Estimation of Energy Expenditure in Breeding Cows Grazing Rangelands with Different Herbage Allowance

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**Estimation of energy expenditure in breeding cows grazing rangelands
with different herbage allowance**

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Abstract

The energy partitioning between total heat production (HP) and retained energy (RE) on the efficiency of energy use was evaluated throughout the annual production cycle (gestation-lactation) of 46 multiparous beef cows grazing on two herbage allowances (HA) of Campos grassland (4 vs. 7 kg dry matter/kg body weight; BW; LO vs. HI). Total RE was greater ($P < 0.01$) for HI than LO cows and presented minimum values during early gestation and maximum values during early lactation associated to the greater ($P = 0.02$) RE-milk in the former ones. Whole-animal HP, estimated by the heart rate-O₂ pulse technique, and cow metabolized energy (ME) intake did not differ between HA treatments, but relative to $BW^{0.75}$, HP was greater ($P = 0.04$) for LO than HI cows. Total HP and ME intake were minimum in gestation and maximum in early lactation and ME intake was greater during early lactation for HI than LO cows, and per unit of $BW^{0.75}$, tended ($P < 0.10$) to be less for HI than LO cows in winter. The energy efficiency of the annual cycle was not affected by treatments (0.19 vs. 0.12 ± 0.02 for HI and LO respectively; $P > 0.10$) and there were no differences between treatments in terms of grams of calf per MJ of ME intake ($P > 0.10$). Management of grazing intensity of *Campos* grasslands with high herbage allowance improved energy balance of the beef cow-calf system through partitioning of cow ME intake towards RE instead of maintenance.

Keywords energy efficiency, beef cows-calf systems, grazing

Introduction

Campos region is the largest ecological unit of native grasslands in South America (FAO, 2005) where grassland-based livestock production is one of the most

important agricultural activities of the region, having a significant contribution to the world beef meat industry (FAOSTAT, 2017). Cow-calf operations are often conducted in extensive grazing production systems in which nutrient availability - biomass production and pasture chemical composition - fluctuates according with seasonal changes in rainfall and temperature (Berretta et al., 2000). This variation throughout the year affects, among other factors, affects beef cow energy intake (Aharoni et al. 2013) and maintenance requirements (Brosh, 2007). Particularly, in winter and early spring when forage availability and production are low and beef cow energy requirements rise due to gestation and early lactation, a negative energy balance is established (Laporta et al., 2014). This negative energy balance is reflected in low body condition score (BCS) at calving and breeding season (Soca et al., 2013a; Do Carmo et al., 2016) and determines extended postpartum anestrus, early embryonic death, and reduced pregnancy and weaning rates, explaining reduced reproductive and productive responses (Hess et al., 2005; Soca et al., 2014).

Beef cow-calf systems are long-term energetically inefficient as they use 70-75% of the energy intake for animal maintenance (Ferrell and Jenkins, 1985; Montañó-Bermudez et al.,1990). The partition of energy between maintenance and production is associated with energy balance (Dickerson, 1978) and when it favors production and reproduction, results in a greater productive efficiency of grazing cow-calf systems (Soca et al., 2013b; Do Carmo et al., 2016). Several factors affect the cost of maintenance, some inherent to animal characteristics such as genotype, physiological stage, BCS and body composition, and others related to external conditions such as climate, pastures chemical composition and grazing activity (NASEM, 2016). The

control of energy costs for maintenance has a direct impact on the improvement of feed efficiency as well as environmental sustainability in beef cow-calf operations.

Reducing grazing intensity of native pastures, through increased herbage allowance (HA), increased forage mass, height and growth of native pastures in *Campos*, allowing maintenance of stocking rate and increasing cow energy intake, body weight (BW), BCS, and kilograms of calf weaned of cow-calf systems when compared with low HA (Do Carmo et al., 2018). Also, retained energy (gestation, milk, BW, BCS) as a proportion of the total energy intake in cows grazing high HA increased, thus, a dilution of the energy cost of maintenance was expected, which improved biological efficiency (Do Carmo et al., 2018). In addition, an increase in HA of native grasslands, affected gastrointestinal tract organ mass, cellularity, or gene expression of mitochondrial proteins which could be related with regulation of energy utilization and efficiency (Casal et al., 2014). In addition, herbage mass and height affected animal behavior and thus, energy cost of grazing in steers grazing cultivated pastures (Di Marco et al., 1996). Previous work in beef cows reported that both, average daily energy expenditure and metabolized energy (ME) intake, during the annual cycle of gestation-lactation was greater for beef cows grazing at low vs. high stocking rate (Brosh et al., 2006; Aharoni et al., 2004).

In order to estimate correctly energy requirements of breeding cows on grazing conditions more information on energy expenditure and efficiency of breeding cows throughout their annual production cycle as well as of the result of their grazing management is needed (Brosh, 2007; NASEM, 2016). Our hypothesis was that the greater production efficiency of beef cows grazing high-HA is associated not only to increased energy intake but also to decreased energy maintenance requirements,

especially during winter gestation when forage mass and height decreased when compared with cows grazing low-HA. Therefore, the objective of the present study was to evaluate the effect of grazing intensity of *Campos* grassland, through management of HA, on energy partitioning between total heat production (HP) and retained energy (RE) and on the efficiency of energy use during the annual production cycle (gestation-lactation) of beef cows.

Material and methods

Experimental site

The experiment was conducted on 95 ha of *Campos* grassland located at the Experimental Station Bernardo Rosengurt (School of Agronomy, Universidad de la República, Uruguay, 32°S, 54°W) and lasted from March 2017 to May 2018. Average annual rainfall is almost 1200 mm, and the climate type is classified as Cfa (subtropical, humid, without dry season, where mean temperature in the coldest month is between –3 and 18°C and the warmest is above 22°C) according to Köppen (Panario and Bidegain, 1997). Native pastures were dominated by summer-growing C4 grasses (*Poaceae*), with few C3 grasses associated with the winter cycle. The main for families included *Asteraceae*, *Fabaceae*, *Rubiaceae* and *Umbelliferae*, similar to *Campos* grassland botanical composition (Altesor et al., 1998).

Animals and experimental design

Forty-six multiparous pregnant beef cows of 5 years old (Hereford, Angus, and crossbred; average calving date 11/02/17 ± 13 days) were used in a randomized block design with two blocks (block 1: sandy loam soil, 59 ha and block 2: clay loam soil, 47 ha) and four plots in each block into which two treatments of HA (high and low; HI and

LO) were allocated ($n = 23$ per HA). The HA, defined as the ratio between forage mass and stocking rate (kg of dry matter (DM) per kg of BW; Sollenberger et al., 2005), represented 8 and 5 kg DM/kg BW of annual mean (for HI and LO, respectively) and varied with season of year (Table 1). Chemical composition for different herbage allowance treatments did not differ and average 89%, 7.5% and 35% for OM, CP, and ADF, respectively. Herbage mass (kg DM/ha) was estimated monthly by the comparative yield method (Haydock & Shaw, 1975). A continuous stocking method was applied throughout the year, and HA in each plot was adjusted monthly by the ‘put-and-take method’ (Mott, 1960). Experimental cows were maintained in the same plot throughout the experiment, and ‘put-and-take’ cows were added or removed on the basis of herbage mass available to adjust forage allowance and thus, stocking rate. Cows did not receive any additional feed throughout the experiment except during the first 20 d of the breeding season during which cows were supplemented with 2 kg/cow on a fresh basis of rice middling (*Oryza sativa*; 86.5% DM, 13.5% CP, 44% NDF, and 13.5% ether extract) and were suckling restricted for 14 d (for details see Do Carmo et al., 2018). Cows grazed on the same HA (HI or LO) from May 2016.

Data and sample collection

Cows’ BW and BCS (scale 1 to 8; Vizcarra et al., 1986) were determined every month by the same observer throughout the experiment. Calf weight was determined at birth and monthly until weaning (05/02/2018; 181 ± 13 days of age). Milk yield and composition were individually measured at 50 and 180 ± 13 days of lactation by machine-milking (Quintans et al., 2010) and milk samples were collected and

subsequently analyzed for fat, protein and lactose by a milk analyzer mid-infrared spectrophotometry (NIRS, Milko-Scan, Fross Electric, Hillerød, Denmark).

Heat production measurements

At the end of the fall (second third of gestation; -145 ± 4 days relative to calving), end of the winter (last third of gestation; -75 ± 4 days relative to calving), mid-spring (start of breeding season and lactation; $+50 \pm 4$ days relative to calving) and end of summer (breeding season and lactation; $+175 \pm 4$ days relative to calving) heat production (HP) was determined individually using the heart rate (HR) - oxygen (O_2) pulse technique (O_2P) (Brosh et al., 1998). The HR- O_2P technique which was validated to estimate HP for different ruminant species, diets and environmental conditions (Brosh, 2007) and recently used for measuring HP in grazing dairy cows (Jasinsky et al., 2019; Talmon et al., 2020). This technique is based on the indirect estimation of HP by O_2 consumption (VO_2) measurement calculated as $VO_2 = HR \times O_2P$ where O_2P is the amount of O_2 consumed per heartbeat.

Heart rate (HR; beats/min) was measured continuously for 4 d per animal using HR monitors (Polar RCX3, Electro Oy, Kempele, Finland) with a transmitter Polar WearLink® (Polar Electro Oy) and a data logger programmed to record HR at 5 s intervals. The devices were attached to the thorax behind the forelegs by means of a specifically designed elastic belt. To calculate the O_2P (mL O_2 /beat per kg $BW^{0.75}$), in a short-term interval (10 to 15 min), the HR and O_2 consumption (mL O_2 /kg $BW^{0.75}$ per h) were measured simultaneously, at 1 s intervals, in each cow. Oxygen consumption was measured using a facemask open-circuit respiratory system (Fedak et al., 1981), with a paramagnetic oxygen analyzer (SERVOPRO 1440, Crowborough, East Sussex, United

Kingdom). The O₂P was measured immediately after the HR measurement period (2 days between 06:00 and 15:00 h). The accuracy of the system was checked gravimetrically by nitrogen injection (N₂ recovery) into the facemask (McLean and Tobin, 1990); N₂ recovery testing was performed at least three times in each day of measurement to confirm the entire system calibration and averaged 0.86±0.02 along the experiment.

Daily average HP and HP throughout the day were quantified from the individual HR, O₂P and 20.47 kJ/L constant of O₂ consumed (Nicol and Young, 1990) according to the following equations (Brosh, 2007):

Daily HP (MJ / cow per day) = specific HP (kJ kgBW^{0.75}/d) x BW^{0.75} (kg) / 1000; where specific HP (kJ/kg BW^{0.75} per day) = HP (beats/min) x O₂P (mL/beats per kg BW^{0.75}) x (20.47 kJ/L O₂ consumed/1000) x 60 x 24.

During second third of gestation (-145 ± 4 days relative to calving; end of fall) and last third of gestation (-75 ± 4 days relative to calving; end of winter) the mean temperature and humidity index was 15.0 ± 2.2 °C, 83.4 ± 6.5 % and 15.8 ± 2.8 °C, 78.6 ± 10.9 % respectively. At the start of breeding season and lactation (+50 ± 4 days relative to calving; mid-spring) and breeding season and lactation (+175 ± 4 days relative to calving; end of summer) the mean temperature and humidity index was 25.7 ± 3.6 °C, 58.4 ± 10.7 % and 19.2 ± 2.3 °C, 76.31 ± 10.2 % respectively. Thus, during spring and summer measurements (+50 and +175 days) if corresponded, O₂P was corrected for the effect of temperature humidity index (THI) on O₂P (Aharoni et al., 2003).

Calculations and statistical analyses

Data from -14 to 14 days around HP measurements were used for energy balance calculation. Retained energy for gestation (fetus + gravid uterus; RE-gest) was estimated from calf birth weight and days of gestation (NASEM, 2016) while RE for lactation (RE-milk) was estimated from milk yield and composition using the coefficients of 38.5, 23.8, and 17.5 MJ/kg of fat, protein, and lactose, respectively. The RE in body reserves (RE-tissue) was estimated from the changes in BW and BCS (NASEM, 2016). Total RE was calculated as sum of RE-gest or RE-milk and RE-tissue. Metabolize energy (ME) intake was estimated as the sum of total HP and total RE and individual gross energy efficiency was calculated as total RE divided by ME intake.

Data were analyzed using the SAS Systems program (SAS® University Edition, SAS Institute, Inc., Cary, NC, USA) using a mixed model with a repeated measure analysis using the MIXED procedure. The model included HA (HI vs. LO), measurement period (-145, -75, +50 vs. +175 days relative to calving) and their interaction as fixed effects, block, plot within block and cow as random effects and calving date as a covariate. Calf birth weight and cow average milk yield and composition were analyzed with a model that included only HA as fixed effect. The UNIVARIATE procedure was used to identify outliers and verify normality of residuals. The relationships between the different variables were studied through correlation and regression analysis. For all variables, mean separation was performed using Tukey test ($\alpha=0.05$). Pearson correlation coefficients to describe relationships between variables were estimated using the CORR procedure. Results are presented as least square means $\pm$ pooled S.E.

Results

Productive responses and energy partitioning during the gestation-lactation cycle

During the annual cycle, forage mass and height differed between HA treatments (2532 vs. 1790 ± 237 kg DM/ha; $P = 0.03$ and 6.5 vs. 4.4 ± 0.5 cm; $P = 0.04$ for HI and LO respectively) and between seasons (Table 1) with lower values of forage mass for winter and spring. In accordance with herbage allowance, cow BW and BCS were low during winter and increased during spring and summer ($P < 0.01$; Figure 1A-B) and while BW tended ($P = 0.08$) to be greater for HI than LO cows, BCS did not differ between HA treatments (Table 2). However, BW was greater ($P < 0.05$) for HI than LO cows on summer.

Calf birth and weaning weight did not differ between HA treatments (Table 2) and cow milk production although did not differ between HA treatments ($P = 0.69$; Table 2), decreased ($P < 0.01$) from 50 to 180 days (6.9 vs. 4.5 ± 0.3 kg). Milk fat and lactose contents decreased ($P \leq 0.05$) from 50 to 180 days (3.3 vs. 2.6 ± 0.2 and 5.0 vs. 4.4 ± 0.2 , respectively). In addition, milk protein percentage tended ($P = 0.09$) to be less in HI than LO cows while milk fat percentage was greater ($P = 0.03$) for HI than for LO at early lactation (day 50 relative to calving, spring; 3.6 vs. 2.9 ± 0.2).

Total RE was greater ($P < 0.01$) for HI than LO cows and was affected by days relative to calving ($P < 0.01$), with minimum values during early gestation in fall (-145 ± 4 days relative to calving) and maximum values during early lactation in spring (50 days relative to calving) (Table 2; Figure 2A). However, total RE tended ($P = 0.07$) to be affected by the interaction between HA and days as there were no differences between HA treatments during gestation (fall-winter) but it was greater ($P < 0.05$)

during lactation (spring-summer) for HI than LO cows associated to their greater ($P = 0.02$) RE-milk (Table 2; Figure 2A).

Whole-animal HP (MJ/d) and cow ME intake (MJ/d) did not differ between HA treatments and were affected by days relative to calving as they were minimum in gestation (fall-winter) and maximum in early lactation (spring) (Table 2; Figure 2B). However, ME intake was affected by the interaction between HA and days relative to calving ($P = 0.04$) as differences during early lactation (spring) were more evident for HI than LO cows (Figure 2C).

Energy partitioning during the gestation-lactation cycle per unit of metabolic body weight

Heart rate was not affected by HA and increased ($P < 0.01$) during late gestation in winter (at -75 days) and early lactation in spring (at +50 days). Nevertheless, O_2P was lower ($P < 0.01$) for HI than LO cows (Table 3) and decreased ($P < 0.01$) during late gestation in winter (at -75 days) when compared with other periods evaluated. When expressed in terms of metabolic BW (kJ/kg BW^{0.75} per day), total RE tended to be greater ($P = 0.06$) for HI than LO cows, was affected by days relative to calving ($P < 0.01$) and tended ($P = 0.06$) to be affected by the interaction between HA and days as it did not differ between HA treatments during gestation (fall-winter) but were greater ($P < 0.05$) during lactation (spring-summer) for HI than LO cows (Table 3; Figure 3A). Heat production per unit of BW^{0.75} was greater ($P = 0.04$) for LO than HI cows (Table 3) and decreased ($P < 0.05$) in winter, especially for cows grazing HI-HA (Figure 3B). In addition, ME intake (kJ/kg BW^{0.75} per day) did not differ between HA treatments and was affected by days relative to calving as they were minimum in gestation (fall-winter)

and maximum in early lactation (spring) (Table 3; Figure 3C). However, ME intake tended ($P < 0.10$) to be less in winter and greater in spring for HI than LO cows.

Energy efficiency during the gestation-lactation cycle

Energy efficiency for the gestation-lactation cycle evaluated (320 days), calculated as the relation between the total RE and ME intake, tended to be greater ($P < 0.10$) for HI than LO-HA (0.19 vs. 0.12 ± 0.02). However, biological efficiency did not differ between HA when estimated as either grams of calf weaned, per MJ of ME intake (6.8 vs. 7.6 ± 0.6 g/MJ for HI and LO, respectively) or grams of calf produced per ME intake per unit of cow $BW^{0.75}$ (0.67 vs. 0.73 ± 0.07 grams of calf /kJ of ME intake per kg $BW^{0.75}$ for HI and LO, respectively).

Discussion

Energy partitioning during the fall and winter gestation

Although in winter and early spring, when requirements rise due to gestation and early lactation (NASEM, 2016) and ME intake could be limited (Laporta et al., 2014; Casal et al., 2014), the deferment of herbage from previous growing season to winter through the HA management prevented, in this study, the negative energy balance, as herbage intake increased with herbage mass (Do Carmo et al., 2021). In the present study, losses of BW and BCS in winter were minimal (less than 0.25 units of BCS). Indeed, RE-tissue, either measured as MJ/d or kJ/ $BW^{0.75}$ per day, during fall and winter gestation was not different from zero for both, HI and LO cows, indicating that in average cows were at maintenance. In the present work, HA in which was based the management of grazing intensity, was 1.6-fold greater (especially in spring) than in previous studies in cow-calf systems (Do Carmo et al., 2018), determined that herbage

mass and height was incremented for both HA treatments in fall (2-fold greater) and winter (3-fold greater).

The greater herbage mass and height determined a ME intake 35% greater than the reported previously for beef cows grazing *Campos* grasslands during fall and winter gestation (Laporta et al., 2014) which allowed cows to reach energy maintenance requirements. Indeed, although cow ME intake was minimum in fall and winter gestation, ME intake per unit of $BW^{0.75}$ was in agreement with previous research that allowed maintenance of the beef cows during gestation (376 kJ/kg $BW^{0.75}$ per day; Houghton et al., 1990; Freetly et al., 2000). As expected, in agreement with the high correlation between HP and ME intake (Brosh, 2007), HP during fall and winter gestation decreased when compared with spring and fall. Heat production reported here during gestation (~550 kJ/kg $BW^{0.75}$ per day) were in the range of reported values of HP for beef cows at maintenance (Brosh et al., 2002, 2004). Reduced HP per unit of $BW^{0.75}$ for HI than LO cows in winter was associated with a reduced O_2P as no differences between HA treatments in HR were observed during this season. Similarly, Brosh (2007) determined increased HP due to greater O_2P , without changes in HR, for grazing vs. confined cows, probably due to short-term effects of exercise. Thus, this could be related to greater animal activity (walking grazing and bite rate) for LO than HI cows as reported by Machado et al. (2017). Moreover, total HP is the sum of HP for maintenance (HP_m) and HP for production (HP_p) (Miron et al., 2008). As total RE did not differ between HA treatments during fall-winter gestation but total HP was 25% less for HI than LO cows, it could be expected that HP_p was maintained while HP_m decreased for HI than LO cows. