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Productive performance of lactating Brown Swiss cows grazing on an agrosilvopastoral system in a dry tropical region in central Mexico: contribution of grass, herbaceous and woody species

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Abstract Cattle production in agrosilvopastoral systems (ASPS) in the dry tropical regions of Mexico relies on forages under extensive management with limited supplementation. Information about the botanical composition of the diet (BCD) and the contribution of available forages in ASPS to cattle is scarce. The objectives of the study were to determine the BCD of lactating Brown Swiss cows, grazing on an ASPS during the dry and rainy seasons in a dry subtropical region of Mexico, and to determine the contribution of forage species to the cows dry matter intake (kg/day), crude protein (CP) (kg/day) and metabolizable energy (ME) (MJ/day) requirements. Fifteen lactating cows were monthly monitored for one year to determine the BCD by microhistological analysis, as well as its productive performance. A mixed procedure of SAS was used to determine the effects of the season as a fixed effect and cow as a random effect on animal productive performance and BCD variables. The forages in the BCD were grouped as grasses, herbaceous and woody species. During the dry season grass and woody groups represented 84.2 and 15.7% of the BCD, whereas in the rainy season grass, herbaceous and woody groups represented 57.6, 26.6, and 7.4% of the BCD, respectively. During the dry season grass and herbaceous groups contributed with 64% of the cows nutritional requirements. Whereas during the rainy season grass, herbaceous and woody groups contribution to the cows nutritional requirements was 87%. It is concluded that grass, herbaceous and woody groups contributed to DMI, CP and ME to the requirements of lactating cows grazing on an agrosilvopastoral system with seasonal differences.

Keywords Botanical composition of the diet · Productive performance · Dry and rainy season · Nutrient contribution

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Introduction

The use of shrubs and trees as a supplementary forage for ruminants has become a key element in silvopastoral systems, providing a wide variety of benefits to cattle (energy, protein and other nutrients), as well as to the environment as recently reviewed by Vandermeulen et al. (2018a). However, farmers do not consider the contributions of shrubs and trees to their cattle nutritional requirements to determine the amount and, the characteristic of supplements provided during the dry season; neither they know the nutritional characteristics of those forage sources. This same situation has been found in other countries as reported by Vandermeulen et al. (2018b), who also mentioned the lack of information regarding cows browsing behavior (i.e. botanical composition of the diet), and its effects on cattle nutrition and productivity.

In the tropical and subtropical regions of Mexico, dual-purpose cattle production (milk and weaned calves) is developed on extensive grazing systems, that could be classified as unintended agrosilvopastoral systems (ASPS) where crops and pastures mix with shrubs and trees, remnants of the original vegetation at different stages of secondary succession (Albarrán-Portillo et al. 2019; Albores-Moreno et al. 2020).

In recent years it has been promoted the establishment of intensive silvopastoral systems (ISS), that combine improved grasses with high density leguminous trees like *Leucaena leucocephala* (Bacab-Pérez and Solorio-Sánchez 2011; Bottini-Luzardo et al. 2016; Vandermeulen et al. 2018a). The main goal of the ISS is to supply forage of higher quality, animal welfare and increase the resilience of the system (Ibrahim et al. 2006).

The unintended ASPS in the tropical and subtropical regions of Mexico are characterized by a wide diversity of plant species (Albarrán-Portillo et al. 2019; Albores-Moreno et al. 2020). The knowledge of the botanical composition of the diet by grazing cattle in complex grazing lands is a tool that helps in the development of management strategies oriented towards improvement in the efficiency of forage resources which would result in reduced production costs and competitive animal production (Bartolomé et al. 2011). Therefore, the first objective of this study was to determine the botanical composition of the diet of lactating Brown Swiss cows, grazing on an agrosilvopastoral system during the dry and rainy seasons, in a dry subtropical region of Mexico. The second objective was to determine the contribution of forage species to the cows dry matter intake (kg/day), crude protein (CP) (kg/day) and metabolizable energy (ME) (MJ/day) requirements.

