dead material	1975±322[a]	1555±430[a]	2343±399[a]	3244±538[a]	2078±389[b]	583±46[c]
Total	5430±727[a]	5471±792[a]	4694±354[a]	7642±958[a]	5940±83[b]	2870±232[c]
Dry season						
Leaves	2229±300[a]	2658±766[a]	1812±385[a]	727±17[a]	915±237[a]	1045±256[a]
Stems	2476±542[a]	2451±527[a]	1720±20[a]	1022±216[a]	791±179[a]	1107±277[a]
Dead material	2599±380[a]	2116±476[a]	895±425[a]	1309±136[a]	681±120[a]	519±40[a]
Total	7304±1184[a]	7225±1157[a]	4427±523[a]	3058±405[a]	2387±481[a]	2671±566[a]

[1]Means followed by the same letter within a row during a specific period and season are not significantly different (P≤0.05).

The contribution of native (NG; 86.9 %) and introduced (IG; 2.9 %) grasses in the pastures, as determined before and after grazing, is summarized in Table 4. The contribution of NG to botanical composition increased positively with stocking rate during all three seasons of 2005-2006. In 2006-2007, during the rainy and dry seasons, IG contributed more at the lower stocking rate than with 3 or 4 cows ha^{-1}. Native grasses showed a similar trend with stocking rate during 2006-2007, while introduced grasses did not show a defined trend. During the rainy and dry seasons their contribution decreased with increasing stocking rate, while during the windy season they remained the same.

Table 3. Percentage use of the same plant components before grazing, in native grass-based pastures stocked at 2, 3 and 4 cows ha^{-1} during the rainy, winter and dry seasons during two consecutive grazing periods.

Component	2005-2006			2006-2007		
	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}
	Percentage use					
	Rainy season					
Leaves	14.8±10.7 ^{a1}	26.2±10.3^{a}	40.6±10.6^{a}	8.4±3.3^{a}	33.8±8.6^{b}	27.7±8.9^{ab}
Stems	15.7±11.2^{a}	30.5±6.0^{a}	46.6±8.7^{a}	11.7±4.7^{a}	30.8±8.7^{b}	11.5±6.3^{b}
Total	18.6±11.2^{a}	19.3±7.0^{a}	32.5±11.6^{a}	8.8±5.0^{a}	35.6±5.3^{b}	15.4±6.0^{b}
	Winter season					
Leaves	30.0±8.4^{a}	46.2±10.4^{a}	43.6±14.9^{a}	43.7±3.7^{a}	36.9±9.9^{ab}	20.6±8.4^{b}
Stems	24.8±11.0^{a}	43.3±9.8^{a}	49.0±17.9^{a}	30.9±8.3^{a}	26.0±8.9^{a}	6.1±5.3^{b}
Total	19.5±9.7^{a}	31.7±10.0^{a}	49.1±8.9^{a}	40.0±5.2^{a}	30.4±10.5^{a}	10.0±4.7^{b}
	Dry season					
Leaves	42.6±7.0^{a}	40.7±15.8^{a}	36.5±14.3^{a}	50.6±1.9^{a}	39.1±10.2^{a}	34.3±14.8^{a}
Stems	17.2±8.4^{a}	27.9±14.8^{a}	39.3±16.0^{a}	37.5±8.7^{a}	13.1±8.1^{a}	21.4±11.9^{a}
Total	11.6±5.6^{a}	27.0±8.8^{a}	28.2±7.7^{a}	38.2±5.3^{a}	27.7±8.5^{a}	23.3±9.1^{a}

[1]Means followed by the same letter within a row during a specific period and season are not signifantly different (P≤0.05).

Table 4. Percent contribution (mean ± s.e.) of native (NG) and introduced (IG) grasses to botanical composition, during the rainy, windy and dry seasons, in pastures grazed at 2, 3 and 4 cows ha^{-1} during two grazing periods in the humid tropics of Mexico.

Component	2005-2006			2006-2007		
	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}
	Rainy season					
NG	71.5±3.5^{a1}	80.7±2.4^{b}	81.6±2.9^{b}	71.2±4.8^{a}	89.8±1.2^{b}	90.8±1.4^{b}
IG	15.2±3.2^{a}	7.1±0.9^{a}	9.2±2.4^{a}	8.0±1.7^{a}	2.4±0.6^{b}	1.9±0.3^{b}
	Windy season					
NG	74.9±2.3^{a}	78.6±2.6^{a}	89.1±1.8^{b}	78.3±2.9^{a}	90.3±1.5^{b}	92.9±1.8^{b}
IG	9.2±1.7^{a}	4.5±0.5^{a}	1.6±0.7^{a}	1.5±0.2^{a}	4.2±1.2^{a}	3.1±1.0^{a}
	Dry Season					
NG	61.7±3.5^{a}	88.4±1.4^{bc}	91.0±2.4^{c}	67.6±2.0^{a}	86.5±1.5^{b}	91.9±1.4^{b}
IG	10.2±1.2^{a}	1.6±0.3^{a}	1.9±1.1^{a}	11.8±2.0^{a}	4.5±0.8^{b}	3.4±1.4^{b}

[1]Means followed by the same letter within a row during a specific period and season are not significantly different (P≤0.05).

