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DRY MATTER AND NUTRIENT INTAKE AND DIET COMPOSITION IN *Leucaena leucocephala* – BASED INTENSIVE SILVOPASTORAL SYSTEMS

[CONSUMO DE MATERIA SECA Y NUTRIENTES Y COMPOSICIÓN DE LA DIETA EN SISTEMAS SILVOPASTORILES INTENSIVOS BASADOS EN *Leucaena leucocephala*]

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SUMMARY

Knowledge of forage intake and grazing selectivity is vital to improve the use of feed resources by grazing animals. To estimate forage selectivity and intake by steers grazing in intensive silvopastoral systems (ISS) under tropical dry forest (bs-T) conditions, intake was evaluated using the n-alkane technique in: 1) a *Leucaena leucocephala* (over 10000 shrubs/ha) and *Megathyrsus maximus* ISS system and, 2) a *M. maximus* monoculture system. Eight steers with an average weight of 248±23.1 kg live weight were evaluated. Animals grazing in the ISS system had greater dry matter intake (26.1 vs. 20.4 g kg^{-1} d^{-1} of BW, P = 0.044) and had greater intake (g d^{-1}; P $\leq$ 0.02) of crude protein (954 vs. 499), calcium (62.1 vs. 36.2) and fat (94.2 vs. 69.6) than those grazing in the *M. maximus* monoculture system, respectively. Compared to conventional pastures, DMI of animals grazing in ISS increases, contributing to greater animal productivity.

Key words: beef cattle; legume; n-alkane; silvopastoral system; voluntary intake

RESUMEN

El conocimiento del consumo de forraje y la selectividad de pastoreo es vital para mejorar el uso de los recursos forrajeros. Se determinó la selectividad y el consumo de forraje de novillos en sistemas silvopastoriles intensivos (SSPi) en bosque seco tropical (bs-T). El consumo de materia seca (CMS) y de nutrientes se evaluó usando la técnica de n-alcanos en: 1) un SSPi basado en *Leucaena leucocephala* (más de 10000 arbustos / ha) y *Megathyrsus maximus* y, 2) un sistema de monocultivo de *M. maximus*. Se evaluaron ocho novillos con un peso promedio de 248 ± 23.1 kg de peso vivo. Los animales que pastaron en el SSPi tuvieron mayor CMS (26.1 vs. 20.4 g kg^{-1} d^{-1} de BW, P = 0.044) y también mayor consumo (g d^{-1}, P $\leq$ 0.02) de proteína cruda (954 vs. 499), calcio (62.1 vs 36.2) y grasa (94.2 vs. 69.6) que los que pastaron en el sistema de monocultivo de *M. maximus*, respectivamente. Comparado con sistemas convencionales, el CMS se incrementa en los SSPi, lo que contribuye al aumento de la productividad animal.

Palabras clave: consumo voluntario; ganado de carne; leguminosa; n-alcano; sistema silvopastoril.

INTRODUCTION

The mechanisms that regulate dry matter intake (DMI) and forage selectivity are complex and highly variable among species and individuals (Gordon and Prins, 2008) and are affected by a diversity of factors including sward height and density (Barahona and Sanchez, 2005). Understanding how animals select their diet is essential to improve their utilization of natural resources, especially in consideration to the high diversity of forages that can be used in animal feeding (Poppi *et al*., 2000). One approach for assessing forage selectivity and DMI is the use of the alkane technique (Mayes *et al*., 1986), which uses alkanes in the cuticle of forages as internal markers. This technique has been tested in different grazing systems in the tropics (Hendricksen *et al*., 2002; Gaviria *et al*., 2015) and in different animal species such as cattle (Unal and Garnsworthy, 1999), sheep (Dove *et al*., 2000), goats (Ferreira *et al*., 2005) and buffaloes (Hendricksen *et al*., 2002). The main difficulties reported for this technique is that forages contain varying concentrations of alkanes, which may be very low in some tropical grasses and as C_{33} alkane is not present in sufficient quantities, estimates of dry matter intake using the pair C_{32}/C_{33} in these forages may not be suitable (Laredo *et al*., 1991; Rodríguez *et al*., 2007).

