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Self-feeding improved animal performance of calves grazing native grasslands during winter on extensive livestock production systems

El auto-suministro mejoró el desempeño de terneros pastoreando campo natural diferido en invierno en sistemas ganaderos extensivos

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ABSTRACT

Supplementing calves on deferred native grasslands during their first winter, helps overcoming the nutritive deficits which occur during this season. However, the demand of both qualification and availability of labour may restrain its adoption. The objective of this work was to evaluate calves' average daily live weight gain (ADG) and supplemental feed efficiency (SFE) as a response to self-feeding methods. Two experiments (Exp) were carried out: i) Exp A, on sandy soils with Braford calves and, ii) Exp B on basaltic soils with Hereford calves. In each experiment 40 castrated male calves were used and randomly allotted to one of two replicates of these treatments: non-supplemented control (C); everyday restricted supplementation (E); restricted self-fed supplementation delivered two times a week (RSF); *ad libitum* self-fed (ASF). Exp A registered lowest ADG for C (0.155 kg an^{-1} day^{-1}), similar ADG between E and RSF (0.623 kg an^{-1} day^{-1} on average) and highest for ASF (1.135 kg an^{-1} day^{-1}) ($p<0.05$). For Exp B, ADG was affected being C ≤ E ≤ RSF < ASF (0.158, 0.390, 0.588 and 1.319 kg an^{-1} day^{-1}, respectively). SFE values were not different ($p>0.05$) between treatments for Exp A, even though ASF presented a 50% higher SFE (9.4) than RSF (6.2) and E (6.1). SFE was affected ($p<0.05$), being ASF (7.7) < E = RSF (3.9 on average). It is possible to overcome winter live weight losses through the combination of deferred native grasslands and restricted self-feeding.

RESUMEN

La suplementación de terneros en su primer invierno pastoreando campo natural diferido compensa los déficits nutricionales registrados durante esta estación. No obstante, las necesidades de calificación y disponibilidad de mano de obra puede restringir su adopción. El objetivo de este trabajo fue evaluar la ganancia media diaria (GMD) y la eficiencia de uso del suplemento (EUS) como respuesta a métodos de auto-suministro. Se realizaron dos experimentos: i) Exp A, sobre suelos arenosos utilizando terneros Braford y, ii) Exp B, sobre suelos de basalto utilizando terneros Hereford. En cada experimento se utilizaron 40 machos castrados en su primer invierno y fueron asignados al azar a una de las dos repeticiones de estos tratamientos: testigo no suplementado (T); suplementación diaria restringida (DR); suplementados restringidamente dos veces por semana mediante auto-suministro (ASR); suplementados *ad libitum* mediante auto-suministro (ASA). En el Exp A se registró la menor GMD para T (0,155 kg an^{-1} día^{-1}), similares valores entre DR y ASR (promedio 0,623 kg an^{-1} día^{-1}) y la más alta para ASA (1,135 kg an^{-1} día^{-1}) ($p<0{,}05$). Para el Exp B, la GMD fue afectada, siendo T ≤ DR ≤ ASR < ASA (0,158; 0,390; 0,588 and 1,319 kg an^{-1} día^{-1}, respectivamente). EUS no fue afectada en Exp A ($p>0{,}05$), si bien ASA presentó valores 50% superiores que ASR (6,2) y que T (6,1). En el Exp B, EUS fue afectada ($p<0{,}05$), siendo ASR (7,7) < DR = ASR (3,9 promedio). Es posible superar las pérdidas peso mediante una combinación de diferimiento de forraje y auto-suministro restringido.

Palabras clave: Pasturas nativas, suplemento, ganado de carne, suplementación infrecuente, Uruguay.

INTRODUCTION

Livestock production systems have been undergoing several changes in the last years, forcing farmers to become more efficient in order to keep their business profitable (Montossi *et al.*, 2016a). Within a sustainable intensification context, Montossi *et al.* (2016b) proved that overall farm productivity and profitability dramatically rises through an acceleration of the rearing phase of beef production. Supplementing calves during winter on native grasslands is a way to increase animal production (Bailey *et al.*, 2001), because supplemental feed is added to the system during periods of plant dormancy (Pordomingo *et al.*, 1991) and low forage growth rates (Montossi *et al.*, 2016b), which happens during winter in Uruguay.

Despite the benefits of supplementation, an everyday frequency basis for this practice implies higher labour costs (Kunkle *et al.*, 2000) and more complex production system practices. Infrequent supplementation (Moriel *et al.*, 2012) and self-feeding strategies (Muller *et al.*, 1986) are two ways to minimise labour-associated costs. As for infrequent supplementation, Farmer *et al.* (2001) found that even though forage utilisation of dormant tallgrass prairie improved with an increased frequency, no differences were to be expected on animal performance. As for self-feeding, these schemes were generally carried out using intake limiters, such as salt (Muller *et al.*, 1986; Riggs *et al.*, 1953). Other chemical intake limiters, such as ammonium chloride, ammonium sulphate or calcium hydroxide (Schauer *et al.*, 2004), were later considered in order to allow *ad libitum* feeding strategies. Still, another way to allowing *ad libitum* self-fed supplementation may be through the adding of industrial rice by products, specifically given its fibre concentration.