Overall, stocking rate had no effect on pasture quality variables during the study (Tables 5, 6). Leaves had more crude protein and lower NDF concentrations than stems throughout the experiment. During 2005-2006, leaf crude protein was higher at all stocking rates during the windy (P<0.0007) and dry seasons (P<0.005) than during the rainy season (P<0.03). Stems showed differences between rainy and dry seasons (P<0.01), and ISDMD was greater during the rainy season compared to the windy (P<0.04) and dry seasons (P<0.02). However, crude protein and leaf ISDMD levels were higher overall during 2006-2007, and declined as the year progressed. At all stocking rates in all seasons, stem ISDMD was comparable to or slightly higher than that for leaves.

Under set-stocked conditions, as stocking rate increases the quantity of HMP and bite size normally decline (Stobbs, 1973; Jones and Jones, 2003). To avoid a reduction in DM intake, animals compensate by increasing both biting rate and grazing time (Jones and Jones, 2003). Therefore, increasing the stocking rate increases the severity of grazing (Burns and Sollenberger, 2002), affecting both standing forage and its degree of utilization (O'Donovan *et al*., 2004). In the present study where rotational grazing was applied, stocking rate did not affect standing DM at the commencement of grazing, nor utilization rates of leaves and stems during the first year. Grazing intensity was therefore higher on pastures stocked at higher rates. During the regrowth period, the more heavily grazed pastures compensated by producing more growth than the pasture stocked at the lower rate so that pre-grazing DM levels were equivalent at all stocking rates.

Table 5. Nutritional value (mean ± s.e.) of leaves and stems (true stem + leaf sheath) of native grasses in pastures grazed at 2, 3 and 4 cows ha^{-1} during the rainy, windy and dry seasons during 2005-2006 in the humid tropics of Mexico.

Component[1] (% of DM)	Leaves			Stems		
	Cows ha^{-1}			Cows ha^{-1}		
	2	3	4	2	3	4
			Rainy season			
CP	7.7±0.4[a2]	8.2±0.2[a]	8.7±0.7[a]	5.2±0.3[a]	6.0±0.4[a]	5.6±0.1[a]
NDF	68.6±5.8[a]	71.9±6.2[a]	71.9±5.8[a]	73.6±1.2[a]	80.2±2.5[a]	79.7±1.4[a]
ADF	42.9±1.4[a]	45.5±1.1[a]	43.2±0.7[a]	44.1±1.1[a]	45.1±0.0[a]	44.6±0.4[a]
LIG	8.7±2.0[a]	10.6±2.4[a]	9.9±1.6[a]	9.5±0.4[a]	9.1±0.2[a]	9.7±0.4[a]
ISDMD	59.3±0.9[a]	57.6±1.3[a]	61.4±2.4[a]	62.9±0.8[a]	62.6±2.0[a]	63.7±3.3[a]
			Windy season			
CP	11.9±1.5[a]	13.0±1.4[a]	11.6±0.3[a]	5.1±0.2[a]	7.4±0.8[a]	7.9±0.4[a]
NDF	63.8±7.5[a]	62.6±4.8[a]	62.3±6.5[a]	72.5±0.7[a]	69.9±0.5[a]	69.7±0.5[a]
ADF	35.5±0.1[a]	33.1±0.4[a]	35.2±1.0[a]	36.5±0.7[a]	34.1±0.5[b]	34.2±0.7[ab]
LIG	7.0±1.3[a]	7.8±1.7[a]	9.7±0.5[a]	6.0±0.1[a]	6.1±0.8[a]	7.7±0.5[a]
ISDMD	65.4±2.0[a]	67.4±1.2[a]	69.2±4.1[a]	65.3±3.1[a]	69.7±2.0[a]	71.0±0.2[a]
			Dry season			
CP	9.0±0.6[a]	10.8±0.5[a]	11.9±0.3[a]	6.3±0.2[a]	7.0±1.3[a]	8.2±0.8[a]
NDF	62.8±6.5[a]	60.9±6.4[a]	61.7±4.8[a]	70.2±3.0[a]	66.5±2.6[a]	67.3±2.8[a]
ADF	34.7±1.4[a]	30.3±0.8[b]	31.3±0.9[ab]	33.2±1.8[a]	31.3±2.6[a]	32.6±0.9[a]
LIG	8.1±2.5[a]	6.7±1.0[a]	7.±1.0[a]	6.5±0.6[a]	5.9±0.01[a]	6.5±0.9[a]
ISDMD	62.8±1.0[a]	69.5±0.8[a]	70.1±3.1[a]	66.0±0.6[a]	68.4±0.2[a]	70.1±0.7[a]

[1]CP=crude protein; NDF=neutral detergent fibre; ADF=acid detergent fibre; LIG=lignin; ISDMD=*in situ* present herbage mass digestibility.

[2] Means followed by the same letter within a row during a specific period and season are not significantly different (P≤0.05).

Table 6. Nutritional value (%) (mean ± s.e.) of leaves and stems (true stem + leaf sheath) of native grasses in pastures grazed at 2, 3 and 4 cows ha^{-1} during the rainy, windy and dry seasons during 2006-2007 in the humid tropics of Mexico.

