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REGULAR ARTICLES

Herbage intake of dairy cows in mixed sequential grazing with breeding ewes as followers

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Abstract This study aimed to evaluate the hypothesis that mixed sequential grazing of dairy cows and breeding ewes is beneficial. During the seasons of spring–summer 2013 and autumn–winter 2013–2014, 12 (spring–summer) and 16 (autumn–winter) Holstein Friesian cows and 24 gestating (spring–summer) and lactating (autumn–winter) Pelibuey ewes grazed on six (spring–summer) and nine (autumn–winter) paddocks of alfalfa and orchard grass mixed pastures. The treatments "single species cow grazing" (CowG) and "mixed sequential grazing with ewes as followers of cows" (MixG) were evaluated, under a completely randomized design with two replicates per paddock. Herbage mass on offer (HO) and residual herbage mass (RH) were estimated by cutting samples. The estimate of herbage intake (HI) of cows was based on the use of internal and external markers; the apparent HI of ewes was calculated as the difference between HO (RH of cows) and RH. Even though HO was higher in CowG, the HI of cows was higher in MixG during spring–summer and similar in both treatments during autumn–winter, implying that in MixG the effects on the cows HI of higher alfalfa proportion and herbage accumulation rate evolving from lower residual herbage mass in the previous cycle counteracted that of a higher HO in CowG. The HI of ewes was sufficient to enable satisfactory performance as breeding ewes. Thus, the benefits of mixed sequential grazing arose from higher herbage accumulation, positive changes in botanical composition, and the achievement of sheep production without negative effects on the herbage intake of cows.

Keywords *Medicago sativa* · *Dactylis glomerata* · Herbage mass · Herbage accumulation · Botanical composition

Introduction

The sustainability of Mexican small-scale dairy farms is jeopardized by the low milk prices paid to farmers coupled with international trade liberalization; on the contrary, between 2010 and 2017, the national price of lamb increased, making current lamb finishing a profitable activity. However, sheep production in Mexico is divided into breeding and finishing phases; extensive breeding systems with low productivity are limiting the growth of Mexican sheep production (Améndola et al. 2006). The nutrient requirements of grazing dairy cows are high and demand conditions that enable high rates of intake of excellent quality herbage; conversely, the nutrient requirements of grazing breeding ewes are low for 7 months of the year (Nicol and Brookes 2007). Hence, dairy cows and breeding ewes may become complementary, particularly within a mixed sequential grazing system with breeding ewes as followers. Such a combination of small-scale dairy and sheep breeding could provide an opportunity to increase the sustainability of both systems.

As a result of a meta-analysis, d'Alexis et al. (2014) reported increases in live weight gain per hectare of both species in mixed grazing compared to single species grazing. Some studies have found advantages of sequential grazing of cattle and

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sheep. Wright et al. (2001) stated that grazing by one species can influence sward structure and composition and provide benefits to a subsequent species of grazer; this is termed facilitation. These authors quoted the effect of a previous grazer that created short vegetation that benefited the subsequent grazer by providing a dense and digestible sward.

Narrowing margins of profits of cattle and sheep systems require the development of grazing management guidelines to achieve the most efficient use of the grassland resource (Fraser et al. 2007). This study aimed to evaluate, under small-scale Mexican farm conditions, the hypothesis that mixed sequential grazing of dairy cows and breeding ewes is beneficial, because breeding ewes grazing as followers of dairy cows would graze to a shorter stubble. This could create a dense and leafy sward for the next grazing cycle of cows, improving their herbage intake (HI).

Material and methods

The experiment took place during the seasons spring–summer 2013 (between May and August, 2013) and autumn–winter 2013–2014 (between December, 2013, and February, 2014) at Chapingo University, Mexico. The site is located at 19°29′N and 98°54′W and an altitude of 2240 m, under temperate subhumid climate with summer rains.