In spite of the fact that self-fed *ad libitum* schemes in young animals, such as creep feeding of nursing calves, may significantly increase average daily gain (ADG) (Faulkner *et al.*, 1994), it is critical to evaluate the supplemental feed efficiency (SFE) of this practice, so as to keep it profitable. Thus, an alternative to self-fed *ad libitum* schemes would be to limit the amount of offered supplement to control SFE, while aiming at moderate ADG.

Therefore, we hypothesised that restricting the offered supplement to beef calves grazing native grasslands through a combined strategy of self-feeding and infrequent supplementation, would result in moderate ADG while achieving efficient SFE ratios, compared with other more labour-intensive or costly options such as daily restricted supply or self-fed *ad libitum* supplementation. The objective of this study was to compare ADG and SFE between different supplementation strategies to evaluate whether restricted and infrequent supplementation combined with a self-feeding supplement delivery method would increase winter calves´ production without increasing SFE.

MATERIALS AND METHODS

Sites and treatments

Two independent experiments were carried out during winter 2014, on two separate experimental sites. The first experiment (Exp A) was carried out at "La Magnolia" Research Station of the National Institute of Agricultural Research (INIA Tacuarembó, Uruguay, S 31° W 55°) and lasted 97 days from 9th July to 14th October. The soils of this research station are acidic and sandy with high potential rooting depth (Hapludalfs). The second experiment (Exp B) was carried out at "Glencoe" Research Station of the National Institute of Agricultural Research (INIA Tacuarembó, Uruguay, S 32° W 57°) and lasted 120 days from 11th June to 9th October. The soil of this research station has a basaltic origin, with high clay content and medium-high potential rooting depth (Hapludolls).

All procedures in these experiments were carried out according to the rules set by the Uruguayan Honorary Animal Ethics Committee (CHEA). Forty Braford calves (179 ± 28 kg live weight; LW) for Exp A and forty Hereford calves (180 ± 9 kg LW) for Exp B were allocated in four experimental groups according to a completely randomised experimental design with two replications, based on their age and LW. In both experiments, the treatments were: 1) "Control" (C; n = 10) in which animals had no access to supplement; 2) "Everyday" (E; n = 10) in which animals were supplemented every day at a 1.2 % LW supplementation rate (Exp A) or 0.8% LW supplementation rate (Exp B); 3) "Restricted self-fed" (RSF; n = 10) in which animals were supplemented at the same daily average rate as E, but distributed two times a week and using self-feeders; 4) "*Ad libitum* self-fed" (ASF) in which animals were supplemented *ad libitum* in self-feeders. The animals were 8 months of age and were all castrated and grazed continuously at a 2.23 calves ha^{-1} stocking rate.

Native grasslands (NG) paddocks underwent an intensive grazing session at the end of the summer, so as to start a forage accumulation from autumn to winter, aiming to minimise the dead forage content on offer. Animals were kept off NG paddocks to allow forage transfer from autumn to the beginning of the winter, where the trials begun.

The supplement used was a totally mixed ration with 9% of rice cull content (fibre). Crude protein content (CP) of the supplement was 14.7%, acid detergent fibre (ADF) 11.99%, dry matter content (DM) 87.88% and metabolizable energy concentration (ME) was 2.56 Mcal kg^{-1}. Both restrictedly and *ad libitum* supplemented animals were group fed using one self-feeder per plot. Offered supplement was weighed before it was dispensed; animals of treatments E and RSF did not leave any residuary supplement, while the residuary supplement for ASF was weighed to estimate its intake.

The quantity of supplement delivered was adjusted for E and RSF every time animals were weighed, according to the supplementation rate of each experiment. All animals had *ad libitum* access to fresh clean water and minerals on each plot. Calves were drenched to control internal parasites at the beginning of the trial and three animals chosen at random from each plot were sampled every 28 days for faecal egg count (FEC) (dosing criterion was FEC ≥ 300 eggs gram^{-1}).

Measurements

At the beginning of the experiments and every 14 days thereafter, herbage mass was measured. These measurements were made by 10 ground level clipped samples with electric scissors of 5 m length x 0.075 width (0.375 m^2) on representative areas of each plot. Plastic bags containing green forage mass were closed immediately after clipping and were opened individually when they had to be weighed, to minimise the possibility of different dehydration grades of each of them in the forage laboratory. Each sample was individually fresh-weighed and then all samples were mixed in one single homogeneous pool per plot. Two subsamples were extracted from this pool, which were then individually fresh-weighed and afterwards dried at 60 °C for 48 hours until a constant weight was reached, to estimate the dry matter (DM) content of both subsamples. Then, using the fresh weights of each sample and the estimated DM content of the two subsamples, average herbage mass ha^{-1} was estimated for each sample.

Sward height was measured using a common ruler, at the same time and place as forage samples were clipped. Fifteen height measurements were taken on the same forage that was later to be clipped, and an additional thirty measurements were taken on other representative areas of the paddocks.