Component[1] (% of DM)	Leaves			Stems		
	Cows ha^{-1}			Cows ha^{-1}		
	2	3	4	2	3	4
				Rainy season		
CP	14.5±0.9[a2]	15.9±0.3[a]	15.4±0.9[a]	7.9±0.5[a]	10.1±0.1[b]	9.4±0.8[ab]
NDF	66.8±1.7[a]	66.6±1.1[a]	65.9±0.3[a]	71.2±1.1[a]	68.8±0.8[a]	68.3±1.4[a]
ADF	32.9±1.8[a]	31.9±0.3[a]	31.0±0.7[a]	35.9±1.2[a]	33.2±0.3[a]	33.2±1.4[a]
LIG	7.7±0.8[a]	7.2±0.4[a]	7.1±0.2[a]	6.5±0.4[a]	5.7±0.1[a]	5.4±0.2[a]
ISDMD	79.2±1.6[a]	79.0±2.1[a]	79.4±0.9[a]	71.9±1.7[a]	76.6±1.4[a]	76.2±2.2[a]
				Windy season		
CP	13.2±1.1[a]	14.2±0.4[a]	14.8±0.2[a]	7.4±0.3[a]	7.3±0.5[a]	9.0±0.2[a]
NDF	69.9±0.5[a]	68.4±0.9[a]	67.4±0.6[a]	67.8±0.3[a]	65.2±0.7[a]	63.4±0.1[a]
ADF	36.7±0.9[a]	36.8±1.0[a]	33.0±0.1[b]	36.4±0.1[a]	33.0±0.8[a]	31.1±0.3[a]
LIG	8.9±0.9[a]	8.0±1.1[a]	7.9±0.3[a]	7.6±0.7[a]	5.2±1.1[b]	4.0±0.8[b]
ISDMD	70.7±1.0[a]	74.6±1.6[b]	76.7±1.5[b]	73.4±2.0[a]	76.7±0.9[a]	78.8±0.5[a]
				Dry season		
CP	11.4±0.5[a]	12.6±0.5[a]	13.2±1.0[a]	6.5±0.2[a]	7.2±0.3[a]	7.9±0.5[a]
NDF	67.8±0.6[a]	68.8±0.3[a]	67.3±0.6[a]	66.8±0.6[a]	65.7±0.3[a]	64.4±0.3[a]
ADF	32.7±0.2[a]	35.0±0.7[a]	32.4±0.2[a]	32.9±0.6[a]	29.1±0.9[a]	28.7±0.6[a]
LIG	6.4±0.4[a]	7.6±0.8[a]	7.2±0.4[a]	5.8±0.1[a]	4.9±0.1[a]	5.2±0.2[a]
ISDMD	69.8±0.8[a]	75.0±2.1[a]	70.1±0.6[a]	66.9±1.2[a]	76.4±1.5[a]	77.5±0.3[a]

[1]CP=crude protein; NDF=neutral detergent fibre; ADF=acid detergent fibre; LIG=lignin; IPHMD=*in situ* present herbage mass digestibility.

[2]Means followed by the same letter within a row during a specific period and season are not significantly different ($P \leq 0.05$).

However, utilization rates of leaves and stems varied during the study. While levels were generally high in 2005-2006, with a peak of 49% for stems at 4 cows ha^{-1} during the windy season, this contrasts with the utilization rate of 6% for the same treatment in the same season during 2006-2007 (Table 3). During 2005-2006, utilization rates of leaves and stems were generally comparable, in contrast to the pattern during 2006-2007, when utilization of leaves was generally higher than that for stems. Thus, animals preferentially select leaves rather than stems. Surprisingly, ISDMD values for stems were at least equal to those for leaves at all stocking rates during most seasons in both years, despite stems having less crude protein and higher NDF levels than leaves. This could explain why the cows did not preferentially graze leaves versus stems. Pasture availability, in relation to grazing time per day, decreased as stocking rate increased, even though during the rainy season total and leaf DM availability remained similar. During the windy and dry seasons, grazing time increased with stocking rate, while availability decreased with stocking rate (i.e., animals compensated for the reduction in available DM by increasing their grazing time).

However, DM availability does not necessarily significantly affect grazing time or biting rate (Kennedy *et al*., 2007), as it was the general trend for the results of this study. Here, grazing time was long and ruminating time short, which can be related to pasture quality (Van Vuuren *et al*., 2005). Larger grazing time values have been reported, but it has the same relationship with ruminating time as those obtained in the present experiment (Stobbs, 1970). Due to the short period of paddock recovery (27 days), pasture quality variables such as less lignified cell walls (7.2±0.3 %) make the ingested forage less resistant to degradation by rumination. However, grazing time was shortened due to the reduction in pasture availability.

The interaction between stocking rate and season for pasture DM availability is related to the morphological response of the plants to increased stocking rate. In pastures with low stocking rates, plant height is greater than at high stocking rates (Kennedy *et al*., 2007), and tiller density is lower at low stocking rates (Van Vuuren *et al*., 2005) or with less grazing frequency (McCarthy *et al*., 2007), as is the number and size of leaves. In *Paspalum notatum*, as cutting height decreases, leaf appearance rate increases and conversely, leaf extension rate decreases (i.e., more, but shorter, leaves appear) (Ayala *et al*., 2000). This may be a compensatory mechanism leading to equivalent degrees of pasture availability among stocking rates.

Pasture utilization was similar for the three stocking rates, but different among seasons, indicating that utilization remains high as long as favourable climatic conditions (rainy=25.5%) for plant growth exist, even though during the windy and dry seasons leaves were defoliated more (36.8 and 40.6%, respectively). Pasture utilization was greater with higher stocking rate, at least during the second year. Increased utilization with increased stocking rate suggests a leafier pasture structure (Nochebuena *et al*., 1994; Hirata, 2000).