Materials and methods

Location of the study and precipitation

The study was performed in the municipality of Zacazonapan in the southwest of the Estado de Mexico between 19º 00′ 17″ and 19º 16′ 17″ north latitude and between 100º 12′ 55″ and 100º 18′ 13″ west longitude, at an altitude of 1.470 m above sea level. The climate in this region is semi-hot of the A group according to the Köppen climate classification, with summer rains and a marked dry season from November to May, classified as A(C) (w2), with a mean temperature of 23 °C and 1,115 mm of annual rainfall (SMN 2020).

Precipitation and temperature

The total precipitation was 972.5 mm of which 88% occurred from May to October. The average temperatures during the dry (November to May) and rainy (June to October) seasons were 21.2 and 17.8 °C, respectively (Fig. 1).

Production unit and experimental cows

The study was conducted from July 2015 until June 2016 in a low input dual-purpose farm with a total land surface (TLS) of 100 ha with a perimetral fence with no subdivisions under extensive grazing management. The TLS was composed of 60% grazing land with scattered shrubs and trees and, 40% destined for maize cropping (*Zea mays*). The facilities were restricted to a small building to store feeds used for the elaboration of supplements and a shed where cows were milked.

Grazing lands were not fertilized; farmers only apply fertilizer to maize crops. Also, there were no forage conservation practices since most of the TLS is on steep slopes making it difficult the use of machinery for forage conservation purposes. The excess of

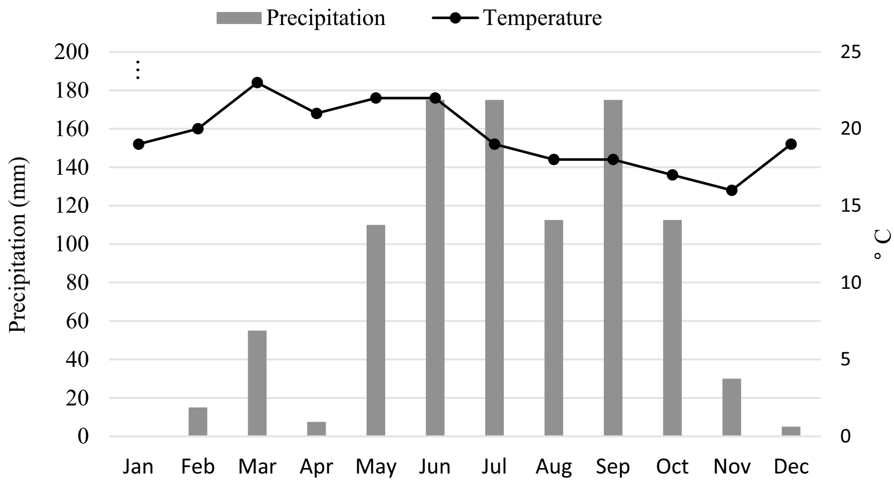

Fig. 1 Precipitation and average temperature

forage grown during the rainy season remained in the grazing lands to be consumed by cattle during the dry season.

The herd was composed of 25 lactating Brown Swiss (BS) with average body weight (BW) of 417 ± 24 kg and their calves of less than 6 months of age (range from 1 to 5 months). Cows were hand milked once a day (from 7:00 a.m. to 9:00 a.m.) in the presence of the calf for milk let-down (standard management for most farms in the region). After milking, calves suckled the remaining milk and stayed with their mothers in the grazing areas until 2:00 p.m.

After the withdraw of the calves from their mothers, cows continue grazing in grazing lands for the rest of the day, spending the night in the upper parts of the grazing land. Every morning cows gather around the milking area to receive the supplement and to be milked. The whole herd remains in the grazing areas 24 h a day all year round. The stocking rate during the period of study was 0.4 animal units (AU)/ha.

During the dry season due to the reduction of herbage quality and availability on grazing lands, cows were supplemented with 5.0 (kg/cow/day) of a mixture of cracked corn and soybean meal, resulting in 14% of CP. During the rainy season, the level of supplementation was reduced to 1.5 (kg/cow/day).

Experimental cows

From the herd, fifteen lactating cows of 4 ± 2 parity (mean ± standard deviation) and 109 ± 32 days in milk, were selected and monitored once a month on the same day, to record productive variables and, species consumed during grazing (from 9:00 a.m. until 6:00 p.m.) by direct observation. Fresh samples of feces were collected from the rectum right after milking.