To determine sward botanical composition, two subsamples of the above-mentioned pool were used, which were separated into green and dead material. Each fraction was fresh-weighed and then dried at 60 °C for 48 hours until a constant weight was reached to estimate the dry matter (DM) content of each fraction.

In order to estimate the nutritive value of the sward, similar forage pool subsamples as the above mentioned were generated from each plot. These subsamples were manually ground and then analysed to estimate crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF). CP content was estimated according to AOAC (1990) while NDF and ADF were estimated according to the methodology described by Van Soest (1982). Dry matter digestibility (DMD) was calculated through the following equation (Temel and Pehluvan, 2015):

$$\mathrm{DMD} = 88.9 - (0.779 * \mathrm{ADF}) \tag{1}$$

while metabolizable energy (ME) was calculated by the following equation (ARC, 1980):

$$\mathrm{ME\ (Mcal\ kg^{-1})} = \frac{(4.4 * 0.82 * \mathrm{DMD})}{100} \tag{2}$$

Animals were weighed early in the morning at the beginning of the experiment and every 14 days thereafter to determine LW. Shrunk live weight (SLW) was measured at the beginning and at the end the experimental period (after approximately 16 hours of fasting). Supplemental feed efficiency was calculated as:

$$\mathrm{SFE} = \frac{(\text{Supplemented gain} - \text{Control gain})}{\text{Total supplement intake}} \tag{3}$$

Twice for each experiment, rib eye area (REA), fat thickness (FT) and P8 fat depth (P8) were recorded, according to the ultrasound methodology described by Whittaker *et al.* (1992).

Animal behaviour was recorded once for both experiments on RSF supplement delivery days. It was assessed during daylight hours through four observers, who periodically rotated between treatment groups to avoid an eventual observer bias. These observers registered every 15 minutes the following animal activities: grazing, rumination, resting, and water or supplement consumption. After that, the total amount of time spent at each activity was estimated, to calculate the proportion of time allocated to each activity (Montossi, 1995).

Total and green forage allowance (FA) estimation was calculated by dividing each plot´s herbage mass average by the average live weight of each group of animals.

Statistical analyses

Normality of residuals and homogeneity of variances were verified at the beginning of the statistical analysis. In a complete randomised design with four treatments and two replications per treatment, forage and animal data sets were analysed using mixed models with a repeated measures design. The experimental unit was the group of animals on one hand, and the plot on the other hand, for animal and plant parameters, respectively. Time, treatment and their interaction were considered as fixed effects in the model, and plot was fitted as a random effect. Variance analyses were carried out using Tukey tests ($\alpha = 0.05$). ADG were calculated through simple linear regression (one slope value β of each group of animals as a whole) and then variance-analysed using Tukey tests. SFE and FA were compared using ANOVA. Ultrasound measurements were calculated with final SLW as a co-variable. Animal behaviour was analysed through a Principal Component Analysis partitioned by treatment, which resulted in the first two Principal Components explaining 65% of the variation or more. For all statistical analysis InfoStat software (Di Rienzo *et al.*, 2008) was used.

RESULTS

None of the forage related parameters were affected by treatments in both experiments (Table 1). Average forage mass and height was 1745 kg DM^{-1} and 8.4 cm for Exp A, respectively, while these parameters were 2432 kg DM ha^{-1} and 9.4 cm for Exp B, respectively. Average dead forage content was 61.8% for Exp A and 54.8% for Exp B.

A similar situation was observed for the average nutritive value of forage (Table 2). For Exp A, average forage nutrient content was 57.5%, 9.8%, 40.4%, 72.6% and 1.0 Mcal kg DM^{-1} for DMD, CP, ADF, NDF and ME, respectively. For Exp B, the average nutrient content was 59.0%, 7.2%, 38.5%, 69.4% and 1.4 Mcal kg DM^{-1}, respectively.

The two first Principal Components account for more than 65% of the total variance for both experiments, when analysing animal behaviour (Figure 1). Control animals presented the greatest grazing time in both experiments compared to the rest of the treatments. On the other hand, resting activities and supplement consumption were positively correlated with the ASF group for both experiments.

Table 1. Effect of supplement delivered everyday (E), restricted self-feeding delivered twice a week (RSF) and *ad libitum* self-feeding (ASF) on beef calves grazing native grasslands during winter, on average pasture parameters of Experiments A and B.

Cuadro 1. Efecto del suplemento entregado diariamente (E), auto-suministro restringido entregado dos veces por semana (RSF) y auto-suministro *ad libitum* (ASF) en terneros de razas carniceras pastoreando sobre campo natural durante el invierno, sobre parámetros promedio de las pasturas de los Experimentos A y B.

Exp	Parameter	C	E	RSF	ASF	p	sem
A	Herbage mass (DM ha^{-1})	1772.3	1462.6	1846.0	1899.4	ns	167.8
	Herbage height (cm)	9.1	7.4	8.4	8.7	ns	0.6
	Dead forage content (%)	62.3	63.3	60.4	61.0	ns	3.2
B	Herbage mass (DM ha^{-1})	2241.1	2367.0	2432.2	2688.5	ns	185.0
	Herbage height (cm)	9.0	9.1	9.0	10.5	ns	0.6
	Dead forage content (%)	48.1	52.5	60.7	57.7	ns	2.8

ns: not significant (p >0.05); C: control; DM: dry matter; sem: standard error of the mean.