Animals and pastures

Six (spring–summer) and nine (autumn–winter) paddocks of alfalfa (*Medicago sativa* L.) and orchard grass (*Dactylis glomerata* L.) mixed pastures between 1 and 5 years old were used. Total areas were 3.2 (spring–summer) and 4.4 (autumn–winter) ha, with a larger area in autumn–winter due to the lower growth rates of pastures in that season. The experimental animals were 12 (spring–summer) and 16 (autumn–winter) New Zealand Holstein Friesian cows of 500 ± 77 kg (spring–summer) and 537 ± 64 kg (autumn–winter) live weight (LW), and as followers 24 yearling gestating (spring–summer) and lactating (autumn–winter) Pelibuey ewes of 43 ± 7 kg LW.

Treatments and experimental design

Treatments were single species cow grazing (CowG) and mixed sequential grazing (MixG) with ewes as followers. Animals were divided into two replicates in a random design; therefore, experimental units were four groups of three (spring–summer) or four (autumn–winter) cows, including 12 ewes in MixG; paddocks were divided into four equally sized plots. The experimental units included the respective grazed areas. Given the negative effect of age on the productivity of alfalfa-based grasslands (Améndola et al. 2006), pastures were classified as young (1 and 2 years old) or mature (3 to 5 years old).

Grazing and animal management

Cows were milked at 06:30 and 15:30 h, after which they received 1.6 kg cow^{-1} of concentrate and remained in the paddocks. During autumn–winter, cows were also fed with 2.1 kg dry matter (DM) cow^{-1} day^{-1} of maize silage. Ewes grazed between 08:00 and 17:00 h and (for security reasons) were penned overnight with access to water and mineral supplement. During autumn–winter, the ewes were lactating and, hence, they were supplemented with 0.4 kg DM ewe^{-1} day^{-1} of maize silage.

Grazing was rotational with, on average, periods of 6 (spring–summer) and 4 (autumn–winter) days grazing, and 37 (spring–summer) and 45 (autumn–winter) days resting. In MixG, ewes grazed as followers 1 day after grazing by cows. Prior to the experiment, one adaptation grazing cycle took place, and between the spring–summer and autumn–winter measurement periods, grazing management continued as described above. Grazing areas were allotted based on herbage allowance to cows, which was defined by considering the following: (i) a goal of total DM intake of 3.2 kg 100 kg LW^{-1} day^{-1}, (ii) the DM intake of supplemental feed, and (iii) a target grazing efficiency of 70% (spring–summer) and 80% (autumn–winter); during autumn–winter, grazing efficiency is usually higher. Areas allotted were calculated for each experimental unit, considering the LW of the group of cows and the DM herbage mass of the plot.

Variables measured or calculated

The HI of cows was estimated based on fecal output measured using internal and external markers (Ramírez-Mella et al. 2010). The apparent HI of ewes was calculated as the difference between herbage mass on offer (HO) and residual herbage mass (RH).

Variables measured for the pastures were HO and RH; on each plot, six strips of 0.52 m × 4 ± 0.5 m were mown at a 5-cm height using a Trupper® P-520 rotary mower; herbage mass between ground level and 5-cm height was estimated by cutting two 0.5 × 0.5 m samples within each mown strip; each sample of RH was coupled with one HO sample. To calculate the HI of ewes, the RH of cows was considered as the HO of ewes.

Herbage samples were oven-dried at 55 °C until constant weight, thereafter they were ground in a Wiley® 4 mill with a 1-mm mesh; ash content was determined to correct for soil contamination of samples. The estimation of HI was carried out using chromium oxide (Cr_2O_3) as the external marker and acid insoluble ash (AIA) as the internal marker

(Ramírez-Mella et al. 2010). Cows were dosed with 5 g of Cr_2O_3 after each milking. Feces samples were taken from the rectum after each milking on the last 2 grazing days of each paddock; the four samples from each cow were mixed to compose a single cow-per-paddock sample. Herbage samples were taken by hand-plucking from each plot. Samples were oven-dried until constant weight at 100 °C (feces) and 55 °C (herbage) and ground in a Wiley® 4 mill with a 1-mm mesh.

Feces and feed (hand-plucked herbage, concentrate, maize silage) samples were submitted to AIA analysis; the chromium content in feces samples was also determined. Fecal output was calculated using Eq. 1 (Ramírez-Mella et al. 2010).

$$FO = \frac{MD}{MCF} \tag{1}$$

Where, *FO* is fecal output (g DM day^{-1});*MD* is marker dose (g day^{-1});and *MCF* is marker concentration in feces (g g^{-1}).

HI was calculated using Eq. 2 (Ramírez-Mella et al. 2010).

$$HI = \frac{\{(AIA)F \times FO\}–[\{(AIA)C \times CI\}–\{(AIA)S \times SI\}]}{(AIA)H} \tag{2}$$

Where, *HI* is herbage intake (kg DM day^{-1}); (*AIA*)*F* is AIA concentration in feces (g kg^{-1} DM); *FO* is fecal output (kg DM day^{-1}); (*AIA*)*C* is AIA concentration in concentrate (g kg^{-1} DM); *CI* is concentrate intake (kg DM day^{-1}); (*AIA*)*S* is AIA concentration in maize silage (g kg^{-1} DM); *SI* is maize silage intake (kg DM day^{-1}); (*AIA*)*H* is AIA concentration in hand-plucked herbage (g kg^{-1} DM).

The estimation of the botanical composition of hand-plucked samples was carried out by hand separation and oven-drying of components at 100 °C for 48 h.

Statistical analysis

For the analysis of variance of HO, RH, and botanical composition, models included the effects of treatment (CowG and MixG) and age of pastures (young and mature pastures) and their interaction. For the analysis of ewes' HI, the model only included the effect of age of pastures. Independent analyses were carried out per season using the SAS (SAS 2004) GLM procedure. The linear mixed model used for the analysis of variance of cows' HI included fixed effects of treatment, age of pastures and their interaction, and the random effect of replicates. Least-square means were compared using orthogonal contrasts and *t* tests.

Results

Herbage samplings (offer and residual)

Table 1 shows the least-square means performance of HO and RH variables under spring–summer and autumn–winter conditions. During spring–summer, the HO and RH of cows were higher ($P < 0.0001$) in CowG than in MixG (19 and 30%, respectively). During autumn and winter, HO tended ($P = 0.054$) to be higher in CowG than in MixG (8%) and RH was higher ($P < 0.05$) in CowG than in MixG (20%).

In the CowG treatment (Table 2a), HO did not differ ($P > 0.05$) between young and mature pastures during spring–summer, but during autumn–winter it was higher ($P < 0.05$) in young than in mature pastures (10%). Age of pastures did not affect RH ($P > 0.05$). In MixG (Table 2b), the age of pastures did not affect ($P > 0.05$) the HO or RH of cows; however, the RH of ewes was higher ($P < 0.05$) in mature than in young pastures in both seasons: spring–summer (39%) and autumn–winter (50%).

Herbage intake

There was no effect of the interaction treatment × age of pastures ($P > 0.05$) on the HI of cows. The HI of cows was higher ($P < 0.05$) in MixG than in CowG (23%) during spring–summer, but not during autumn–winter ($P > 0.05$); in addition, HI was higher ($P < 0.01$) in young than in mature pastures during both seasons: spring–summer (41%) and autumn–winter (28%) (Table 3).

The HI least-square mean of breeding ewes in mixed sequential grazing as followers of dairy cows (Table 4), estimated as the difference between HO (residual of grazing by cows) and RH, was higher ($P < 0.05$) in young than in mature pastures during autumn–winter (30%) and showed a trend ($P = 0.077$) to also be higher during spring–summer (32%).

Table 1 Herbage mass (kg DM ha^{-1}) of alfalfa and orchard grass pastures grazed by cows under single species cow grazing (CowG) and mixed sequential grazing of dairy cows with breeding ewes as followers (MixG)

Response variable	Season	MixG	CowG	SE	*P*
Herbage mass on offer (HO)	Spring–summer	3384	4021	92	< 0.0001
	Autumn–winter	2950	3197	84	0.054
Residual herbage mass (RH)	Spring–summer	1702	2213	56	< 0.0001
	Autumn–winter	1792	2146	100	0.027

SE standard error of means, *P* probability of differences

Table 2 Herbage mass (kg DM ha^{-1}) of alfalfa and orchard grass pastures of different ages under: (a) single species cow grazing (CowG) and (b) mixed sequential grazing of dairy cows with breeding ewes as followers (MixG)

Treatment/response variable	Season	Age of pastures			
		Young[a]	Mature[b]	SE	*P*
(a) CowG					
Herbage mass on offer (HO)	Spring–summer	3631	3774	65	0.144
	Autumn–winter	3165	2889	103	0.043
Residual herbage mass (RH)	Spring–summer	1958	1956	56	0.984
	Autumn–winter	1957	1992	87	0.827
(b) MixG					
Herbage mass on offer (HO)	Spring–summer	3282	3485	93	0.174
	Autumn–winter	2972	2906	90	0.682
Residual herbage mass (RH) of cows	Spring–summer	1691	1712	66	0.828
	Autumn–winter	1724	2026	121	0.182
Residual herbage mass (RH) of ewes	Spring–summer	595	825	42	0.008
	Autumn–winter	1198	1802	118	0.016

SE standard error of means, *P* probability of differences

[a] Young, 1- and 2-year-old pastures

[b] Mature, 3- to 5-year-old pastures

The proportion of alfalfa in herbage grazed by the cows (Table 5) was higher ($P < 0.0001$) under the MixG treatment than in CowG (25% during spring–summer and 18% in autumn–winter); the opposite occurred with the proportion of orchard grass, which under CowG was higher ($P < 0.0001$) than in MixG (61% during spring–summer and 81% in autumn–winter). The proportion of weeds was low and similar ($P > 0.05$) in both treatments and seasons.

Discussion

Effects of grazing systems on herbage intake

Ewes grazing as followers of cows necessarily grazed to lower residual herbage mass than in CowG (Table 2), due to their natural ability to graze close to the ground (Sollenberger et al. 2013). The herbage mass on offer was lower under MixG (Table 1), evolving from lower residual herbage mass in the previous cycle. Based on the herbage mass on offer, residual herbage mass (Tables 1 and 2), and resting periods, a rough estimate of the herbage accumulation rate was calculated. This estimate resulted in a 30% higher accumulation rate in MixG than in CowG during spring–summer (72 vs 56 kg DM ha^{-1} day^{-1}) and a 19% higher accumulation rate in MixG than in CowG during autumn–winter (32 vs 27 kg DM ha^{-1} day^{-1}). This positive response of herbage accumulation to close grazing of ewes was linked to the dominance of alfalfa in these pastures, since this species is better adapted to low harvest heights (Hernández Garay et al. 2012). Based on the results of Isselstein et al. (2007), this regrowth from a lower residual herbage mass should have led to a sward with a higher proportion of green leaves and a lower proportion of stems and dead material, which in turn, may have caused a bigger bite mass (Cosgrove and Edwards 2007), and hence improved the HI of cows in MixG during spring–summer. The lack of a positive effect during autumn–winter was probably due to the lower HI intake in that season than

Table 3 Herbage intake (HI, kg DM 100 kg LW^{-1} day^{-1}) of dairy cows in single species grazing (CowG) and in mixed sequential grazing with breeding ewes as followers (MixG), in pastures of different ages

Season	MixG	CowG	SE	*P*
Spring–summer	2.22	1.81	0.07	0.0019
Autumn–winter	1.48	1.34	0.07	0.1937
Age of pastures				
	Young[a]	Mature[b]		
Spring–summer	2.35	1.67	0.07	< 0.0001
Autumn–winter	1.53	1.17	0.10	0.0028

SE standard error of means, *P* probability of differences

[a] Young, 1- and 2-year-old pastures

[b] Mature, 3- to 5-year-old pastures

Table 4 Herbage intake (kg DM 100 kg LW^{-1} day^{-1}) of breeding ewes in mixed sequential grazing as followers of dairy cows, in young (1 and 2 years old) and mature (3 to 5 years old) pastures