Intensive silvopastoral systems (ISS) are a promising alternative to intensify livestock production in the tropics, improving the competitiveness of livestock enterprises and significantly improving forage and animal productivity (Tarazona *et al*., 2013; Cuartas *et al*., 2014). An ISS is a form of agroforestry with high densities (from 5000 to 30000 shrubs/ha) of fodder shrubs such as *Leucaena leucocephala* cv. Cunningham and *Tithonia diversifolia* associated with high-biomass producing grasses and timber trees, fruit trees or palms (from 50 to 500 trees/ha). The ISS incorporates intensive rotational grazing by dividing the paddocks with electric fences, and offering a constant water supply and mineralized salt ad libitum, thus allowing high stocking rates and high milk and meat production per hectare (Cuartas *et al*., 2014).

As little information is available thus far, the aim of this study was to evaluate the selectivity and intake of forages of beef steers grazing in intensive silvopastoral systems with different forages and relate them to their nutrient intake and nutritional requirements.

MATERIALS AND METHODS

Location

The study was conducted on a beef farm located in Sucre, Colombia (09°51'24.86"N; 75°26'02.44"W). The life zone corresponds to tropical dry forest (T-df). The ISS is at 134 m of altitude, receives an average rainfall of 1000 mm/year, with a relative humidity of 83.5% and an average temperature of 27.1 °C.

Grazing systems evaluated

Two grazing systems were included in the study: (a) an intensive silvopastoral system (ISS) with *Leucaena leucocephala* (over 10000 shrubs ha^{-1}) and *Megathyrsus maximus*, associated with 500 timber trees of the species *Cordia gerascanthus* and *Tabebuia rosea* and (b) a *M. Maximus* pasture also associated with 500 timber trees of the species *C. gerascanthus* and *T. rosea*. The *M. maximus* pasture included some *Guazuma ulmifolia* trees, but dry matter (DM) yield estimates showed that the contribution of this legume to the diet did not exceed 10%. Thus, this system provided a good contrast to the ISS. The timber trees associated to both systems are not normally part of the diet, but their presence affects the forage production in both systems.

Animals and grazing management

Two animal groups, one for each pasture system, were utilized, and each was composed of four steers Zebu steers of different crosses of 248± 23.1 kg live weight (LW). The daily grazing area was 600 m^2, further divided into two strips with 12 hours of occupation in the ISS or used as a single strip with 24 hours of occupation in the *M. maximus* pasture. Hence, grazing strips had 44,5 and 44 days of rest, respectively. The comparative yield technique (Haydock and Shaw, 1975) was used to provide weekly estimates of edible biomass in both systems.

Estimation of DMI with the n-alkane technique

Alkanes were offered in gelatin capsules with 250 mg of a mixture with known amounts (75 mg) of n-dotriacontane (C_{32}) and n-hexatriacontane (C_{36}). Animals were first used to the presence of the persons supplying the capsules. Two of such capsules were administered daily for 15 days. The first ten days, corresponded to an adaptation period and starting on day 11^{th}, fecal samples were collected during five consecutive days in the morning and evening. Fodder samples were collected on days 1, 10 and 15 of the experiment, which were kept frozen until the end of the experimental period, when they were dried at 55°C in a forced air oven. Dry samples were ground to pass a 1 mm sieve and stored in glass vials for subsequent analysis.

Alkanes were extracted from duplicate fecal (0.1 g) and fodder (0.2 g) samples following the protocol of Dove and Mayes (2006). Both n-docosane (C_{22}) and n-tetratriacontane (C_{34}) served as internal standards. N-alkanes were determined in a gas chromatograph fitted with a 20 m x 0.25 mm x 0.25 µm capillary column. Injector and detector temperatures were 280 and 320°C, respectively. Column temperature started at 200°C and was increased at a rate of 10°C min^{-1} until reaching a final temperature of 300°C, which was maintained for 20 min. Hydrogen (20 mL min^{-1}) was used as the carrier gas.

To calculate forage intake (kg DM d^{-1}), the equation of Dove and Mayes (2006) was used:

$$DMI\left(\frac{kg}{d}\right) = \frac{\frac{F_i}{F_j} * D_j}{H_i - \left[\left(\frac{F_i}{F_j} * H_j\right)\right]}$$

Where:
F_i = concentration (mg kg DM^{-1}) of odd-chain n-alkane in faeces;
F_j = concentration (mg kg DM^{-1}) of even-chain n-alkane in faeces;
D_j= amount of synthetic n-alkane offered (mg d^{-1})
H_i = odd-chain *n*-alkane concentration (mg kg DM^{-1}) in forage;
Hj = even-chain *n*-alkane concentration (mg kg DM^{-1}) in forage.