Table 2. Effect of supplement delivered everyday (E), restricted self-feeding delivered twice a week (RSF) and *ad libitum* self-feeding (ASF) on beef calves grazing native grasslands during winter, on average forage nutritive value of Experiments A and B.

Cuadro 2. Efecto del suplemento entregado diariamente (E), auto-suministro restringido entregado dos veces por semana (RSF) y auto-suministro *ad libitum* (ASF) en terneros de razas carniceras pastoreando sobre campo natural durante el invierno, sobre parámetros promedio del valor nutritivo de las pasturas de los Experimentos A y B.

Exp	Parameter	C	E	RSF	ASF	p	sem
A	DMD (%)	56.8	57.6	58.4	57.0	ns	0.62
	CP (%)	10.0	9.6	10.0	9.5	ns	0.38
	ADF (%)	41.2	40.1	39.2	40.9	ns	0.78
	NDF (%)	74.7	71.9	71.2	72.5	ns	0.78
	ME (Mcal kg DM^{-1})	0.98	0.98	1.00	1.01	ns	0.04
B	DMD (%)	58.8	58.9	58.6	59.5	ns	0.51
	CP (%)	7.4	7.7	6.8	7.0	ns	0.42
	ADF (%)	38.6	38.6	38.9	37.7	ns	0.66
	NDF (%)	69.9	68.8	69.4	69.3	ns	0.63
	ME (Mcal kg DM^{-1})	1.40	1.36	1.35	1.37	ns	0.03

C: control; DMD: dry matter digestibility; CP: crude protein; ADF: acid detergent fibre; NDF: neutral detergent fibre; ME: metabolizable energy; DM: dry matter; ns: not significant (p >0.05); sem: standard error of the mean.

The main animal parameters (ADG and LW) were affected by treatments in both experiments (Table 3). ADG was highest for ASF and lowest for C, and in intermediate position E and RSF, which in turn did not differ between each other, in both experiments. Furthermore, final LW followed the same trend for both experiments, and *in vivo* carcass quality measurements were not affected by treatments in either case.

Both experiments presented similar LW evolution trends (Figure 2). In the case of Exp A, for ASF, LW value separates from the rest of the treatments on 25th September and keeps the statistical differences until the

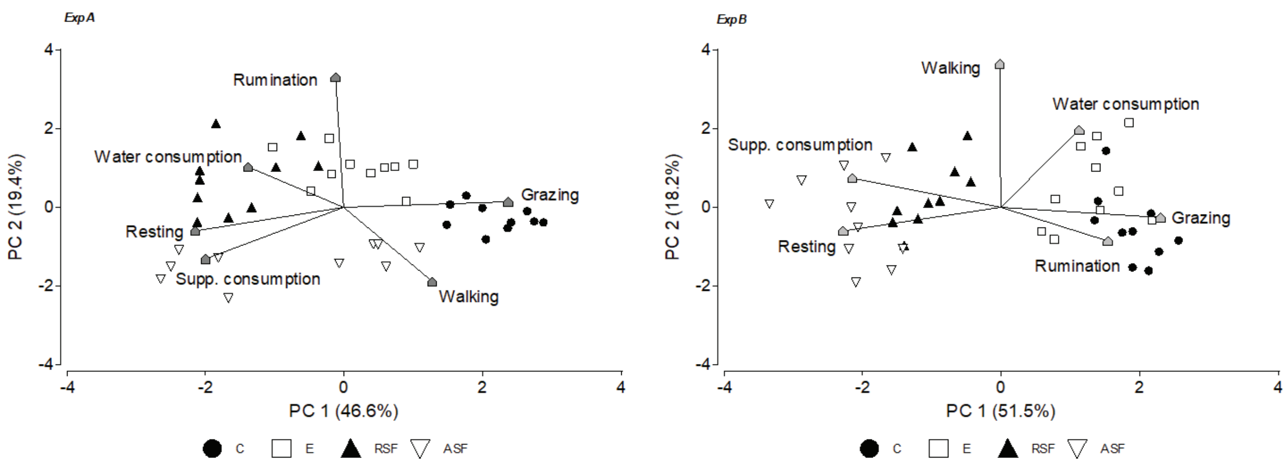

Figure. 1. Ordination diagram showing results of principal components analysis of relationships among animal behaviour parameters and treatments. (C: control, E: supplement delivered every day, RSF: restricted self-feeding delivered twice a week, ASF: *ad libitum* self-feeding).

Figura 1. Diagrama con resultados del análisis de componentes principales de las relaciones entre parámetros de comportamiento animal y tratamientos. (C: control, E: suplementado diariamente, RSF: auto-suministro restringida entregada dos veces por semana, ASF: auto-suministro *ad libitum*).

Table 3. Effect of supplement delivered everyday (E), restricted self-feeding delivered twice a week (RSF) and *ad libitum* self-feeding (ASF) on beef breed calves grazing native grasslands during winter, on animal performance parameters of Experiments A and B.

