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Pasture dry matter intake per cow in intensive dairy production systems: effects of grazing and feeding management

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*The competitiveness and sustainability of low input cost dairy production systems are generally supported by efficient use of pasture in the diets. Therefore, pasture intake directly affects overall efficiency of these systems. We aimed to assess feeding and grazing management main factors that affect pasture dry matter intake (**DMI**) in commercial dairy farms during the different seasons of the year. Fortnightly visits to 28 commercial dairies were carried out between June 2016 and May 2017 to record production and price, supplement offered and price, pasture access time **(PAT)**, herbage mass (**HM**) and allowance (**HA**). Only farms with the most contrasting estimated pasture DMI per cow (**eDMI**) were compared as systems with high (HPI;* N = 8*) or low (LPI;* N = 8*) pasture DMI. Despite a lower individual milk production in HPI than LPI (19.0* v. *23.3 ± 0.7 l/cow,* P < 0.01*), daily margin over feeding cost was not different between groups (3.07* v. *2.93 ± 0.15 U$S/cow for HPI and LPI, respectively). During autumn and winter, HPI cows ingested more pasture than LPI cows (8.3* v. *4.6 and 5.9* v. *2.9 ± 0.55 kg DM/cow per day, respectively,* P < 0.01*) although PAT, HM and HA were similar between groups. Both groups offered high supplementation levels during these seasons, even though greater in LPI than HPI (14.7* v. *9.7 ± 0.7 kg DM supplement/cow per day, respectively,* P < 0.01*). On the other hand, differences between groups for both pasture and supplement DMI were more contrasting during spring and summer (13.1* v. *7.3 ± 0.5 and 4.0* v. *11.4 ± 0.4 kg DM/cow per day for HPI and LPI, respectively,* P < 0.01*), with higher PAT in both seasons (*P < 0.05*) and higher HA during summer in HPI than LPI (*P < 0.01*). Unlike LPI, during these seasons HPI adjusted offered supplement according to HA, achieving a higher pasture eDMI and making more efficient use of available pastoral resource than LPI. As there was no grazing limiting condition for pasture harvesting in either group, the main factor affecting pasture DMI was a pasture by supplement substitution effect. These results reinforce the importance of an efficient grazing management, and using supplements to nutritionally complement pasture intake rather than as a direct way to increase milk production.*

Keywords: pasture-based, forage consumption, supplementation, substitution, commercial dairy systems

Implications

This work attempts to define the major factors that determine individual pasture intake by cows in commercial dairies. The results demonstrate that farms could better benefit according to grazing conditions not only in spring and summer but also in winter and autumn. Pasture intake was limited by the substitution effect of supplements. Due to high supplementation, dairies with greater individual milk production did not achieve higher economic profit. This reinforces the importance of efficient grazing management, applying supplementation as a complementary tool to balance the diet and not as an isolated food, disconnected from the offered forage.

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Introduction

The competitiveness of low input cost dairy production systems is generally supported by efficient use of pasture in the diets (Dillon *et al.*, 2005). Nonetheless, the relatively low DM and metabolizable energy (**ME**) content of pastures often constrains DM and ME intake and, therefore, milk production of high potential dairy cows (Kolver and Muller, 1998). At the same time, pasture growth rate and therefore herbage production vary among seasons and are limiting in some periods of the year (Penno *et al.*, 2006). Thus, pasture-based dairy production systems generally increase supplementation of conserved forage and concentrate in order to ensure high DM and ME intake by cows all year. Efficiency of pasture and supplement use will often determine the success of pasture-based dairy production systems.

Pasture dry matter intake (**DMI**) by cows depends on sward state (i.e. sward height, herbage mass (**HM**)), access time to grazing pasture, and herbage allowance (**HA**). Sward height and HM (kg DM/ha) determine bite mass (Laca *et al.*, 1992) and hence, intake rate. At low sward height and mass (i.e. less than 18 cm and/or 1800 kg DM/ha at ground level) pasture DMI could be constrained by low bite mass (Chilibroste *et al.*, 2000). In contrast, tall swards or high HM (i.e. more than 30 cm and/or 4000 kg DM/ha) leads to heavy selective grazing behaviour, therefore reducing bite mass and intake rate (Mezzalira *et al.*, 2014). In general terms, if sward structure constrains bite mass, cows can compensate totally or partially by increasing grazing time (Gibb *et al.*, 1999; Chilibroste *et al.*, 2000). In such circumstances, access time to grazing is a key factor influencing the quantity of forage harvested (Chilibroste *et al.*, 2015). If grazing time and sward structure are not limiting, a curvilinear relationship between DMI and HA has been reported (Peyraud *et al.*, 1996). According to Baudracco *et al.* (2010), to achieve maximum pasture DMI, HA should be equivalent to two- to four-fold potential DMI. However, a high HA per cow could result in a low harvest efficiency and high amount of wasted pasture (Peyraud *et al.*, 1996; Holmes *et al.*, 2002), which could impair future pasture production (Stockdale, 2000).

Ingestive behaviour and consequently pasture DMI also depends on feeding motivation. The predominance of stimulatory or inhibitory signs of intake when starting a grazing session is determined by ruminal distension and/or nutritional deficit related to ME demand (Chilibroste *et al.*, 2007; Baudracco *et al.*, 2010). As ruminal fill increases, orexigenic signals become weaker (Gregorini *et al.*, 2009), consequently, pasture DMI is reduced because grazing time decreases (Stockdale, 2000). In addition, metabolites from hepatic oxidation of absorbed nutrients might act as inhibitory signals of intake (Allen, 2014). Thus, the motivation to graze will decrease, and the substitution rate of pasture by supplements will increase as the relative ME deficit at the start of the grazing session decreases (Allen, 2014). Moreover, although DM digestibility and total nutrient supply usually improve with supplementation (Dixon and Stockdale, 1999), inclusion of cereal grains in forage-based diets often reduces ruminal pH (Leddin *et al.*, 2010), fibre digestibility (Van Soest, 1994) and pasture intake (Elizalde *et al.*, 1999). The magnitude of these effects largely depends on supplementation levels (Dixon and Stockdale, 1999; Elizalde *et al.*, 1999). As the substitution rate increases, the productive response to supplementation decreases (Walker *et al.*, 2001). Ultimately, pasture DMI and animal response to feeding management are explained not only by sward structure and pasture management but also by cow motivation to harvest forage.

Much of the information available in the literature was generated in short-term trials, under control conditions (i.e. mono-specific uniform swards) and with a low number of cows per treatment (Chilibroste *et al.*, 2015). The objective was to determine the main factors associated with pasture DMI per cow in commercial dairy systems in various seasonal herbage production scenarios. The hypothesis was that systems that have higher pasture DMI per cow have better conditions for grazing, in terms of pasture access time (**PAT**), HM and HA, and require lower amounts of supplement.

Material and methods

Study design

An exploratory study was completed between June 2016 and May 2017 using 28 commercial dairy farms situated in the traditional dairy areas of Uruguay. The criteria for selecting farms were to have a technical consultant who visited the farms periodically and keeps reliable records. Monitored dairy farms had in average 228 ± 201 (mean ± SD) lactating cows, which weighed 563 ± 41 kg and grazed on 191 ± 127 ha (haPP, grazing area for lactating cows). All systems studied had a high proportion of Holstein cows in the herd, with calving season mostly distributed during autumn. Mean stocking rate was 1.28 ± 0.35 milking cow/haPP, which is 25% to 30% above Uruguayan dairies average stocking rate (Fariña and Chilibroste, 2019). In all systems, cows had access to grazing temperate pastures all year round. Pastures were composed of a variety of species of grasses and legumes, with two to five of: lucerne (*Medicago sativa*), bird's-foot trefoil (*Lotus corniculatus*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), chicory (*Cichorium intybus*), tall fescue (*Festuca arundinacea*), brome grass (*Bromus catharticus*) and orchard grass (*Dactylis glomerata*). Annual species included ryegrass (*Lolium multiflorum*), oat (*Avena sativa*) and sorghum (*Sorghum bicolor*). Estimated daily DMI per cow (annual average) for the 28 dairy farms was 7.5 ± 4.0, 4.1 ± 3.2 and 5.8 ± 2.1 kg DM of grazed forage, conserved forage and concentrate, respectively. Mean daily milk production was 20.5 ± 4.3 l, with 4.78 ± 0.12%, 3.78 ± 0.24% and 3.35 ± 0.12% of lactose, fat and protein, respectively.

Data collection, measurements and estimates

Every 2 weeks, each dairy farm was visited to collect data according to a pre-established protocol. Each dairy farm was assigned to be visited by one of two trained visitors during all the monitored period. In each visit, the number of producing cows per herd, milk production, cows daily routine (i.e. time of access to grazing plots, feedbank, rest areas) and type, quantity and costs of supplement offered (i.e. concentrate and conserved forage as hay, haylage and silage) were recorded. Monthly data of milk composition (i.e. fat, protein, lactose) and milk price were obtained.

When cows had access to pasture a transect on each paddock to be grazed was walked to determine presence of pasture, bare soil or weeds every 10 m in order to ensure a minimum of 20 observations per paddock. In case of presence of pasture, HM (kg DM/ha) was visually determined above ground level. Periodic calibration training in commercial establishments for each pasture resource was done every 15 days during autumn, winter and summer and every 7 days during spring using the method of Haydock and Shaw (1975). Reference quadrants (20 × 50 cm) of paddocks representing high, medium and low HM and their replicates (2) were cut to ground level with scissors and dried for 48 h at 65°C to estimate HM. The size of the allocated paddock in each grazing session was measured and the area was adjusted by discounting the percentage of weeds and areas of bare soil. Herbage allowance per cow in each grazing session was established based on the average HM of the paddock and the instantaneous animal stocking rate (i.e. number of milking cows in the adjusted area). If cows grazed two paddocks a day, daily HA per cow was determined as the sum of HA offered in each paddock.

Supplement intake was determined as the difference between offered and rejected feed at the feeder. Actual pasture DMI per day (kg DM/cow) was estimated based on NRC (2001) and potential pasture DMI was estimated based on Baudracco *et al.* (2010). Estimated pasture DMI according to NRC (2001), from here on 'eDMI', was determined as the amount of pasture necessary to supply the difference between net energy (**NE**) requirements and that provided by supplements in the diets. The average NE requirements of the cows were estimated as the sum of maintenance and milk production requirements, assuming no growth nor pregnancy requirements, and a balance between cows losing and gaining BW. Average BW data of the cows of each dairy farm were obtained by weighing culling cows taken to the slaughterhouse. Maintenance requirements were computed on the basis of 80 kcal of NE/kgBW$^{0.75}$ (NRC, 2001), with an increase of 20% due to grazing activity (CSIRO, 1990). Production NE requirements were estimated considering the herd daily average of solids production by milking cows (NRC, 2001):

$$\text{NEL(Mcal/kg)} = 0.0929 \times Fat\% + 0.0547 \times \text{Crude protein\%} + 0.0395 \times \text{Lactose\%}$$

The NE provided by supplements was estimated as the sum of NE supplied by the intake of each supplement in the diet. The NE density of pasture was adjusted based on the season of the year (1.45 Mcal/kg DM for autumn, winter and spring and 1.25 Mcal/kg DM for summer).

Potential pasture DMI per cow was estimated from HA for each visit to each dairy farm using the equation of Baudracco *et al.* (2010) for dairy cows grazing without supplementation. It was determined when HA was greater than 5.3 (intercept) and less than 100 kg DM/cow per day:

$$\text{Pasture DMI} = 5.3216 + 0.3447 \times HA - 0.00220 \times \text{HA}^2 (R^2 = 0.80; n = 49)$$

where HA is herbage allowance at ground level expressed as kg DM/cow per day. Differences between both pasture DMI estimates were determined for each visit as an indicator of feeding management efficiency (**FME**), where high difference between estimates indicates low FME and low difference between estimates indicates high FME.

Feed conversion efficiency (**CE**) was defined as feed DMI (pasture plus supplement) necessary to produce a litre of milk (**kg tot/l**). Concentrate CE was expressed both in grams of concentrate necessary to produce a litre of milk (**gconc/l**) and kilograms of concentrate per kilogram of solid (**kgconc/kgsolid**).

Nutrient concentration in the diets was determined considering the quantity and quality of each feed supplied to the cows at each visit. Samples of wet grains, haylages and silages from all the new batches used were analysed for DM by drying at 105°C to constant weight (Method 7.003; AOAC, 1997) in order to estimate the kilograms of DM daily offered to the cows. Crude protein (%), NDF (%) and NE for lactation (NEL, MCal/kg DM) content of concentrate, supplement and total diet were calculated based on chemical composition tables (NRC, 2001). The margin over feeding costs was calculated for each of the visits as the difference between milk incomes and cost of the different components of the diet (i.e. grazed forage, conserved forage, concentrate).

Statistical analysis

In order to evaluate two contrasting groups of farms according to pasture eDMI, only the dairy farms with the lowest and highest annual average pasture eDMI were compared (low pasture intake group; **LPI**, $N = 8$, *v.* high pasture intake group; **HPI**, $N = 8$, respectively). Table 1 shows a brief description of each of the 16 commercial dairy farms.

Data were analysed using the MIXED procedures of SAS Systems programme (SAS Institute Inc., Cary, NC, USA) following the model:

$$\text{Yij} = \mu + \text{Gi} + \text{Sj} + \text{Gi} * \text{Sj} + \text{eij}$$

where Yij is the pasture DMI, μ is the population mean, Gi is the 'group' (i = LPI or HPI) and Sj is the 'season' (j = winter, spring, summer or autumn) fixed effects, Gi *Sj is their interaction and eij is the residual error term. Dairy farm was considered the experimental unit. Data obtained from fortnightly visits were analysed as repeated measures in time. Each season included at least six observations for all the variables. Data were analysed annually and by season (considering August, September and October as spring, November, December and January as summer, February, March and April as autumn and May, June and July as winter). Mean comparisons were performed by Tukey–Kramer analysis. On dairy farms that owned more than one herd of lactating cows, the variables of individual production and margin over feeding cost per cow were analysed as the average of all cow herds, while DMI, difference between estimates, HM, HA, time at pasture and feed CE variables were analysed for the high-producing herd. Mean differences were considered significant at $P \leq 0.05$ and tendency when $0.05 < P \leq 0.10$.

Table 1 *Some characteristics of the 16 commercial dairy farms utilized*

Group	Farm	Number of lactating cows	BW (kg)	Hectares[2]	Stocking rate[3]	Number of herds
HPI[1]						
	1	94	550	108	0.87	1
	2	88	580	59	1.50	1
	3	113	650	91	1.24	1
	4	172	550	161	1.07	1
	5	149	500	168	0.88	1
	6	104	520	100	1.04	1
	7	166	570	137	1.21	2
	8	68	550	59	1.17	1
LPI[1]						
	9	144	600	94	1.54	1
	10	117	550	87	1.34	1
	11	167	500	148	1.12	1
	12	358	590	302	1.19	3
	13	186	550	147	1.27	2
	14	202	600	104	1.94	1
	15	701	620	499	1.41	3
	16	783	585	642	1.22	3

[1]From the monitoring carried out in 28 farms from the dairy basin of Uruguay, those dairy farms with the most contrasting forage intake were selected and compared as systems with high (HPI, $N=8$) and low (LPI, $N=8$) forage intake per cow.
[2]Grazing area for lactating cows (grazing platform).
[3]Number of lactating cows per hectare of grazing platform.

Results are presented as least square means ± SEM. For more details, please see Supplementary Material.

Results

Table 2 presents feed intake per cow, grazing management characteristics, milk production, feed CE, margin over feeding cost and diet composition of dairy farms with low ($N=8$) or high ($N=8$) individual pasture DMI classification by year and by season. All the variables, except feed CE in gDM concentrate/l milk, were affected by season. Grazed forage and conserved forage DMI was also affected by group ($P<0.01$) and group*season interaction ($P\leq 0.05$). Cows of HPI group graze on average +4.6 kg DM per day more than cows of LPI group. The greatest pasture eDMI differences between groups were observed in summer and spring (+6.7 and +4.9 more kg DM/cow per day in HPI than LPI group for summer and spring, respectively, $P<0.01$). The lowest pasture eDMI differences between groups were observed in winter and autumn (+3.0 and +3.8 more kg DM/cow per day in HPI than LPI group for winter and autumn, respectively, $P<0.01$). With regard to conserved forage DMI, HPI group cows ate on average −2.7 kg DM per day less conserved forage than cows on LPI group. The greatest conserved forage DMI differences between groups were observed in summer and spring (−3.9 and −3.2 kg DM/cow per day less in the HPI than LPI group, summer and spring, respectively, $P<0.01$) and the lowest DMI differences were observed in winter and autumn (1.4 and 2.2 kg DM/cow per day less in the HPI than LPI group, winter and autumn, respectively, $P\leq 0.06$). Concentrate DMI was affected by group ($P<0.01$) and season ($P<0.01$), with no group*season interaction effect. Cows of HPI group ate 3.5 kg DM/cow per day less concentrate than LPI group cows ($P<0.01$). Concentrate DMI was higher in winter than in the other seasons ($P<0.01$). During spring, summer and autumn cows ate similar amount of concentrate.

There was a group*season interaction effect on time at pasture ($P=0.03$), with no differences between groups neither in autumn nor in winter, but with a greater time at pasture in the HPI group in spring ($P=0.02$) and summer ($P<0.01$). An effect of the season on HM was observed ($P<0.01$), with no group neither group*season interaction effect. Herbage mass in autumn was similar than in winter and both were lower ($P<0.01$) than in spring and summer (similar to each other). Herbage allowance was affected by season of the year ($P<0.01$), group ($P=0.01$) and their interaction ($P<0.01$). Daily HA differences between groups in the year were explained by a higher summer daily HA in the HPI than in the LPI group ($P<0.01$). A tendency for lower winter daily HA in the HPI than LPI group ($P=0.10$) was observed, and no differences between groups in spring and autumn daily HA were detected.

Figure 1 shows the variations in the FME (difference between pasture eDMI estimated by energy balance and HA) in each season of the year for the LPI and HPI group. Feed management efficiency was affected by season of the year (4.7, 3.9, 5.5 and 6.8 ± 0.42 kg DM/cow per day in spring, summer, autumn and winter, respectively, $P<0.01$) and group (6.9 *v.* 3.6 ± 0.3 kg DM/cow for LPI and HPI, respectively, $P<0.01$), without group*season interaction effect. For both groups, the worst FME was observed in winter ($P<0.01$) and the best FME occurred during summer. Spring FME was intermediate between summer and autumn. The smallest differences between groups in FME were observed in autumn and winter ($P<0.01$), while the highest differences in FME between groups were observed during spring and summer ($P<0.01$). The best FME was detected in the HPI group during summer (lowest differences between pasture eDMI; Figure 1).

Neither milk production nor milk composition was affected by group*season interaction. Group and season affected milk production, protein and lactose content, while fat content was only affected by season (Table 2). Daily milk production in winter (21.8 ± 0.57 l/cow) was intermediate between spring and summer (22.3 and 20.9 ± 0.57 l/cow, $P<0.01$), and higher than autumn (19.5 ± 0.57 l/cow, $P<0.01$). Cows of the LPI group produced more milk with similar fat and higher protein and lactose concentration than cows of the HPI group. As a consequence, energy excreted in milk was higher in animals of the LPI than the HPI group (Table 2).

Despite the LPI group had higher feed CE (kgtot/l) than cows in the HPI group ($P<0.01$), concentrate CE expressed both in gconc/l and kgconc/kgsolid were lower in the LPI than in the HPI cows ($P<0.01$). Feed CE was also affected by season

Table 2 *Feed intake per cow, grazing management characteristics, milk production per cow, feed conversion efficiency, margin over feeding cost and diet composition by year and by season in the 16 commercial dairy farms according to pasture intake classification*[1]

	Year		Autumn (A)		Winter (W)		Spring (Sp)		Summer (Su)			*P*-value		
	LPI	HPI	LPI	HPI	LPI	HPI	LPI	HPI	LPI	HPI	SEM	Group	Season	Group × season
Feed intake per day (kgDM/cow)														
Total	19.0	17.3	18.3	16.7	19.2	16.4	18.9	17.3	19.7	18.6	0.37	<0.01	<0.01	0.12
Grazed forage[2]	5.5	10.1	4.6[b]	8.4[a]	2.9[b]	5.9[a]	7.6[b]	12.5[a]	7.0[b]	13.7[a]	0.55	<0.01	<0.01	<0.01
Conserved forage	4.9	2.2	5.2[a]	3.0[b]	7.3	5.9	3.2[a]	0.0[b]	4.0[a]	0.1[b]	0.42	<0.01	<0.01	0.05
Concentrate	7.1	3.6	6.3	3.2	7.8	4.7	7.2	3.2	7.1	3.3	0.38	<0.01	<0.01	0.45
Grazing management														
Time at pasture (hour)	12.3	13.0	12.3	11.7	10.3	9.6	14.4[b]	16.3[a]	12.1[b]	14.5[a]	0.63	0.14	<0.01	0.03
Herbage mass (kgDM/ha)	2398	2208	1827	1717	1817	1589	3037	2354	2909	3171	178	0.16	<0.01	0.13
Herbage allowance (kgDM/cow)	23.2	29.4	15.8	17.1	23.8[x]	17.8[z]	31.8	34.6	21.5[b]	48.3[a]	3.1	0.01	<0.01	<0.01
Milk production per day														
l/cow	23.3	19.0	21.9	17.1	24.0	19.7	24.6	20.1	22.7	19.1	0.80	<0.01	<0.01	0.74
Fat (%)	3.73	3.81	3.83	3.81	3.82	3.81	3.53	3.65	3.66	3.86	0.07	0.35	<0.01	0.16
Protein (%)	3.39	3.30	3.40	3.35	3.39	3.29	3.36	3.24	3.41	3.31	0.03	0.01	<0.01	0.19
Lactose (%)	4.80	4.75	4.68	4.59	4.85	4.85	4.87	4.82	4.87	4.82	0.02	0.03	<0.01	0.09
Mcal NEL/cow	16.7	13.7	15.9	12.5	17.5	14.3	17.2	14.2	16.2	13.9	0.55	<0.01	<0.01	0.57
Feed conversion efficiency														
kgDM total feed/l milk	0.79	0.90	0.83[b]	0.97[a]	0.78[b]	0.84[a]	0.74[b]	0.85[a]	0.82[b]	0.97[a]	0.02	<0.01	<0.01	<0.01
gDM concentrate/l milk	283	204	267	208	317	258	263	164	285	184	15	<0.01	0.24	0.58
kgDM concentrate/kg solid	3.80	2.82	3.26	2.68	4.11	3.62	3.79[a]	2.39[b]	4.05[a]	2.59[b]	0.24	<0.01	<0.01	0.09
Margin over feeding cost per day (U$S/VM)	2.93	3.07	3.03	2.69	2.54	2.59	3.33	3.57	2.84[z]	3.41[x]	0.21	0.53	<0.01	0.08
Chemical composition														
Supplement offered														
Energy (Mcal NEL/kg DM)	1.60	1.63	1.59	1.57	1.55	1.54	1.65	1.72	1.62	1.70	0.03	0.39	<0.01	0.28
CP (%DM)	14.4	12.0	14.8[a]	11.9[b]	13.3[a]	10.8[b]	14.7[a]	11.7[b]	14.7	13.6	0.49	<0.01	<0.01	0.06
NDF (%DM)	35.7	36.7	37.7	36.0	37.9[b]	47.2[a]	32.9	35.0	34.1	28.6	2.17	0.60	<0.01	<0.01
Total diet offered														
Energy (Mcal NEL/kg DM)	1.55	1.49	1.54[a]	1.44[b]	1.56	1.55	1.59	1.55	1.50[a]	1.41[b]	0.02	<0.01	<0.01	<0.01
CP (%DM)	15.4	15.0	15.3	14.2	14.8	14.6	16.6	16.9	14.7	14.4	0.38	0.31	<0.01	0.23
NDF (%DM)	40.5	47.0	40.4	46.3	39.4	46.3	38.7	43.9	43.5	51.4	1.11	<0.01	<0.01	0.60

[1] From the monitoring carried out in 28 farms from the dairy areas of Uruguay, those dairy farms with the most contrasting pasture intake were selected and compared as systems with high ($N = 8$) or low ($N = 8$) pasture intake per cow.
[2] Pasture DMI estimated by energy balance (NRC, 2001).
[a,b] Means within season with different superscripts differ ($P < 0.05$).

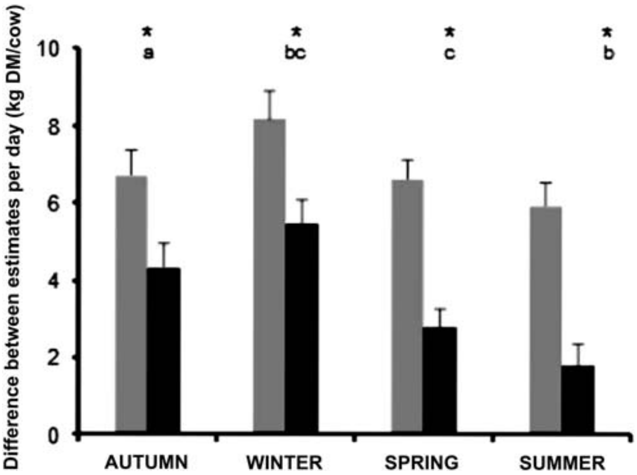

Figure 1 Mean (±SE) of difference between pasture DMI estimated by energy balance (NRC, 2001) and considering herbage allowance per cow in accordance with Baudracco *et al.* (2010), for the low (■) and high (■) pasture intake groups, according to the season of the year. Asterisks indicate significant differences between groups ($P \leq 0.01$). Letters a, b and c indicate significant differences between seasons ($P \leq 0.05$). Difference between both pasture DMI estimates was determined for each visit as an indicator of efficiency of FME; high difference between estimates indicates low FME, while low difference between estimates indicates high FME. Dry matter intake = DMI; feeding management efficiency = FME.

($P < 0.01$) and group*season interaction ($P < 0.01$), with winter feed CE being similar to spring (0.80 ± 0.01 kgtot/l), and autumn feed CE being similar to summer (0.90 ± 0.01 kgtot/l), with more accentuated differences between groups during autumn and summer than during winter and spring (Table 2). Concentrate CE expressed as gconc/l was not affected by season neither group*season interaction, while CE expressed as kgconc/kgsolid was influenced by season ($P < 0.01$) and tended to be influenced by group*season interaction ($P = 0.09$). The HPI group was more efficient than the LPI group converting concentrate to milk in spring and summer ($P < 0.01$) but similar in autumn and winter.

There were no differences in the margin over feeding cost per cow between groups under the price scenario registered in the monitoring period. It was affected by season ($P < 0.01$), with autumn (2.86 ± 0.14 U$S/cow per day) similar to summer (3.13 ± 0.15 U$S/cow per day) and different from winter and spring (2.56 ± 0.15 and 3.45 ± 0.14 U$S/cow per day, respectively, $P < 0.05$), and tended to be affected by group*season interaction ($P = 0.08$), with no differences between groups in margin over feeding costs during autumn, winter and spring, but a tendency for higher margin in the HPI than LPI group during summer (3.41 *v.* 2.84 ± 0.21 U$S/cow per day, respectively, $P = 0.07$).

No differences were detected in supplement energy and NDF concentration between groups (Table 2). However, the HPI group offered lower supplemental concentration of CP than the LPI group. In accordance with higher levels of supplement in the diet, the total diet of LPI had greater concentrations of energy and less concentrations of NDF than diets of HPI. No differences in CP concentration in the total diet offered were detected between groups (Table 2).

Discussion

The present work attempts to understand which of the multiple factors that influence pasture intake have the greatest impact on Uruguayan pastoral commercial dairy systems in the different seasons of the year. Although the results appear clear and in general terms seasons covered in this work were representative of historical climatic conditions in the area, the lector must be taken into account that the present work was an exploratory study and the presented results are derived of only one year of monitoring.

The conformed groups clearly denote two different productive strategies, systems that aimed for a higher yield per cow based on a greater supplementation level (LPI group) *v.* systems that aimed to produce under a limited amount of supplement and controlled feeding cost (HPI group). The higher milk production and feed CE (kg tot/l) in the LPI group were coherent with a higher concentrate DMI and therefore a higher energy and lower NDF content per kilogram of total DM (Reis and Combs, 2000). The LPI group systems balanced supplement CP concentration to pasture contribution, achieving similar total diet CP content than the HPI group and reaching the recommended CP levels for high milk production (15%; NRC, 2001). However, concentrate to milk CE (both g conc/l and kg conc/kg solid) was lower in the LPI group. Given the lower CE of the LPI group and the higher feeding costs of supplement compared to pasture, the LPI group did not enhanced economic profit respect to HPI group. Therefore, LPI group could have been subject to an increased economic risk in case of concentrate price increases. Systems with a greater inclusion of pasture in the diet equalled the economic margin achieved by systems with more milk production per cow, as reported in previous studies (White *et al.*, 2002; Fontaneli *et al.*, 2005).

In both groups, although at different intensities, pasture eDMI was conditioned by supplementation level and not by grazing management, since cows could have harvested higher amounts of pasture according to sward structure (HM), PAT and HA (Baudracco *et al.*, 2010; Chilibroste *et al.*, 2015). Differences in grazing and feeding management between both groups varied along the different seasons of the year, so they will be discussed separately in the next sections.

Autumn to winter

During moments of the year of less pasture growth rate (winter and autumn), grazing management and supplementation level were less contrasting between groups than in those times when pasture growth accelerates (spring and summer). Moreover, both groups achieved worst FME in winter and autumn indicating a disconnection between grazing management (i.e. HA) and supplement level offered. In fact, this situation occurred in a context of high levels of supplementation, although under satisfactory conditions for a high pasture harvest by cows, as grazing access time, HM and HA would allow an intake of 10.5 kg DM/cow per day (Baudracco *et al.*, 2010). Supplementation causes negative associative effects with pasture (Dixon and Stockdale, 1999), affecting rumen environment and digestibility (Bargo *et al.*, 2002; Leddin *et al.*, 2010), while generating metabolic (Allen, 2014) and neuroendocrine signals (Gregorini *et al.*, 2009; Sheahan *et al.*, 2013) that have hypophagic effects. These mechanisms could have an impact on the ingestive behaviour of animals, resulting in less time spent in grazing activity, leading to substitution of pasture by supplement intake as reported by Bargo *et al.* (2002).

Open-sky productive systems are highly influenced by climatic conditions, specially in times where forage growth decreases or stops. In times of rainfalls and soil flooding the inclusion of high amount of supplement in the diet could be a consequence of a stability criterion that attempts to achieve a less fluctuating diet, while protecting pastures from trampling, for greater persistence. In fact, according to the value of the historical median (Instituto Nacional de Investigación Agropecuaria, 2018) autumn and winter of 2016 were particularly rainy seasons, exceeding by 400 mm the rainfall that occurs in the March to August semester. This could be a reason why neither of the two groups was efficient harvesting pasture in winter (HA was almost five times greater than achieved pasture DMI). During autumn 2017, with precipitation levels within normal values, FME was higher than in winter 2016. Additionally, FME differences between groups were higher in autumn than winter, in accordance with the greater differences observed in pasture and conserved forage intake between HPI and LPI.

Spring to summer

In the moments of the year where there was active forage growth and better climatic conditions for intensive pasture management, we recorded the highest contrast in pasture eDMI per cow, supplementation levels and FME between the LPI and HPI groups. Although both groups decreased supplement DMI in spring and summer with respect to winter and autumn, the LPI group only reduced supplement supply by 22%, while the HPI group reduced supplement by 59% in these seasons, even with a lower supplementation base in autumn and winter. This would indicate that pasture substitution by supplement continued to cause low pasture DMI in the LPI group.

A contrasting HM of 2353 *v.* 3037 ± 184 kg DM/ha for the HPI and LPI group during spring, although not significant, could mean that the animals of the LPI group faced a lower quality pasture (Stakelum and Dillon, 2007; Wims *et al.*, 2010), impairing ingestion rate and pasture DMI (Fulkerson and Donaghy, 2001; McEvoy *et al.*, 2009; Mezzalira *et al.*, 2014).

During summer, differences in pasture DMI between groups were even more contrasting than in spring. Annually differences in HA between groups were explained by summer differences in HA between groups. Notwithstanding, the high HA observed in the HPI group was complemented by a key reduction in conserved forage DMI, and a higher time at pasture than in the LPI group, achieving the highest daily pasture DMI and FME of the year. It should be considered that a greater extent of the forage grazed at this season were tropical grass species, which contain lower energetic concentration (NRC, 2001), and require a different grazing management with respect to temperate pastures. In both seasons, HPI group systems made a good pastoral resource exploitation, achieving pasture DMI values close to their potential according to HA, while LPI group systems demonstrated a lack of control over pasture management and its combination with supplementation.

Conclusions

According to this study, although there were higher opportunities to graze in spring and summer, conditions for large amounts of grazed pasture were given in autumn and winter as well. At these latter seasons, differences between groups were less contrasting, meaning that both groups misspent available pasture. Instead, during spring and summer, with similar sward condition (HM) for pasture harvest than LPI, HPI made a tighter management of supplement offered with respect to HA, and gave more PAT, achieving a higher pasture eDMI and therefore a more efficient use of available pastoral resource. The major issue that provoked the low pasture eDMI per cow in the monitored commercial dairy farms, mainly in the LPI group and during winter and autumn seasons, was pasture by supplement substitution effect.

Since the competitiveness of low input cost dairy production systems is generally supported by an efficient use of pasture in the diets, our results reinforce the importance to adjust the supplementation levels according to pasture management, applying supplementation as a complementary tool to balance the diet and not as an isolated food, disconnected from the offered forage.

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Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

Ethics statement

As this study was a monitoring and did not manipulate animals, no ethical approval for animal experimentation was required.

Software and data repository resources

None of the data were deposited in an official repository.

Supplementary material

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