Botanical composition of the diet

The BCD (percentage of present species) was estimated by identifying epidermal fragments in the feces by microhistological analysis. Slides (patterns) were assembled using sampled species (leaf and steam) consumed by cattle while grazing, which were processed to determine patterns of tissue and, temporary slides were prepared using the feces following the procedures described by Castellaro et al. (2007).

Botanical composition of pastures

Herbage mass in pastures (grasses) was determined once a month by using quadrats (n = 6) of 0.25 m^2 placed within the pastures where cows were grazing after the morning milking, cut at ground level, and then in the laboratory separated into different plant species to determine the botanical composition of pastures (BCP). Results are expressed on a dry matter basis as a proportion of the total herbage mass (Fig. 2).

Woody and herbaceous species

By direct observation during the grazing after the morning milking (9:00 a.m.) and through the day

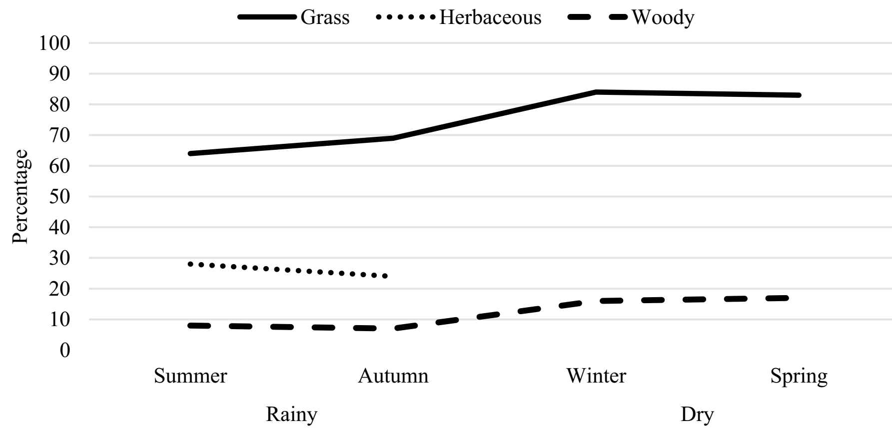

Fig. 2 Botanical composition of the diet of lactating Brown Swiss cows grazing on agrosilvopastoral system according to season

and until evening (6:00 p.m.), cows were followed within the grassland to observe herbaceous and woody species consumed at ten minutes interval per grazing event (Bryant et al. 1981). Samples of plant species (leaves and stems) were sampled by hand directly from the plant. Forage samples (200 g fresh base approximately) were packed fresh and transported to the laboratory for chemical analysis.

The chemical composition of the herbaceous and woody species (leaves and stems) was analyzed for dry matter (DM), crude protein (CP), NDF, ADF, ADL according to AOAC (1995), and in vitro dry and organic matter digestibility were analyzed according to Mauricio et al. (1999). To estimate the in vitro dry matter digestibility (IVDMD) of the diet, each component of the diet was included giving its proportion in the diet according to the results of the microhistological analysis. Estimated Metabolizable Energy (eME) was derived from digestibility of organic matter (OMd) (AFRC, 1993): eME (MJ/kg DM) = 0.0157 *OMd.

Herbage dry matter intake

Herbage dry matter intake of cows (DMI) was estimated indirectly from animal performance, using forage and supplements nutritional composition, BW, BCS, MY and milk composition, using the program NASEM Dairy-8 (2021). Of the resulting nutritional composition of the diet, it was estimated the contributions of dry matter intake (kg/DM/day), crude protein (kg/day), and metabolizable energy (MJ/kg) by supplements and forages to the cows requirements.

Animal productive variables

Milk yield was recorded once a month using a clock spring balance with a capacity of 20 kg. Cows were weighed after miking on a Smart Scale 200 (Gallagher®) of 1500 kg capacity. The body condition score (BCS) of cows was determined on a 1 to 5 points scale (Wildman et al. 1982). Milk samples were taken individually from each cow directly from the milk bucket, once the milking was finished. Milk components fat and protein (g/kg) were determined immediately after milking with a portable ultra-sound (Lactoscan Milk Analyzer®, serial 9414, Milkotronic, Bulgaria, 2008). Milk urea nitrogen (MUN) was subsequently determined in laboratory by enzymatic colorimetry. Fat and protein corrected milk (FPCM) and energy corrected milk (ECM) were calculated according to (IDF 2015).