Trends in fiber and lignin in leaves and stems was similar to crude protein, which was likely related to the age of regrowth. In a 35-42 day study of regrowth in Bahiagrass (*P. notatum*), increases in lignin and NDF of 6.2% and 71%, respectively, have been observed (Mears and Humphreys, 1974).

Ingestive behaviour

During the rainy season, grazing time decreased as stocking rate increased from 2 to 4 cows ha^{-1}. However, during the windy and dry seasons in both years, the longest grazing time was recorded for 3 cows ha^{-1}. While time spent grazing was constant among seasons at 2 cows ha^{-1} (P>0.05), it increased at 3 cows ha^{-1} and decreased at 4 cows ha^{-1} during the windy and dry seasons. The average time spent grazing was 420 min d^{-1}, while cows ruminated an average of 367 min d^{-1}.

Table 7. Effects of stocking rate on ingestive behaviours of F1 Holstein x Cebu cows that grazed native grass-based pastures in the humid tropics of Mexico.

Parameter	2005-2006			2006-2007		
	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}	2 cows ha^{-1}	3 cows ha^{-1}	4 cows ha^{-1}
			Rainy season			
Grazing time (min)	476±8[a1]	446±8[b]	353±12[c]	403±8[a]	368±14[b]	382±9[ab]
Ruminating time (min)	316±16[a]	321±13[a]	305±14[a]	451±9[a]	444±10[a]	429±14[a]
Biting rate (bites min^{-1})	49±1[a]	48±1[a]	50±1[a]	49±1[a]	48±1[a]	48±1[a]
			Windy season			
Grazing time (min)	406±9[a]	460±9[b]	420±11[a]	406±11[a]	456±12[b]	367±13[c]
Ruminating time (min)	365±12[a]	398±19[a]	310±12[b]	398±10[a]	381±9[a]	248±10[b]
Biting rate (bites min^{-1})	51±1[a]	45±1[b]	48±1[c]	44±1[a]	49±1[b]	51±1[bc]
			Dry season			
Grazing time (min)	401±11[a]	480±8[b]	427±13[a]	404±15[a]	465±11[b]	439±12[bc]
Ruminating time (min)	411±13[a]	396±14[a]	331±16[b]	379±17[a]	336±12[b]	392±18[a]
Biting rate (bites min^{-1})	49±1[a]	51±1[a]	51±1[a]	48±1[a]	47±1[ab]	45±1[b]

[1] Means followed by the same letter within a row during a specific period and season are not significantly different (P≤0.05).

Biting rate

Biting rate varied from 44 to 51 bites min^{-1} (Table 7). A reduction in biting rate is suggested by a reduction in forage allowance, as was observed during the windy season in 2005-2006 and the dry season in 2006-2007. Biting rate can vary from 70-80 bites min^{-1} at the beginning of grazing to 40-50 bites min^{-1} at the end of a grazing session (Juarez-Lagunes *et al*., 1999). In the research station used for the present study, a comparable mean biting rate with 2 cows ha^{-1} has been reported (46 ± 0.7 bites min^{-1}) (Castillo, 2003). However, other reports have stated that these biting rates are low (Juarez-Lagunes *et al*., 1999; Kennedy *et al*., 2007). Under artificial conditions, the effect of density and tension resistance of grass shoots to grazing was evaluated and found a time per bite of 1.5 to 2.0 seconds (40-30 bites min^{-1}) (Stobbs, 1974). As such, biting rate has been highly correlated with shoot height (Benvenutti *et al*., 2006). However, the present study did not show such an association; pasture height decreased as stocking rate increased, although biting rate means were identical among stocking rates.

In general, grazing patterns were equivalent for all stocking rates, seasons and during both years (Figure 1). There was a period of intense grazing activity when cows were returned to the paddocks after milking at 11:00 h. Peak activity occurred at 18:00 h, followed by a rapid cessation of grazing. There was a second, smaller grazing episode around midnight and an additional brief grazing episode before cows were taken to the milking barn at 8:00 h.

In the present experiment, mean grazing time (396±79 to 436±84 min d^{-1}) was comparable to the 420 min d^{-1} recorded on good quality pastures with adequate DM (Van Vuuren *et al*., 2005). Grazing time was much lower than the 605 and 603 min d^{-1} for the 4.5 and 5.5 cows ha^{-1}, respectively, recorded by Kennedy *et al*. (2007). Grazing times of 395 - 586 min d^{-1} for heifers in native grass pastures, with or without fertilization, have been reported (Benvenutti *et al*., 2006).

Using the same observational technique on pastures equivalent to those in the present study and in the same experimental station, grazing times of 457 ± 13 min d^{-1} and 395 ± 11 min d^{-1} have been reported on native pastures and those associated with *Arachis pintoi* Krapovickas and Gregory (Castillo, 2003).

Among stocking rates, the mean total number of bites per day in different seasons fluctuated between 17,600 and 24,500 with no set pattern. Means of 20,000, 21,400 and 19,400 bites cow^{-1} day^{-1} were recorded for 2, 3 and 4 cows ha^{-1}, respectively. Since available DM at the commencement of grazing was similar at all stocking rates, unless bite size declined as stocking rate increased, utilization rates would have to increase dramatically with increases in stocking rate. Daily patterns of grazing behaviour in this study differed from those normally recorded. Intense grazing peaks usually occur early in the morning and late afternoon, with a resting period and water intake in the middle of the day, especially in tropical areas (Van Vuuren *et al*., 2005). Milking herd management affected grazing patterns, with the longest period of grazing in the afternoon, from 12:00 h to 19:00 h, when the herd returned to pasture after milking. Animals removed from pasture for milking strongly affected grazing behaviour, with a predominance of grazing over other activities during the afternoon grazing session (Benvenutti *et al*., 2006). These authors found that milking cows under continuous grazing normally have 3 or 4 periods of intense grazing activity each day, compared with the 3 periods recorded here.