Cuadro 3. Efecto del suplemento entregado diariamente (E), auto-suministro restringido entregado dos veces por semana (RSF) y auto-suministro *ad libitum* (ASF) en terneros de razas carniceras pastoreando sobre campo natural durante el invierno, sobre desempeño animal de los Experimentos A y B.

Exp	Parameter	C		E		RSF		ASF		p	sem
A	ADG (kg an^{-1} day^{-1})	0.155	c	0.625	b	0.620	b	1.135	a	**	0.05
	LW (kg)	198.4	b	234.5	b	231.0	b	281.1	a	**	10.7
	REA (cm^2)	32.2		32.1		34.1		32.8		ns	1.41
	FT (mm)	1.9		2.1		2.1		2.2		ns	0.12
	P8 (mm)	2.3		2.2		2.3		2.7		ns	0.17
B	ADG (kg an^{-1} day^{-1})	0.158	c	0.390	bc	0.588	b	1.319	a	**	0.05
	LW (kg)	191.0	c	230.7	b	242.3	b	315.9	a	**	5.97
	REA (cm^2)	28.3		28.7		26.7		29.8		ns	0.86
	FT (mm)	1.8		1.8		1.7		2.4		ns	0.65
	P8 (mm)	2.1		1.9		1.8		2.6		ns	0.14

Means within the same row with common letters are not significantly different (** = p <0.01); ns: not significant (p >0.05); C: control; ADG: average daily gain; an: animal; LW: live weight; REA: rib eye area; FT: fat thickness; P8: fat depth; sem: standard error of the mean.

end of the experimental period (p <0.05). On the other hand, E and RSF present similar LW throughout the entire duration of the experiment (p >0.05). As for Exp B, as observed in Exp A, E and RSF never present differences between average LW throughout the experimental period (p >0.05). Significant interactions of treatment x date were observed from 23rd July until the end of the trial (p <0.05). In this experiment, ASF begins to be different from C and E/RSF in the fourth measurement, differences that last until the end of the trial (p <0.05).