Statistical analysis

Data of botanical composition of the grassland was analyzed as a completely random design using the GLM procedure of SAS (SAS OnDemand 2021), by using the following model:

$$Y_{ij} = \mu + S_i + e_{ij}$$

where Y_{ij} was the response variable (percentage of species in grassland), μ was the least squares means, S_i season effect (i = dry and rainy) and e_{ij} was the random error term.

Animal response parameters and BCD parameters were analyzed using a mixed model with cow as random effect and season as fixed effect using the MIXED procedure of SAS (SAS® OnDemand 2021) using the following model:

$$Y_{ij} = \mu + S_i + C_j + e_{ij}$$

where Y_{ij} was the response variable, μ was the least squares means, S_i was the fixed effect of season (i = dry and rainy), C_j was the random effect of cow (j = 1… 15), and e_{ij} was the random error term.

Results

Botanical composition of pastures and woody species

The botanical composition of pastures was grouped into grasses and herbaceous. The grass group consisted of *Cynodon plectostachyus, Paspalum notatum, Paspalum convexum, Andropogon gayanus, Brachiaria humidicola and Zea mays.* The herbaceous group consisted of *Aeschynomene sp., Bidens pilosa, Labiada sp., and Ipomea tricolor*. In addition, woody species consisted of *Acacia farnesiana*, *Crescentia alata*, *Pithecellobium dulce* and *Ceiba pentandra* (Table 1).

There were no significant differences among grasses and herbaceous species between dry and rainy seasons ($P > 0.05$) (Table 1). On average, grasses

Table 1 Botanical composition of pastures (BCP) and botanical composition of the diet (BCD) percentages during the dry and rainy season

Group	Specie	Season	BCP			BCD		
			%	P =	S.E.	%	P =	S.E.
Grass	*C. plectostachyus*	Dry	30.3	0.24	4.62	45.5	0.07	1.96
		Rainy	19.6			39.3		
	P. notatum	Dry	13.3	0.74	2.54	14.2	0.23	1.2
		Rainy	12.0			11.8		
	P. convexum	Dry	15.0	0.63	6.04	4.3	0.36	0.42
		Rainy	10.3			3.6		
	A. gayanus	Dry	8.7	0.59	2.12	5.6	<0.01	0.22
		Rainy	6.8			0.9		
	B. humidicola	Dry	5.1	0.32	3.9	NA		
		Rainy	12.4			8.3		
	Z. mays	Dry	14.5	0.12	1.67	14.6	<0.01	1.95
		Rainy	8.3			2.0		
Herbaceous	*Aeschynomene sp.*	Dry	2.7	0.49	2.93	NA		
		Rainy	6.2			12.2		
	B. Pilosa	Dry	5.0	0.31	3.18	NA		
		Rainy	12.4			7.7		
	Labiada sp.	Dry	2.7	0.49	2.93	NA		
		Rainy	6.0			5.6		
	I. tricolor	Dry	2.7	0.49	2.93	NA		
		Rainy	6.0			1.1		
	A. farnesiana	Dry				10.9	<0.01	0.49
		Rainy				3.4		
	C. alata	Dry				2.6	<0.01	0.24
Woody		Rainy				1.2		
	P. dulce	Dry				2.3	0.02	0.13
		Rainy				1.6		
	C. pentandra	Dry				NA		
		Rainy				1.2		

NA, Not available

represented 78% of the BCP, where *C. plectostachyus* was the most predominant specie in the dry season (30.3%) and the rainy season (19.6%). On average, herbaceous represented 22% of the BCP where *B. pilosa* was the most predominant specie with 5 and 12.4%, in the dry and rainy seasons.