In the present study, the first grazing period ended at 19:00 h. When pasture quantity and quality is good, grazing patterns follow daylight variations, but cattle shift grazing to the darker hours of the day under adverse conditions (Van Vuuren *et al*., 2005). Cows in the present study spent a significant amount of time grazing at midnight, which could have compensated for grazing time lost when cows were being milked.

Pasture management could have a strong impact upon pasture composition, which can affect animal behaviour and productive performance (Boval *et al*., 2007). The pasture species that contribute most to botanical composition as well as DM production can be the basis for maintaining animal production at an optimal level (Gibb *et al*., 1997). Botanical composition in the present experiment differed with stocking rate, with low stocking rate always showing a higher contribution of taller introduced grasses than the medium and high stocking rates, in which short native grasses predominated. This suggests that the introduced grasses and native species had less tolerance for higher grazing pressures and were not able to recover rapidly during the 27-day regrowth periods. Long-term studies are needed to determine if introduced species disappear from comparable pastures over the time.

Rumination patterns alternated with grazing patterns, with limited activity during grazing periods, and peaks of activity when cows were resting after grazing (Figure 1). While grazing was the main activity during the day, time spent ruminating increased dramatically after 18:00 h. This continued until the midnight grazing period, followed by a resting and ruminating period from 03:00 h to 06:00 h.

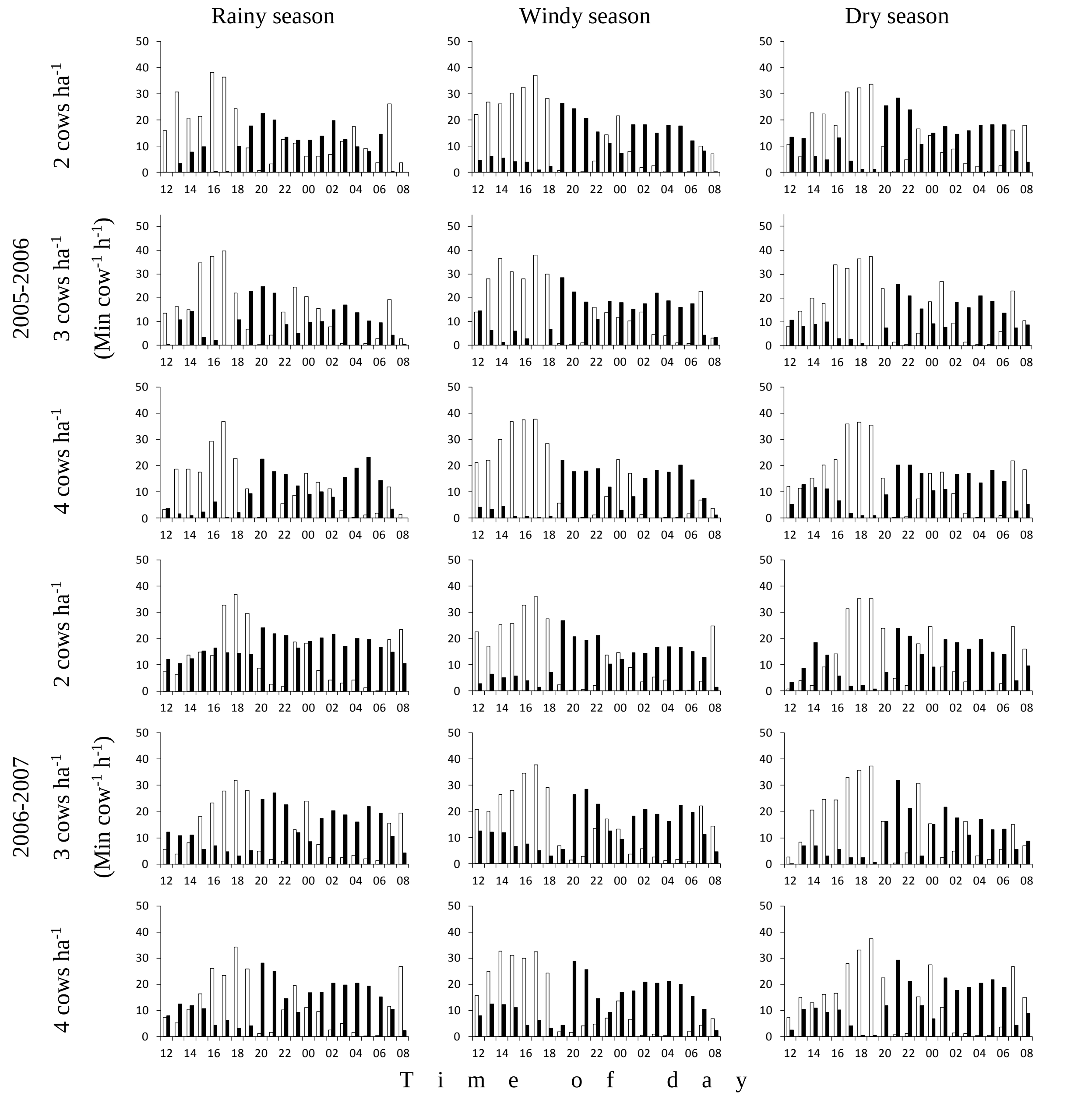

Figure 1. Effects of stocking rate and season on daily grazing (☐) and ruminating (■) times in pastures during 2005-2006 and 2006-2007. Observations were not made when the cows were in the milking shed (08:00-11:00h).