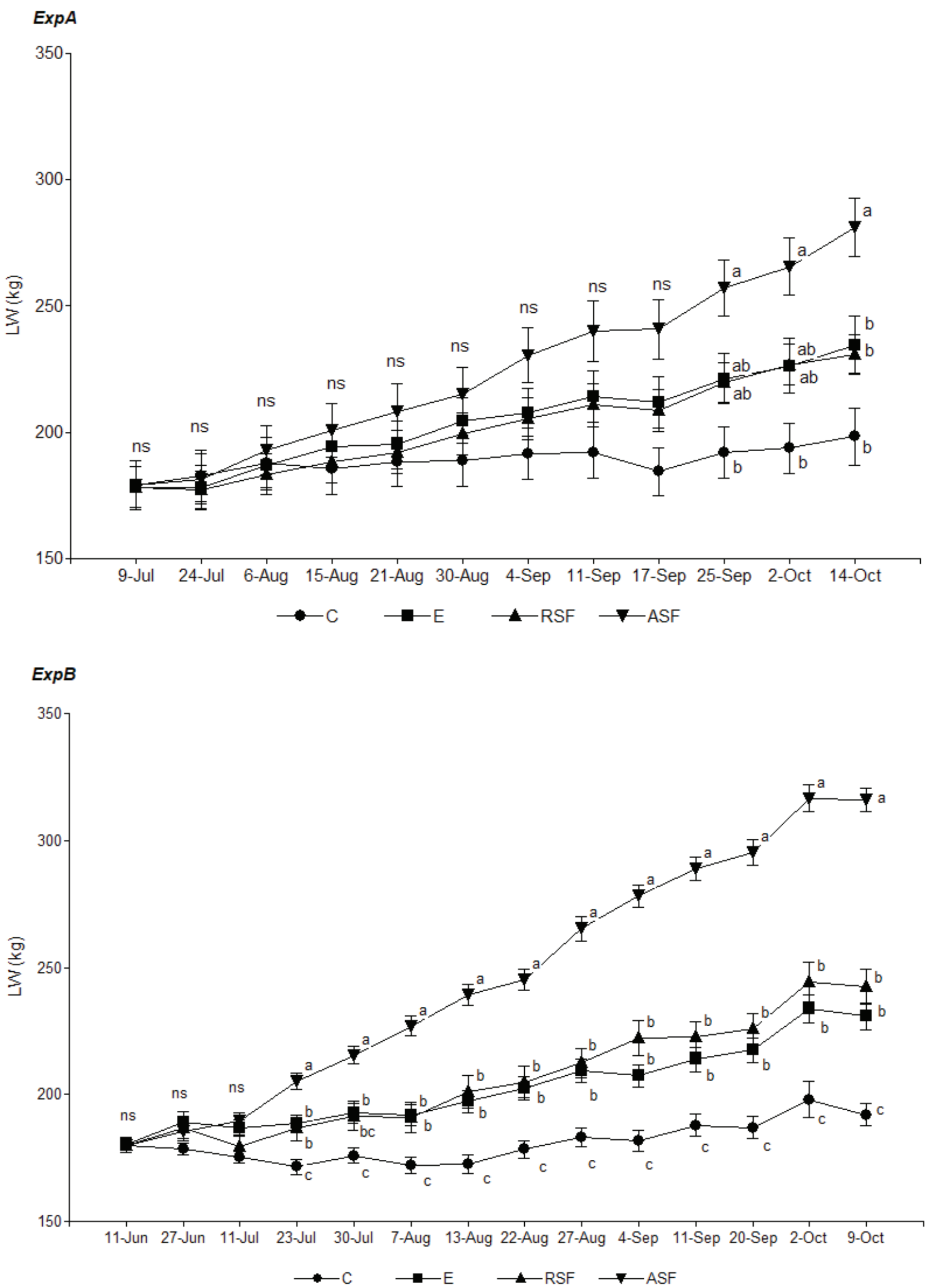

Figure 2. Live weight evolution of non-supplemented beef calves (C), supplemented daily (E), restrictedly self-fed twice a week (RSF) and *ad libitum* self-fed (ASF), grazing native grasslands during winter for Experiments A and B. (Common letters within the same date are not significantly different; p >0.05).

Figura 2. Evolución del peso vivo de terneros no suplementados (C), suplementados diariamente (E), auto-suministrados restringidamente dos veces por semana (RSF) y auto-suministrados *ad libitum* (ASF), pastoreando campo natural durante el invierno para los Experimentos A y B. (letras comunes dentro de la misma fecha no son significantemente diferentes; p >0,05).

Supplemental feed efficiency (SFE) is presented in Figure 3. In the case of Exp A, the high variability observed in supplement consumption did not allow differences to be detected between treatments (p >0.05), even though ASF (9.4) presented 50% higher SFE than RSF (6.2) and E (6.1). As for Exp B, differences were found between ASF (7.7) and the restricted supplementation treatments (E and RSF) which presented similar SFE between each other, being 3.9 on average.

No differences were found between average forage allowances in either of the two experiments (Table 4). For Exp A, average FA was 3.9 and 1.6 kg DM kg LW^{-1}, for total and green (dry matter; DM) FA, respectively. In the case of Exp B, averages were 5.5 and 2.7 kg DM kg LW^{-1}, for total and green DM FA, respectively, and there were no differences between treatments.

DISCUSSION

The use of a restricted self-feeding strategy combined with a twice a week basis supplement delivery resulted in moderate average daily live weight gains while controlling supplemental feed efficiency. Restricted self-fed animals presented no differences on any of the animal performance variables when compared to daily supplemented animals. On the other hand, *ad libitum* self-fed animals presented the greatest animal performance variables but were unable to control their supplemental feed efficiency (Exp B).

Within a certain range, dry matter intake increases when animals are faced with higher sward heights and herbage masses (Da Trindade *et al.*, 2016). A sward structure that allows animals to dedicate less time to

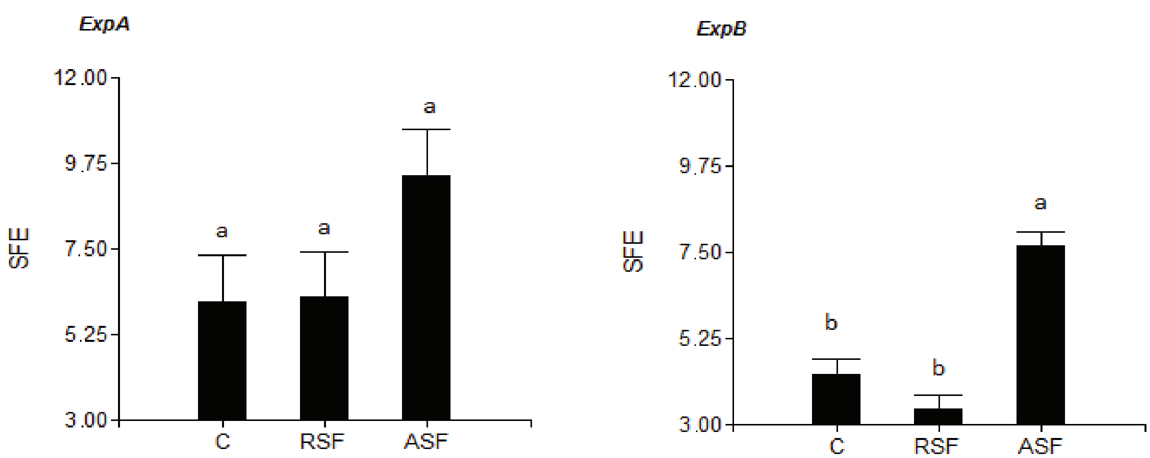

Figure 3. Effect of supplement delivered everyday (E), restricted self-feeding delivered twice a week (RSF) and *ad libitum* self-feeding (ASF) on beef calves grazing native grasslands during winter, on supplemental feed efficiency of Experiments A and B. (C: control, SFE: supplemental feed efficiency).