In turn, diet composition was estimated using the approach of Dove and Mayes (2006):

$$Calculated\ fecal\ alkane_i = \alpha Grass + \beta Legume$$

In this equation, constants α (*grass*) and (β) *legume* are the recovery-corrected fecal concentrations of alkane$_i$ evaluated as unknowns. For determining diet composition, the following equation was used:

$$x = \frac{\alpha}{\alpha + \beta}; y = \frac{\beta}{\alpha + \beta}$$

Estimation of enteric methane (CH_4) emissions

Enteric methane emissions were estimated using the Ym (the percentage of gross energy intake that is emitted as enteric methane) values obtained in the *in vivo* (Molina *et al*., 2015a, 2015b) and *in vitro* (Rivera *et al*., 2015) work of the Fundación Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria – CIPAV and Universidad Nacional de Colombia Sede Medellín – UNAL, for animals consuming diets representative of an ISS (74 g/100 g *Cynodon plectostachyus* and 26 g/100 g *L. leucocephala*) and a grass-only pasture (100 g/100 g *C. plectostachyus*). Methane emissions were also estimated using the Ym values for grazing cattle suggested by the IPCC (2006).

Data Analysis

To compare variables, a completely randomized design ($y_{ij}=\mu + \alpha_i + \epsilon_i$) was used, where y_{ij} is the trait measured; μ is the overall average; α_i is the treatment effect at the ith level and ϵ_i is the experimental error. Treatments consisted of the grazing systems evaluated. Means were compared across treatments using Tukey's test at a significance level of 0.05.

RESULTS

N-alkane concentration

Total concentration of odd-chain alkanes reached values of 850.8, 860.9 and 442.8 mg kg^{-1} for *M. maximus*, *L. leucocephala* and *G. ulmifolia* respectively (Table 1). The most abundant odd-chain alkane was either C_{33} or C_{31}.

Table 1. Odd-chain alkane concentration of the forages included in this study (mg kg^{-1} dry matter)

Alkane	*Megathyrsus maximus*	*Leucaena leucocephala*	*Guazuma ulmifolia*
C_{27}	62.91	32.25	77.23
C_{31}	285.06	288.06	154.41
C_{32}	14.69	11.25	14.76
C_{33}	315.61	299.73	126.75
C_{34}	------	------	------
C_{35}	187.21	240.86	84.44
C_{36}	6.70	7.92	3.81

Dry matter intake

Estimates of DMI are shown in Table 2, which in average were adequate for the animals. However, great variability was observed in individual DMI, with intakes (g kg LW^{-1}) being as low as 16 and as high as 33. On average, DMI of animals grazing on SSP was 5.7 g kg LW^{-1} greater than that of animals grazing on the *M. maximus* pastures ($p<0.05$). Similarly, fecal output was 1.30 times greater in animals grazing in the ISS ($p<0.01$). This was due to the increased DMI of animals in ISS as the apparent digestibility coefficient of dry matter of both diets was similar (0.534 vs. 0.538 for the ISS and *M. maximus* pastures, respectively).

Forage selectivity

The diet of animals grazing in the ISS contained a greater proportion of legume than that of those grazing in the *M. maximus* pasture (30.2 vs 9.0%, respectively, $p<0.01$; Table 3). This obeyed to the greater availability of *L. leucocephala* in the ISS compared to that of *G. ulmifolia* in the *M. maximus* pasture.

One animal grazing on the ISS only consumed 1.0 kg DM of leucaena (18.6% of the diet), while the other three animals consumed on average 2.23 kg (34.8% of the diet). In the *M. maximus* pasture, given the limited supply of *G. ulmifolia*, there was less variability in selectivity. However, the diet of two animals grazing in the *M. maximus* pasture *G. ulmifolia* composed of 11.2% of the diet, while that of the other two animals was comprised of only 5.8% of the diet.

Table 2. Estimated dry matter intake of animals grazing in an intensive silvopastoral system (ISS) with *Leucaena leucocephala* and *Megathyrsus maximus* and in a monoculture system based on *M. maximus*.