Chemical composition

The chemical composition of the forage groups in the dry and rainy seasons is shown in Table 2. The grass group was characterized by their moderate CP (140 g/kg DM in *P. notatum* in the rainy season) to low values (53 g/kg DM, *C. plectostachyus* in the dry season). Metabolizable energy ranged from 7.1 in *A. gallanus* to 11.8 (MJ/kg DM) in *Z. mays*. Herbaceous group CP values ranged from 120 in *Labiada sp* to 260 (g/kg DM) in *Aeschynomene sp.* Metabolizable energy content was not estimated. Furthermore, CP values in woody species ranged from 190 in *C. pentandra* to 260 (g/kg DM) in *P. dulce*. Metabolizable energy values ranged from 9.1 in *C. alata* to 11.3 MJ/kg DM in *A. farnesiana*.

According to the proportion of species in the BCD and the chemical composition of the species, the main chemical composition of the diet during both seasons is presented in Table 3. There were statistical differences ($P < 0.05$) according to the season on nutritive parameters (DM, CP, NDF, ADF, ADL and IVDDM) ($P < 0.05$) except for ME (9.3 and 9.0 MJ/kg DM, dry and rainy season, respectively) ($P > 0.05$). Crude protein (132 g/kg DM) and IVDMD (577.5 g/kg DM) were higher during the rainy season compared to the dry season (113 g/kg DM and 550.5 (g/kg DM), CP and IVDMD, respectively). Dry matter and fiber fractions (NDF, ADF and LDF) were significantly higher ($P < 0.5$) during the dry season.

Agrosilvopastoral system contributions to dry matter, crude protein and metabolizable energy intakes

Grass and woody species contributed 60 and 9%, respectively to the total DMI while supplements contributed 31% during the dry season. During the rainy season grass, herbaceous and woody species contributed 60, 24 and 5% of the total DMI, whereas

Table 2 Chemical composition (g/kg of DM) of species grouped as grass, herbaceous and woody, consumed by lactating Brown Swiss cows grazing in an agrosilvopastoral system during the dry and rainy season

Group	Specie	Season	DM	CP	NDF	ADF	ADL	ME[a]
Grass	*C. plectostachyus*	Dry	670	53	650	330	110	7.8
		Rainy	530	110	620	310	90	NA
	P. notatum	Dry	660	71	630	350	90	8.3
		Rainy	510	140	560	330	90	NA
	P. convexum	Dry	800	84	630	330	120	8.6
		Rainy	480	93	560	310	110	NA
	A. gayanus	Dry	890	60	680	390	80	7.1
		Rainy	560	79	520	350	80	NA
	B. humidicola	Rainy	450	86	650	350	130	NA
	Z. mays	Dry	820	90	660	360	90	11.8
		Rainy	NA	NA	NA	NA	NA	NA
Herbaceous	*Aeschynomene sp.*	Rainy	530	260	560	320	90	NA
	B. Pilosa	Rainy	470	130	680	390	120	NA
	Labiada sp.	Rainy	450	120	660	320	90	NA
	I. tricolor	Rainy	450	130	550	290	100	NA
Woody	*C. alata*	Dry	760	240	560	370	130	9.1
		Rainy	NA	NA	NA	NA	NA	NA
	P. dulce	Dry	460	260	430	230	100	10.6
		Rainy	NA	NA	NA	NA	NA	NA
	A. farnesiana	Dry	890	270	530	440	120	11.3
		Rainy	NA	NA	NA	NA	NA	NA
	C. pentandra	Rainy	780	190	530	310	90	NA

NA, Not available

[a] MJ/kg of DM, Metabolizable energy

Table 3 Nutritive value of the forage-based diet (g/kg of DM) of lactating Brown Swiss cows grazing in an agrosilvopastoral system during the dry and rainy season

Season	DM	CP	NDF	ADF	ADL	IVDMD[a]	ME[b]
Dry	786	113	550	258	104	550.5	9.3
Rainy	579	132	577	296	98	577.5	9.0
P =	0.01	< 0.01	0.01	0.03	0.01	0.04	0.23
S.E.	1.54	1.62	0.25	0.25	0.05	4.03	0.25

[a] IVDMD, in vitro dry matter digestibility; [b]ME, Metabolizable Energy (MJ/kg of DM)

Table 4 Contributions of supplements and forages to dry mater intake (DMI) (kg/day), crude protein (CP) (kg/day) and metabolizable energy (ME MJ/kg DM) (% within brackets) of cows grazing on an agrosilvopastoral system during the dry and rainy season