Figura 3. Efecto del suplemento entregado diariamente (E), auto-suministrados restringidamente dos veces por semana (RSF) y auto-suministrados *ad libitum* (ASF) sobre terneros de razas carniceras pastoreando campo natural durante el invierno, sobre la eficiencia del uso del suplemento de los Experimentos A y B. (C: control, SFE: eficiencia de suministro suplementario).

Table 4. Effects of supplement delivered everyday (E), restricted self-feeding delivered twice a week (RSF) and *ad libitum* self-feeding (ASF) on beef breed calves grazing native grasslands during winter, on average forage allowance.

Cuadro 4. Efecto del suplemento entregado diariamente (E), auto-suministro restringido entregado dos veces por semana (RSF) y auto-suministro *ad libitum* (ASF) en terneros de razas carniceras pastoreando sobre campo natural durante el invierno, sobre la asignación de forraje de los Experimentos A y B.

Exp	Parameter	C	E	RSF	ASF	p	sem
A	Total DM FA (kg DM kg LW^{-1})	4.2	3.2	4.2	4.0	ns	0.41
	Total GDM FA (kg DM kg LW^{-1})	1.8	1.2	1.8	1.6	ns	0.16
B	Total DM FA (kg DM kg LW^{-1})	5.9	4.9	5.9	5.1	ns	0.32
	Total GDM FA (kg DM kg LW^{-1})	3.2	2.6	2.6	2.3	ns	0.23

ns: not significant (p >0.05); C: control; DM: dry matter; GDM: green dry matter; FA: forage allowance; LW: live weight; sem: standard error of the mean.

grazing activities implies a herbage mass of 1400-2000 kg DM ha^{-1} and a sward height of 9-13 cm (Da Trindade *et al.*, 2012). In this case, all treatments of both experiments presented an average herbage mass within these ranges (Table 1). Nonetheless, sward height was bellow or barely around 9 cm for all treatments and both experiments (Table 1), suggesting that it is possible that animals may have had forage intake constraints in some circumstances along the experiments. Therefore, non-supplemented animals which depended entirely from pasture to increase their LW, experienced forage intake limitations which in turn was reflected in lower ADG.

Grassland plant communities are inherently heterogeneous because of plant species diversity (Toombs *et al.*, 2010), giving animals the chance to exercise selectivity. Diet quality is determinant of energy intake (Carvalho *et al.*, 2015), therefore selecting the highest quality diet is of utmost importance to increase ADG (Boval *et al.*, 2015). In both experiments, dead forage content was not affected by treatments (Table 1), so it can be assumed that all animals had the same opportunity to select green forage (leaves in particular) within each experiment. In addition, the nutritive value of forage was not affected by treatments either (Table 2), which means that all treatments of each experiment had similar nutritive offer from forage. Based on this, it is assumed that selectivity did not play a predominant role in the explanation of ADG, and therefore animal performance differences were mostly explained by supplementation consumption rather than by differences in quantity and quality of forage, for both experiments.

The high dead forage content of more than 25% (Thompson and Poppi, 1990) resulted in high NDF contents and low DMD (Table 2), therefore affecting the nutritive value of the forage. In addition, as discussed before, sward height might have been limiting for all treatments of both experiments to achieve moderate to high ADG in calves during winter. In order to compensate for the reduced intake rates caused by constraints of canopy structure, grazing time allocation may increase as a compensatory behaviour mechanism (Glienke *et al.*, 2016). Besides, according to Carvalho *et al.* (2015), when diet quality is low, and animals have little opportunity to change it through selectivity, grazing time should be the main variable explaining variation in ADG. In both experiments, grazing activities were highly correlated with non-supplemented animals (Figure 1), even though this increased grazing time allocation was not enough to compensate for the lack of nutrients that would have allowed them to register similar ADG as the supplemented treatments. When supplementary feeds are eaten by cattle, their forage dry matter consumption is usually reduced, although total dry matter intake is increased (Holmes, 1987). In this case, since control animals grazed more time that all supplemented treatments, we can conclude that the latter presented a certain amount of forage substitution for supplement consumption.

As Poppi and McLennan (1995) indicated, live weight gain relies mostly on protein and energy supply. For supplemented animals, these nutrients came from both pasture and supplement. Based on nutrient requirements (NRC, 2016), supplemented animals from both experiments presented a positive or nearly positive ME and CP balances, but specifically, ASF animals from both experiments presented the greatest surpluses of these nutrients to achieve LW gains higher than 1 kg animal^{-1} day^{-1}. This implies that from a nutrition balance stand point, ASF animals were highly inefficient, which was corroborated by differences between SFE of restricted treatments vs. the *ad libitum* treatment in the case of Exp B (Figure 3). Furthermore, in the case of ASF, a deviation was observed from the theoretical ADG expected from the sward conditions and supplement supply (NRC, 2016), to the actually observed ADG. Moore *et al.* (1999) mentioned that the deviations between expected and observed animal performance are usually explained by associative effects of supplement upon voluntary intake and available energy concentration of the total diet. Consequently, the identified nutrition inefficiencies of both protein and energy for ASF animals were caused by these associative effects.