Under temperate conditions, at two stocking rates (4.5 and 5.5 cows ha^{-1}) for two 49-day rotational grazing cycles (February and April), increasing the stocking rate in the first cycle significantly increased grazing time, while the reverse happened during the second period (Kennedy *et al*., 2007). An identical trend was observed during the present experiment. Grazing time showed an opposite trend during the first period, while there was no difference between stocking rates during the second period. Grazing time in the present study was comparable between 2 and 3 cows ha^{-1} and significantly increased for 4 cows ha^{-1}.

The latter may be related to leaf availability which decreased as stocking rate increased. Leaf availability increased with stocking rate during the first rotation and decreased during the second one, but without statistical differences between stocking rate (Kennedy *et al*., 2007).

Milk production

Daily milk yield per cow (8.16±2.58 kg) was similar (P>0.05) among stocking rates. Therefore, milk yield per lactation (1894.9±904.3 kg) was also similar (P>0.05). Nevertheless these values stand above the typical milk yield per cow values for the tropics. Orantes-Zebadúa *et al*., (2014) surveyed 246 dual-purpose farmers from Chiapas, México, and found that the mean milk yield per cow was 4.49 l at an approximate stocking rate of 1.5 animal units per ha.

When dry matter availability in the pasture is large enough, there are no limits to intake of pasture by the grazing cow, and there are no limits to animal selectivity and nutritive value of ingested dry matter (Benítez-Bahena *et al*., 2010). As shown by Table 8, the increase in stocking rate lead to a decrease in standing dry matter. However, this decrease did not limit the cow's dry matter intake and consequently milk yield remained the same between stocking rates. On the other hand, the level of pasture utilization and in general the ingestive behavior variables did not show differences among stocking rates, and this coincides with the similar milk production among stocking rates.

The standing dry matter can in itself influence individual milk yield (Castillo *et al*., 2014). A study reports that when the SDM was larger than 2,500 kg/ha the daily milk yield per cow remained unchanged, but below 2,000 kg/ha, intake and grazing time decreased (Cowan and O´Grady, 1976). In the present investigation the three levels of stocking rate had SDM amounts that did not limit intake and thus, individual milk yields.

Overall, the best response in the literature with respect to nutritional value, higher stocking rate and best weight gain per ha has been obtained with an availability of 5 kg de MS/100 kg de PV (Menezes *et al*., 2016). If this latter value is applied to the cows of the present research that weighed on average 531 kg, results in an optimal availability of 26.55 kg of SDM per cow. In our study, the amount of SDM per cow per day was larger than 56.4 kg per cow per day. So pasture availability was enough in all stocking rates for the cows to reach maximum daily intakes, and therefore, similar individual milk yields.

CONCLUSIONS

There was no apparent significant effect from stocking rate on the ingestive behaviour of cows. As well, there was no clear relationship among any pasture variables and ingestive behaviour, except the proportion of native and introduced grasses. However, neither was there a difference in milk yield among stocking rates, which was nevertheless higher than typical grazing conditions of the tropics. Available forage significantly increased during the rainy season, yielding longer grazing periods and higher bite rates. But if pasture response variables were not affected by SR, ingestive behaviour depended on the number of cows per hectare or instantaneous stocking rate. Standing dry matter and its quality were not determinate factors for milk yield in this research.

Table 8. Area per paddock, live weight (LW) per cow, live weight per paddock, total standing dry matter (TSDM) available per paddock, and dry matter available per 100 kg live weight, per cow, lactation length day, milk per cow by day and lactation in a native pasture, grazed by 2, 3 and 4 cows ha^{-1}, in the Mexican humid tropics.

Concept	Stocking rate (cows/ha)		
Number of cows/ha	2	3	4
Area/paddock (ha)	0.5	0.33	0.25
LW/cow (kg)	541	531	501
LW/paddock (kg)	5410	5310	5010
Kg/DM/paddock	2600.9 ± 994.6	2038.5 ± 1167.2	1693.4 ± 855.4)
DM/day (kg)	866.9 ± 331.5	679.5 ± 389.1	564.5 ± 285.1)
DM/100 kg LW (kg)	16.3 ± 5.7	12.8 ± 6.9	10.6 ± 5.0)
DM/cow/day (kg)	86.6 ± 33.1	67.9 ± 38.9	56.4 ± 28.5
Lactation length (days)	249.8 ± 108.7	205.2 ± 66.4	236.0 ± 85.5)
Milk/cow/day (kg)	7.8 ± 2.1	8.6 ± 2.7)	8.0 ± 2.9
Milk/lactation (kg)	2030.5 ± 1177.0	1737.3 ± 671.6)	1917.1 ± 864.3

Mean and standard desviation

REFERENCES

Amendola, R., Castillo, E., Martínez, P.A. 2005. Forage Resource Profiles. Mexico. In: Food and Agriculture Organization (ed.), Country Pasture Profiles. Rome, Italy. On CD.

Association of Official Analytical Chemists. 1980. Official Methods of Analysis. 13th Edn. Washington, D.C., USA.

Ayala, T.A.T., Acosta, G.L., Deregibus, V.A., Moauro, P.M. 2000. Effects of grazing frequency on the production, nutritive value, herbage utilization, and structure of a *Paspalum dilatatum* sward. New Zealand Journal Agricultural Research. 43:467-472.

Benítez-Bahena, Y., Bernal-Hernández, A., Cortés-Díaz, E., Vera Castillo, G., Carrillo Anzures, F. 2010. Producción de forraje de guaje (*Leucaena* spp.) asociado con zacate (*Brachiaria brizantha*) para ovejas en pastoreo Revista Mexicana de Ciencias Agrícolas. 1(3): 397-411.

Benvenutti, M.A., Gordon, I.J., Poppi, D.P. 2006. The effect of the density and physical properties of grass stems on the foraging behaviour and instantaneous intake rate by cattle grazing an artificial reproductive tropical sward. Grass Forage Science. 61:272-281. https://doi.org/10.1111/j.1365-2494.2006.00531.x

Boval, M., Fanchone, A., Archimede, H., Gibb, M.J. 2007. Effect of structure of a tropical pasture on ingestive behaviour, digestibility of diet and daily intake by grazing cattle. Grass Forage Science. 62:44-54. https://doi.org/10.1111/j.1365-2494.2007.00560.x

Burns, J.C., Sollenberger, L.E. 2002. Grazing behavior of ruminants and daily performance from warm-season grasses. Crop Science. 42:873-881. doi:10.2135/cropsci2002.8730

Castillo, G.E. 2003. Improving a native pasture with the legume *Arachis pintoi* in the humid tropics of Mexico. [Doctoral thesis]. Wageningen, The Netherlands, Wageningen University,

Castillo, G.E., Rascón, C.R., García, G.D., Jarillo, R.J., Aluja, S.A., Mannetje, L. ‘t. 2014. Calidad de la pastura ingerida y comportamiento ingestivo de vacas en una asociación grama nativa/*Arachis pintoi* en el trópico húmedo veracruzano. Revista Mexicana Ciencias Pecuarias. 5(4): 487-504.

Cowan, R.T., O´Grady, P. 1976. Effect of presentation yield of a tropical grass-legume pasture on grazing time and milk yield of Friesian cows. Tropical Grasslands.10:213-218.

Dillon, P., Roche, J.R., Shalloo, L., Horan, B. 2005. Optimising financial return from grazing in temperate pastures. Proceeding of a satellite workshop of the XX International Grassland Congress, Cork, Ireland. pp. 131-147.

Gary, L.A., Sherritt, G.W., Hale, E.B. 1970. Behaviour of Charolais cattle on pasture. Journal Animal Science. 30:203-206. https://doi.org/10.2527/jas1970.302203x

Gibb, M. 2006. Grassland management with emphasis on grazing behaviour. In: Fresh Herbage for Dairy Cattle. Elgersma, A., Dijkstra, J., Tamminga, S. (eds.). IGER, Aberystwyth, UK. pp. 141-157.

Gibb, M.J., Huckle, C.A., Nuthall, R., Rook, A.J. 1997. Effect of sward surface height on intake and grazing behaviour by lactating Holstein-Friesian cows. Grass Forage Science. 52:309-321. https://doi.org/10.1111/j.1365-2494.1997.tb02361.x

Haydock, K.P., Shaw, N.H. 1975. The comparative yield method for estimating the dry matter yield of pasture. Australian Journal Experimental Agricultural Animal Husbandry. 15:663-670. http://dx.doi.org/10.1071/EA9750663

Hendricksen, R., Minson, D.J. 1980. The feed intake and grazing behaviour of cattle grazing a crop of *Lablab purpureus* cv. Rongai. Journal Agricultural Science. 95:547-554. https://doi.org/10.1017/S0021859600087955

Hirata, M. 2000. Effects of nitrogen fertiliser rate and cutting height on leaf appearance and extension in bahiagrass (*Paspalum notatum)* swards. Tropical Grasslands. 34:7-13.

Jamieson, W.A., Hodgson, J. 1979. The effect of daily herbage allowance and sward characteristics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. Grass Forage Science. 34:262-264. https://doi.org/10.1111/j.1365-2494.1979.tb01478.x

Jones, R.M., Jones, R.J. 2003. Effect of stocking rates on animal gain, pasture yield and composition, and soil properties from setaria-nitrogen and setaria-legume pastures in coastal south-east Queensland. Tropical Grasslands. 37:65-83.

Juarez-Lagunes, F.I., Fox, D.G., Blake, R.W., Pell, A.N. 1999. Evaluation of tropical grasses for milk production by dual-purpose cows in tropical Mexico. Journal Dairy Science. 82:2136-2145. https://doi.org/10.3168/jds.S0022-0302(99)75457-3

Kennedy, E., O`Donovan, M.O., Murphy, J.P., Delaby, L., O`Mara, F.P.O. 2007; Effect of spring grazing date and stocking rate on sward characteristics and dairy cow production during midlactation. Journal Dairy Science. 90:2035-2046. https://doi.org/10.3168/jds.2006-368

Langer, R.H.M. 1979. How grasses grow. Edward Arnold Publishers Ltd., London, UK.