	DMI	CP	ME
Dry			
Supplement	5.0 (31)	0.700 (40)	59.0 (37)
Forage			
Grass	9.5 (60)	0.680 (40)	85.5 (54)
Herbaceous	–	–	–
Woody	1.4 (9)	0.350 (20)	14.4 (9)
Total	15.9	1.7	158.9
Rainy			
Supplement	1.5 (11)	0.21 (12)	17.7 (15)
Forage			
Grass	8.1 (60)	0.823 (49)	64.8 (55)
Herbaceous	3.2 (24)	0.512 (30)	29.3 (25)
Woody	0.6 (5)	0.144 (9)	6.2 (5)
Total	13.4	1.69	118.1

supplements contributed 11% (Table 4). Based on these proportions and the average CP content by group (Table 3), grasses supplied 40 and 49% of CP (dry and rainy seasons, respectively). Herbaceous that were available only during the rainy season supplied 30% of CP to the cows requirements. Woody species supplied 20 and 9% of CP to the cows requirements during the dry and rainy seasons, respectively. Regarding metabolizable energy supply to cows during the dry season, grass, herbaceous and woody species contributed with 55, 25 and 5%, respectively.

Botanical composition of the diet

During the dry season grass group represented 84.2% of the forage BCD, whereas the woody group contributed 15.7% (Table 1). *Cynodon plectostachyus* (45%), *P. notatum* (14.2%), *Z. mays* (14.6%), and *A. farnesiana* (10.9%) were the most consumed species during the season. In the rainy season, the grass group contributed 65.9% of the BCD. *Cynodon plectostachyus* (39.3%) and *P. notatum* (11.8%) were the most consumed species within the grass group, while herbaceous *Aeschynomene sp.*, was the most consumed specie within the group with 12.2%; altogether, the herbaceous group represented 26.6% of the BCD. The contribution of woody species in the BCD was 7.4%.

There was no effect of season on the BCD regarding C. *plectostachyus*, *P. notatum* and P. *convexum* ($P > 0.05$) (Table 1). *Andropogon gayanus* and *Z. mays* had a significantly higher presence in BCD during the dry season (5.6 and 14.6%, respectively) compared with the rainy season (0.9 and 2.0%, respectively) ($P < 0.01$). There was no presence of herbaceous in the BCD of the cows during the dry season as well as for *B. humidicola* (grass) and *C. pentandra* (woody). *Acacia farnesiana*, *C. alata* and *P. dulce* had significantly higher intakes in the dry season compared with the rainy season.

Cows performance

All animal productive performance variables except for MY (kg/day) and protein yield (kg/day) were significantly higher in the rainy season regarding the dry season ($P < 0.05$) (Table 5). Dry matter intake (15.9 kg/DM/day) was 17% higher in the dry season compared with the rainy season (13.2 kg/DM/day) ($P < 0.05$). Season had no effect on milk yields ($P > 0.05$) with an average of 6.5 kg/day. Fat-protein corrected milk (FPCM) and energy corrected milk (ECM) were 8% higher during the rainy season compared with the dry season ($P < 0.05$). Milk fat concentration (32.5 g/kg) and yield (0.215 kg/

Table 5 Productive variables of lactating Brown Swiss cows grazing in an agrosilvopastoral system during the dry and rainy season

Item	Dry	Rainy	$P =$	S.E.
DMI[a] (kg/day)	15.9	13.3	< 0.01	0.21
Milk yield (kg/day)	6.3	6.6	0.24	0.19
FPCM[b] (kg/day)	5.4	5.9	0.04	0.17
ECM[c]	6.0	6.5	0.04	0.19
Fat (g/kg)	30.5	32.5	< 0.01	0.31
Fat (kg/day)	0.192	0.214	0.01	0.01
Protein (g/kg)	30.1	30.9	< 0.01	0.19
Protein (kg/day)	0.189	0.204	0.06	0.01
MUN[d] (mg/dL)	7.0	10.6	< 0.01	0.35
Body weight (kg)	418.5	436.0	< 0.01	8.47
Body weight change (kg/day)	0.18	0.49	0.09	0.10
Body condition score	2.5	2.7	< 0.001	0.04
Feed efficiency				
Kg of milk/kg of DMI	0.40	0.50	0.93	0.01