Animal supplementation on native grasslands allows nutrient input to increase, having a positive effect on ADG (Boval *et al.*, 2015). In fact, Beck *et al.* (2013) carried out a literature review in which low quality forages were considered, and they concluded that supplementation on warm season forages significantly increased ADG compared to non-supplemented schemes. In the current study, both experiments registered a positive effect of supplementation on ADG, when comparing treatments with restricted supplementation rates (E and RSF; Table 3 and Figure 2). Drewnoski *et al.* (2011) carried out an experiment in which steers were supplemented with an energy-protein concentrate, with their forage basis being medium quality hay. These authors did not find any differences in animal performance between a daily frequency and a two-times a week frequency of supplement allocation. In both Exp A and B, similar results were found for E and RFS treatments, given that ADG did not differ between them This suggests that it is possible to reduce supplement frequency from a daily basis to a twice a week basis and still achieve similar animal performance.

According to Yambayamba and Price (1991), restricting the energy content of the diet prolongs skeletal and muscle growth while delaying fat deposition. In our experiments, neither of them presented differences between treatments for REA, FT and P8 (Table 3), even though the offered energy of the diet was 3.5 and

2.5 times greater for ASF when compared to C (NRC, 2016). It is possible that the experimental period duration was not long enough for these differences to be significant, at least considering the most contrasting treatments in terms of energy intake (ASF vs. C). On the other hand, Vaage *et al.* (1998) state that an animal´s potential for lean tissue growth will influence the energy requirements of the finishing diet, and Neel *et al.* (2007) point out the importance of animal performance during the rearing phase on the subsequent *post mortem* production. According to Yambayamba and Price (1991), restricted ADG for up to 4 months can be fully recovered in terms of both live weight and body composition at no extra feed cost, if subsequently offered adequate nutrition. Given that both experiments lasted less than 4 months, it may be expected that subsequent ADG and slaughter weight may have been similar on average between treatments once the animals entered the finishing phase no carry-over effects during the finishing phase were expected after these experiments were over.

As Bowman and Sowell (1997) stated, changes in trough space may affect competitiveness between animals and thus variation in supplementation consumption. For Exp A, the coefficient of variation of final LW was calculated as a mean to estimate variability, being 13, 11, 18 and 18% for C, E, RSF and ASF, respectively. The highest variability registered for animals that were supplemented with a self-feeding strategy (same trough space) may have reflected a high consumption variability on their final LW. This probably prevented differences to be detected between SFE (Figure 3), even though for ASF, this coefficient was 50% higher than restricted treatments. Considering this, probably a higher number of replicates would have allowed us to detect them. On the other hand, according to NRC (2016), animals from Exp A and treatment ASF presented a greater protein surplus than that of energy, suggesting that poor SFE of this treatment was explained mostly by an excessive protein supply rather than that of energy.

Boval *et al.* (2015) indicated that native grasslands bear great potential to generate satisfactory ADG, especially associated to high dry mater consumption. Forage consumption is positively associated with forage allowance (Da Trindade *et al.*, 2016), and when forage allowances are low, animals extend the time allocated to grazing activities, as a compensatory mechanism (Oltjen and Gunter, 2015), which in this case took place for C for both experiments. On the other hand, McCartor and Rouquette (1977), followed by Sollenberger *et al.* (2005) mention a critical FA of 3.31 kg DM kg LW^{-1} over which, calves grazing a perennial grass are not expected to increase their LW. Although total FA for both experiments were greater than this figure, this was not the case for green FA. Nevertheless, according to Thompson and Poppi (1990) in swards with more than 25% of dead forage content as observed in this study, green FA is a better animal performance predictor than total FA. Therefore, we assume that green FA of these experiments (Table 4) were limiting to allow high forage intake, which was ultimately corroborated by the non-supplemented animal´s performance.

CONCLUSIONS

Under the conditions of these experiments, calves grazing on native grasslands without supplementation experienced forage intake limitations which in turn was reflected in lower ADG. Nonetheless, the utilisation of deferred native grasslands was enough to overcome the expected LW loses. To achieve moderate to high ADG, animal performance differences were mostly explained by the incorporation of supplementation rather than by differences observed in both swards. Increased grazing time allocation for non-supplemented animals was not sufficient to compensate for the lack of nutrients that would have allowed them to register similar animal performances as the supplemented treatments. From a nutrition balance point of view, ASF animals were highly inefficient, and this was corroborated by SFE values. The deviations between observed and expected performance for ASF were influenced by the associative effects of supplement upon voluntary intake and available energy concentration of the total diet. It is possible to reduce supplement allocation, from a daily basis to a twice a week basis, and still register similar animal performance. Even though no differences were found in SFE in Exp A due to LW variability, differences were detected in Exp B, which are mostly explained by protein surplus for animals supplemented *ad libitum* (ASF). FA was low enough to negatively affect dry matter intake for both experiments, especially for non-supplemented animals.

Considering Uruguayan extensive livestock production systems conditions and within a sustainable intensification context, it is possible to improve beef calf winter rearing, through the use of deferred native grasslands and restricted self-feeding, resulting in moderate live weight gains and an efficient use of the supplement.

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