Littell, R.C., Henry, P.R., Ammerman, C.B. 1998. Statistical analysis of repeated measures data using SAS procedures. Journal Animal Science. 76:1216-1231. DOI 10.2527/1998.7641216x

Mannetje, L.'t., Haydock, K.P. 1963. The dry-weight-rank method for the botanical analysis of pasture. Journal British Grassland Society. 18:268-275. https://doi.org/10.1111/j.1365-2494.1963.tb00362.x

McCarthy, S., Horan, B., Rath, M., Linnane, M., O'Connor, P., Dillon, P. 2007. The influence of strain of Holstein-Friesian dairy cow and pasture-based feeding system on grazing behaviour, intake and milk production. Grass Forage Science. 62:13-26. https://doi.org/10.1111/j.1365-2494.2007.00557.x

Mears, H., Humphreys, L.R. 1974. Nitrogen response and stocking rate of *Pennisetum clandestinum* pastures: I. Pasture nitrogen requirement and concentration, distribution of dry matter and botanical composition. Journal Agricultural Science. 83:451-467. https://doi.org/10.1017/S0021859600026940

Menezes, D.A., Oliveira, G.E.N., Vinhas, L.C., Moura, A.L.A., Brandão-Ferreira, Í.C.C., Nogueira, E., Ferreira da Silva, F., Junges, L. 2016. Herbage allowance effects on the characteristics of Brachiaria brizantha cv. Marandu pastures and the production and economic viability of Nellore heifers. Semina: Ciencias Agrárias. Londrina. 37, (4), 1: 2301-2312. http://dx.doi.org/10.5433/1679-0359.2016v37n4Supl1p2301

Nochebuena, N.G., Valles, M.B., De Lucía, S.G.R. 1994; Comportamiento del pastoreo y producción de leche en vacas F1 (Holstein-Cebú) en una pradera de zacate elefante en Veracruz, México. Avances en Investigación Agropecuaria. 3(1):16-27.

O'Donovan, M., Delaby, L., Peyraud, J.L. 2004. Effect of time of initial grazing date and subsequent stocking rate on pasture production and dairy cow performance. Animal Research. 53:489-502. DOI: 10.1051/animres:2004036

Ocaña, Z.E. 2003. Efecto de la carga animal sobre gramas nativas, características del suelo y producción de leche y becerros de vacas Holstein x Cebú en pastoreo intensivo en el trópico mexicano. [Tesis de Maestría]. Montecillo, México. Colegio de Postgraduados,

Orantes-Zebadúa, M.A., Platas-Rosado, D., Córdova-Avalos, V., De los Santos-Lara, M.C., Córdova-Avalos, A. 2014. Caracterización de la ganadería de doble propósito en una región de Chiapas, México. Ecosistemas recursos agropecuarios. 1(1):49-58.

Orskov, E.R., McDonald, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. Journal Agricultural Science. Cambridge. 92:499-503. https://doi.org/10.1017/S0021859600063048

Ortega, R.L., Castillo, H.J.E., Rivas, P.F.A. 2009. Conducta ingestiva de bovinos Cebú adultos en *Leucaena* manejada a dos alturas diferentes (Ingestive behavior of adult Cebu cattle grazing *Leucaena* at two different heights. Técnica Pecuaria México. 47(2):125-134.

Penning, P.D., Rutter, S.M. 2004. Ingestive behaviour. In: Herbage Intake Handbook. Penning, P.D. (ed.). British Grasslands Society. Reading, UK. 151-175.

Rook, A.J., Penning, P.D. 1991. Synchronization of eating, ruminating and idling activity by grazing sheep. Applied Animal Behaviour Science. 32:157-166. https://doi.org/10.1016/S0168-1591(05)80039-5

Silva, S.C., Carvalho, P.C. 2005. Foraging behaviour and herbage intake in the favourable tropics/subtropics. In: Grassland: A global resource. McGilloway, D.A. (ed). Wageningen Academic Publishers, Netherlands. pp. 81-96.

Soder, K.J., Rook, A.J., Sanderson, M.A., Goslee, S.C. 2007. Interaction of plant species diversity on grazing behavior and performance of livestock grazing temperate region pastures. Crop Science. 47:416-425. doi:10.2135/cropsci2006.01.0061

Stobbs, T.H. 1970. Automatic measurement of grazing time by dairy cows on tropical grass and legume pastures. Tropical Grasslands. 4:237-244.

Stobbs, T.H. 1974. Rate of biting by Jersey cows as influenced by yield and maturity of tropical grasses. Tropical Grasslands. 8:81-86.

Stobbs, TH. 1973. The effect of plant structure on the intake of tropical pastures I. Variation in the bite size of grazing cattle. Australian Journal

Agricultural Research 24:809-819. https://doi.org/10.1071/AR9730809

Ungar, E.D., Noy-Meir, I. 1988. Herbage intake in relation to availability and sward structure: Grazing processes and optimal foraging. Journal Applied Ecology 25:1045-1062. DOI: 10.2307/2403765

Van Soest, P.J., Robertson, J.B., Lewis, B.A. 1991. Methods of dietary fibers, and nonstarch polysaccharides in relation to animal nutrition. Journal Dairy Science. 74:3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Van Vuuren, A.M., Van den Pol-Van Dasselar, A. 2006. Grazing systems and feed supplementation. 2005 Proceeding Workshop on Fresh Herbage for Dairy Cattle, The Key to a Sustainable Food Chain. Wageningen University. pp. 85-101.