[a]DMI, Dry matter intake (kg/day); [b]FPCM, Fat protein corrected milk; [c]ECM, Energy corrected milk; [d]MUN, Milk urea nitrogen,

day) were significantly higher during the rainy season ($P \leq 0.01$), compared with the dry season (30.1 g/kg and 0.192 kg/day, respectively); protein content (g/kg) was also significantly higher ($P < 0.02$) in the rainy season (30.9 g/kg) compared with the dry season (30.1 g/kg), while there was a trend ($P = 0.06$) for higher protein yield during the rainy season (0.204 kg/day) compared with the dry season (0.189 kg/day).

Milk urea nitrogen was higher ($P < 0.01$) in the rainy season (10.6 mg/dL) compared with the dry season (7.0 mg/dL) that represents 44% higher levels. Also, BW and BCS were higher in the rainy season ($P < 0.01$). Feed efficiency was not affected by season ($P > 0.05$) with an average of 0.45 kg of milk/kg of DMI (Table 5).

Discussion

The grazing behavior of the cows was not an objective of this study, however, a general description of the grazing patterns of the cows is provided. The initial grazing event of the cows after being released from milking was on open areas of grazing land (i.e. pastures) (from 9:00 a.m. to 12:00 p.m., approximately). After this event, the cows rested under trees and ruminated (from 12:01 to around 1:00 p.m.). After this period, cows continued grazing on open areas in combination with areas where herbaceous (rainy season) and trees were more frequent (from 1:00 until 4:00 p.m., approximately). Then, a similar grazing pattern continued from 6:00 p.m. until sunset.

The nutritional composition of grass species except for *Z. mays* was typical of dry season forages (i.e. low crude protein, low dry matter digestibility and high fiber fractions) (Camero et al. 2001; Hunter and Kennedy 2016), which is in line with reported by López-González et al. (2015) who characterized the nutritional composition of *C. plectostachyus, P. notatum and B. decumbens* from the same region where this study was carried out.

The low nutritive value of grasses as the main source of feed for cattle in the tropics has been pointed out as the main constraint for milk and beef production, and several alternatives have been suggested to overcome this limitation. It has been proposed the production of good quality forages like grass and legumes haylage and, strategic supplementation (Absalón-Medina et al. 2012). Supplementation of sugar cane molasses to steers resulted in greater live weight gains when the basal diet was of low-quality grass than when the grass was of moderate quality (Hunter and Kennedy, 2016).

Usually, farmers do not consider the contributions of herbaceous and woody species to the requirements of DMI, ME and CP of the cows when supplementation decisions are made, they only considered grasses availability in pastures to decide the amount of supplement allotted to cows, particularly during the dry season. However, farmers are aware that cows while grazing consumed other forages different from grasses, and even they are able to identify by their local name which plants are consumed by the cows during the different seasons (Albarrán-Portillo et al. 2019); despite that, they do not know the nutritional characteristics of those forages neither their contribution to fulfilling nutrients requirements to the cows.

Woody species main characteristic was their high CP content besides its availability throughout the year unlike herbaceous. It has been reported that the in vitro dry matter degradability of a tropical grass (*H. rufa*) was increased due to the inclusion of legumes *E. poeppigiana* and *G. sepium* (18% inclusion in each case), having a significantly higher milk yield

(9–10%) compared with urea as a protein supplement (Camero et al. 2001).

Albores-Moreno et al. (2020) mentioned that woody species were highly preferred by cows grazing on tropical dry forest during the dry season, whereas herbaceous were preferred during the rainy season, which is in line with what is reported in this study. In this study, woody species represented 9 and 5% of the DMI of the cows during the dry and rainy seasons, respectively, while herbaceous were consumed only during the rainy season (seasonal availability). Seasonal preferences of woody forage by cattle respond to a reduced grass availability or nutritional value (Costa et al. 2021), as well as to the greater feeding value of woody species (Vandermeulen et al. 2018b).

The contribution of woody and herbaceous altogether was lower than the 34% of the DMI of lactating cows grazing on an intensive silvopastoral system (ISS) (*Leucaena leucocephala* associated with *Cynodon nlemfuensis*) reported by Bottini-Luzardo et al. (2016). In the above-mentioned study, CP levels of *L. leucocephala* were able to support similar milk yield to cows supplemented with concentrate.

Dry matter intake was 17% higher during the dry season than in the rainy season. This could be due to the supplementation level (additive effect) which is in line with reports of lactating cows grazing on intensive silvopastoral systems (Bottini-Luzardo et al. 2016; Flores-Cocas et al. 2021). The higher DMI during the dry season compared to the rainy season might seem counterintuitive because it has been widely demonstrated that low quality forage and fibrous bulk results as the main limiting factor for a maximum DMI; however, ruminants tend to compensate for a low quality diet by increasing their feed intake (Meyer et al. 2010) mediated by their relative large rumen that allows it to accommodate fibrous forages (Van Soest 1994).

The wide availability of forage and the slightly better nutritional composition (CP and IVDDM) during the rainy season allowed higher cow performance except for milk yield, protein yield and BW change, with a limited amount of supplement. FPCM, and ECM were 8% higher during the rainy season, whereas fat and protein concentrations were 6 and 3% higher, respectively. Dietary protein has been positively correlated with milk protein content (DePeters and Cant 1992), which corroborates that milk protein differences among seasons are related to dietary protein. The higher milk fat concentration in the rainy season was related to the higher content of NDF in the diet (53% DM) compared with the dry season (43% DM), according to the nutritional composition of the diet balanced using NASEM (2021). Likewise, body weight and BCS were 4 and 8% higher during the rainy season, respectively, which confirms the better quality of the diet during the rainy season.

Milk urea nitrogen was 34% higher in the rainy season (10.6 mg/dL) compared with the dry season (7.0 mg/dL). However, both were below the benchmark of 12 (mg/dL) which indicates that the cows are not overfed with CP (Kohn et al. 2002). Similar levels of MUN of 10.1 to 6.0 (mg/dL) of cows under intensive management fed with diets with 14.4 and 11.8% of dietary crude protein were reported by Barros et al. (2017) and (Zanton 2019).

It is possible that the better nutritional composition of grasses, along with herbaceous and woody availability might have influenced the significantly higher levels of MUN (10.6 mg/dL) in the rainy season. This better nutritional composition of forages along with the low levels of ME (9.0–9.3 MJ/kg DM) in the diet, could have impaired the efficiency of nitrogen utilization by the rumen micro-organism (i.e. high crude protein degradability and low availability of energy in the rumen) (Flores-Cocas et al. 2021).

On the contrary, during the dry season it is possible that the lower levels of MUN could be due to the combination of grasses of low nutritional value (i.e. CP) and higher intakes of woody. The secondary components of woody species (mainly tannins), might have helped to a reduction of ruminal ammonia nitrogen, by reducing the degradation of crude protein of rumen microorganisms as reported by Dschaak et al. (2011).

According to the mentioned above, the use of high energy ingredients in the cows supplements during rainy and dry seasons might result in increments of the utilization of herbaceous and woody species, with potential animal performance improvements and, reductions of MUN and nitrogen excretions in urine and feces to the environment according to the mentioned by Wattiaux and Karg (2004).

Also, with strategic energy supplementation could be possible to increase feed efficiency (kg of milk/kg of DMI), that in this study was on average 0.45 being lower than reported by (Flores-Cocas et al. 2021) (range 0.47–0.55) when supplementing two energy supplements to cows fed on *L. leucocephala* and *Pennisetum purpureum*.

Conclusion

It is concluded that grass, herbaceous and woody species contributed to DMI, CP and ME to the requirements of lactating cows grazing on an agrosilvopastoral system with seasonal differences. The use of high energy supplements is necessary to counter the lack of forage in quantity and quality particularly during the dry season. Increments of energy in supplements offered to the cows could have a positive impact on feed efficiency and, the utilization efficiency of herbaceous and woody species.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The research did not involve direct work with animals or persons, and followed guidelines accepted by the support Autonomous University of the State of Mexico.

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