Season	Young	Mature	SE	*P*
Spring–summer	3.94	2.99	0.31	0.077
Autumn–winter	3.05	2.35	0.30	0.047

SE standard error of means, *P* probability of differences

Table 5 Botanical composition (% of dry matter) of herbage grazed by dairy cows under mixed sequential grazing with breeding ewes as followers (MixG), and single species grazing (CowG) in alfalfa and orchard grass pastures

Species	Season	MixG	CowG	SE	*P*
Alfalfa	Spring–summer	74.4	59.3	1.495	< 0.0001
	Autumn–winter	81.4	69.2	1.421	< 0.0001
Orchard grass	Spring–summer	25.2	40.6	1.468	< 0.0001
	Autumn–winter	16.2	29.3	1.390	< 0.0001
Weeds	Spring–summer	0.4	0.1	0.286	0.5485
	Autumn–winter	2.4	1.5	0.688	0.3927

SE standard error of means, *P* probability of differences

during spring–summer, which, based on the results of Pérez-Prieto et al. (2011), may be explained by the substitution effect coupled with silage intake.

Close defoliation in MixG favored alfalfa in competition with orchard grass (Table 5), as reported by Hernández Garay et al. (2012), which is consistent with findings in monocultures reported by Shen et al. (2013), who found that lowering the harvest height was coupled with a higher alfalfa yield, and with Jones et al. (2017), who found that low cutting height reduced orchard grass regrowth upon defoliation.

Cow HI was higher in MixG than in CowG during spring–summer, but no effect of grazing method was found during autumn–winter. The higher herbage mass on offer in CowG led us to expect a higher HI as a regular response to herbage mass (Pérez-Prieto et al. 2012). However, the higher proportion of alfalfa was one probable cause counteracting that expected response, since alfalfa is preferred by cows over grass (Villalba et al. 2015). Cow HI results during spring–summer confirmed that the ewes as followers in the previous grazing cycle created a sward with a composition and canopy structure that was beneficial to the cows as a result of a combination of factors rather than a response to a single sward parameter, corroborating statements made by Fraser et al. (2007).

The average HI of ewes during gestation (spring–summer) reached 3.5 kg DM 100 kg LW^{-1} (Table 4) and, including supplemental silage, 3.9 kg DM 100 kg LW^{-1} during lactation. Based on the botanical composition of pasture and the requirements of ewes (Nicol and Brookes 2007), the intake of ewes consuming the residual herbage of cows and only 36 kg DM maize silage per ewe during the lactation period was sufficiently high to allow satisfactory performance as breeding ewes. Such performance of the ewes, together with the effect on HI of cows despite a higher stocking rate, support the hypothesis on the advantage of this mixed sequential grazing system.

Age of pastures

The HI of cows was higher in young than in old pastures ($P < 0.01$), so the HI of ewes was also higher during autumn–winter ($P < 0.05$); during spring–summer, it tended ($P = 0.077$) to be higher. This may be explained by the higher proportion of alfalfa in young pastures (Dear et al. 2007), enabling a higher bite mass for cows (Cosgrove and Edwards 2007) and a lower proportion of dead grass residue after grazing of cows, allowing better herbage utilization by sheep in MixG.

The higher HI on young pastures than old ones draws attention to the need for keeping a short rotation, avoiding high proportions of aging pastures. On average for both seasons and ages of pastures, the inclusion of ewes as followers (Table 3) increased the total herbage harvested (compared to CowG), without negatively affecting the HI of cows. This result corroborates the finding by Wright et al. (2001) on the advantages of sequential grazing of cattle and sheep, based on sufficient complementarity of grazing activity of cattle and sheep, which allows higher total nutrient intake under mixed sequential grazing than under single species grazing.

Compliance with ethical standards

Statement of animal rights The study was carried out in accordance with guidelines of the Research Ethics Committee of the EU Directive 2010/63/EU for animal experiments.

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

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