Parameter	ISS	Monoculture	RMSE	*P value*
Intake, kg d^{-1}	5.99	5.39	2.68	0.35
Intake, g kg LW^{-1}	26.1	20.4	4.9	0.04
Fecal production, kg d^{-1}	2.71	2.40	0.28	0.14
Fecal production, g kg LW^{-1}	11.9	9.1	0.60	<0.01
Digestibility, coefficient	0.534	0.538	0.057	0.90
Live weight (LW), kg	231	266	40.9	0.33

Table 3. Selectivity on dry matter Intake of animals grazing in an intensive silvopastoral system (ISS) with *Leucaena leucocephala* and *Megathyrsus maximus* and in a monoculture based on *M. maximus*.

Parameter	ISS	Monoculture	RMSE	*P* value
Grass intake, % total diet	68.8	91.3	1.00	<0.01
Grass Intake, kg day^{-1}	4.12	4.92	1.81	0.13
Legume intake, kg day^{-1}	1.87	0.47	0.70	<0.01
Grass intake, g kg LW^{-1} d^{-1}	17.8	18.6	2.90	0.72
Legume intake, g kg LW^{-1} d^{-1}	8.2	1.8	0.15	<0.01

Dietary nutrient composition and nutrient intake by grazing animals

The nutrient content of the diet consumed in both systems is shown in Table 4. Animals grazing in the ISS consumed a diet with greater content of crude protein, ether extract and lignin and lower content of NDF, ADF and cellulose. The protein content of the diet consumed in the ISS (159.4 g kg^{-1}) was sufficient to meet the requirements of these animals.

As shown in Table 5, animals in ISS consumed 1.9 times (950 vs 500g) more protein than those grazing in the *M. maximus* pasture (p<0.01). Similarly, intake of ether extract was 1.35 times (94 vs 70 g) greater in these animals than in the *M. maximus* pasture (p = 0.02). Concerning fiber (NDF, ADF and cellulose) intake, there was no difference between both animal groups.

Table 4. Nutrient content (g kg^{-1} DM, unless indicated otherwise) of the diet of animals grazing in an intensive silvopastoral system (ISS) with *Leucanea leucocephala* (Ll) and *Megathyrsus maximus* (Mm) and in a system based on *M. maximus* with some inclusion of *Guazuma ulmifolia* (Gu).

Fraction	ISS		Monoculture		Diet composition, %	
	Mm	Ll	Mm	Gu	ISS	Monoculture
Nitrogen	17.0	44.3	14.4	19.1	25.5	14.8
Crude protein	106.1	276.8	89.9	119.1	159.4	92.4
NDF	663.8	324.2	675.7	290.2	557.7	642.7
ADF	362.6	123.0	365.2	171.4	287.8	348.6
Lignin	63.0	77.0	63.0	63.0	67.4	63.0
Cellulose	299.6	46.0	302.2	108.4	220.4	285.6
Hemicellulose	301.2	201.2	310.5	118.8	270.0	294.1
Calcium	8.6	14.3	5.9	15.2	10.4	6.7
Phosphorus	1.5	2.1	1.7	2.7	1.7	1.8
Ether extract	12.4	2.3.1	12.4	18.1	15.7	12.9
Ash	95.0	69.2	109.0	117.0	86.9	109.7
Organic matter	905.0	930.8	891.0	883.0	913.1	890.3

Table 5. Average nutrient intake (kg d^{-1}) by animals grazing in an intensive silvopastoral system (ISS) with *Leucaena leucocephala* and *Megathyrsus maximus* and in a monoculture system based on *M. maximus*.

Parameter	ISS	Monoculture	RMSE	*P* value
Crude protein	0.95	0.50	0.07	<0.01
NDF	3.34	3.46	0.92	0.74
ADF	1.72	1.88	0.26	0.43
Lignin	0.40	0.34	0.01	0.14
Cellulose	1.32	1.54	0.17	0.18
Hemicelullose	1.62	1.58	0.21	0.85
Calcium, g	62.10	36.20	<0.001	<0.01
Phosphorus, g	10.10	9.60	<0.001	0.69
Ether extract, g	94.20	69.6	<0.001	0.02
Ash	0.52	0.59	0.03	0.25
Organic matter	5.47	5.80	2.19	0.25

Estimated enteric methane (CH_4) emissions

Using the Ym values obtained in *in vivo* (Molina *et al*., 2015a, 2015b) and *in vitro* (Rivera *et al*., 2015) experiments by CIPAV-UNAL, there was no difference in estimated methane emissions of animals grazing in both systems, which were in average 54 kg head^{-1} year^{-1}. Given the greater energy intake of steers in ISS, the use of the Ym values suggested by the IPCC (2006) led to estimations of methane emissions that were 1.22 greater in ISS than in the *M. maximus* pasture.

With average daily weight ga|ins (g) of 818 and 300 (Cuartas *et al*., 2013), to gain 300 kg of live weight, steers would have to graze for 12.0 and 32.8 months in a typical ISS and *M. maximus* pasture, respectively. With an average daily DMI of 10.6 and 8.32 kg/animal (Cuartas *et al*., 2013) throughout that period, based on the Ym values of CIPAV-UNAL (Molina *et al*., 2015a, 2015b, Rivera et al., 2015) methane emissions associated with gaining those 300 kg of LW were estimated to be 92.5 and 232 for animals in the ISS and *M. maximus* pastures, respectively. Hence, it can be estimated that in producing a kilogram of live weight, enteric methane emissions would be 7.09 and 17.79 kg of CO_2 equivalent in ISS and *M. maximus* pastures, respectively.

Table 6. Estimates of methane production by animals grazing in an intensive silvopastoral system (ISS) with *L. leucocephala* and *M. maximus* and in a pasture based on *M. maximus* using the Ym values of CIPAV-UNAL (Molina *et al*., 2015a, 2015b, Rivera et al., 2015) and those of IPCC (2006).

Parameter	ISS		Monoculture	
	CIPAV-UNAL	IPCC 2006	CIPAV-UNAL	IPCC 2006
Intake, kg	5.99		5.39	
GE intake, MJ	110.54		91.13	
Y_m[a]	7.21% ± 0.65%	6.5% ± 1.0%	9.20% ± 0,20%	6.5% ± 1.0%
MJ CH_4[b]	7.97	7.20	8.38	5.94
CH^4 g d^{-1} [c]	143	129	151	106
Kg CH_4 an^{-1} $year^{-1}$	52.27	47.10	55.98	38.90

[a] Ym: methane conversion factor; [b]Mega Joules (MJ) of gross energy (GE) going to CH_4; [c] Grams of CH_4 calculated given that one kg of methane contains 55.65 MJ of GE.

DISCUSSION

Great variability has been reported with regard to the content of alkanes in forages, which could be related to soil and climatic factors and/or the laboratory technique used. For example, the concentration of odd–chain n-alkanes in *M. maximus* ranged between 16.8 and 22.3 mg kg DM^{-1} and 13.4 and 13.7 mg kg DM^{-1} for *L. leucocephala* (Sanchez *et al.*, 2009). In turn, in 25 species of plants used for grazing in Sudan, the concentrations of odd–chain n-alkanes in *Chloris gayana*, *Cenchrus ciliaris* (blooming) and *Stylosanthes guianensis* were 478, 571 and 406 mg kg DM^{-1}, respectively (Ali *et al.*, 2005), values within the ranges reported in this study.

Delgado *et al*. (2000) reported that the largest differences in content (mg kg DM^{-1}) of long chain n-alkanes between *M. maximus* and *L. leucocephala* occurred in C_{31} (69-83 and 31-33, respectively) and in C_{33} (48 and 16, respectively). In our study, this occurred for C_{27} and C_{35} (*L. leucocephala* vs. *M. maximus*), but differences of n-alkane content of these two forages with *G. ulmifolia* were much more contrasting. As it was also observed in this study, Delgado *et al.* (2000) reported that the most abundant odd–chain n-alkanes in *M. maximus* were C_{31} and C_{33}, which disagrees with earlier reports that in tropical forages, C_{33} is not present in sufficient quantities (Laredo *et al*., 1991). Clearly, as with most plant metabolites, the concentration of n-alkanes in forages changes with the time of year (Delgado *et al.*, 2000). Therefore, when using n-alkanes to determine DMI, it is necessary to determine the content of n-alkanes in representative samples of the forages consumed by animals.

Daily DMI intakes (g kg BW^{-1}) found in this study are similar to those reported by Gaviria et al., 2015. In this study, we observed greater DMI (1.28 times) in animals grazing in ISS than those grazing in a *M. maximus* pasture. Forage intake is greatly influenced by its chemical and nutritional quality and the nutritional quality of forages in ISS is superior to that of most tropical pastures (Cuartas *et al.*, 2013). With greater nutritional quality and biomass availability (Cuartas *et al*., 2014), greater DMI is to be expected in ISS.

The maximum DMI occurs when the diet digestibility reaches values between 66 and 68% (Faria and Mattos, 1995). Thus, the greater DMI observed in ISS could obey to changes in rumen residence times, since there were no differences in total tract DM digestibility (Table 2). At the same degree of digestibility, legume intake by ruminants is greater than that of grasses (Niderkorn and Baumont, 2009), because legume particles are cuboidal whereas those of grasses are long and thin, leading to greater rates of passage for legumes (Barahona and Sanchez, 2005). Additionally, management practices in ISS ensure that animals are offered forages closer to their optimal nutritional value (less mature), with low fiber content and thus, increased digestibility (Boval and Dixon, 2012). In turn, protein degradability can be low in *L. leucocephala* due to condensed tannin content (Barahona *et al.*, 2003), with a fraction of the protein protected from hydrolysis in the rumen, favoring protein bypass to the duodenum (Rodriguez *et al*., 2010).

Another factor that can contribute to greater DMI in ISS is that grasses subjected to moderate shading regimes, as occurs in ISS, may have greater protein and lower fiber content those growing at full exposition (Murtagh *et al*., 1987). Additionally, DMI relates to the ability of grazing animals to regulate body temperature under tropical conditions, with high environmental temperatures leading to decreased DMI (Tarazona *et al*., 2013). The shade provided by trees in ISS could have contributed to the results reported in this study. With greater DMI, there is greater productivity and steers grazing in ISS had daily gains between 832 and 856 g/d and reached harvest weight at around 540 days of age (Mahecha and Angulo, 2012).

As observed in this study, forage intake is a parameter of high individual variability. The DMI of steers in the *M. maximus* and ISS systems (20.4 and 26.1 g kg LW^{-1} d^{-1}, respectively), seem low when compared to the DMI of lactating cows. For example, Smith *et al*. (2005) estimated a DMI of 31.5 g kg LW^{-1} d^{-1} in Holstein cows with a live weight of 549 kg and an average milk production of 35 L. This is probably due to the greater nutritional requirements of lactating animals compared to meat producing animals. Estimates of DMI in grazing beef cattle of the Angus and Simmental breeds ranged between 14 and 15 g kg LW^{-1} d^{-1} (Estermann *et al*., 2003).

Fecal DM excretion was greater in ISS, and this related to the greater DMI. Fecal excretion plays an important role in the maintenance of soil fertility and nutrient recycling. Theoretically, the deposition of fecal matter in pastures allows nutrients to be used several times by plants and animals in a short period, contrary to what happens in plants not defoliated by grazing. It has been reported that excreta contain roughly the desired proportions of nutrients needed by plants (Herrero *et al*., 2013).

Greater methane (CH_4) emissions exist in animals that consume more DM. However, enteric CH_4 emissions in ruminants can be modified by the presence of secondary metabolites, which include condensed tannins (Tiemann *et al*., 2008), which occur at significant levels in *L. leucocephala* (Barahona *et al*., 2003). In general, the presence of condensed tannins has been associated with reductions of 13-16% in CH_4 emissions (Patra and Saxena, 2010).

In this study, enteric methane emissions for the production of one kilogram of live weight were estimated to be 340 and 793 g for steers in the ISS and *M. maximus* pastures, respectively. Opio *et al*. (2013) estimated that in the production of one kg of beef carcass weight, there is an emission of 67.8 kg of CO_2 equivalent, of which 28.9 kg correspond to enteric methane emissions. In our experiment, with a dressing percentage of 52% (Montoya, 2015), enteric methane emissions for the production of one kg of beef carcass weight would be 13.7 and 34.2 kg of CO_2 equivalent in ISS and *M. maximus* pastures, respectively.

CONCLUSIONS

In intensive silvopastoral systems, DMI of grazing animals is increased, leading to nutrient intakes in excess of maintenance requirements, thus leading to increased animal productivity. Animals in ISS have greater fecal excretion, leading to greater pasture nutrient availability. Despite similar methane emissions (kg per animal per year) in ISS and in *M. maximus* pastures, given differences in animal productivity which are directly related to changes in DMI, methane emissions per kg of weight gain would be around 40% in ISS compared to the *M. maximus* pasture. Further research should be carried out to determine if this benefit occurs in other (not *L. leucocephala* based) ISS systems.

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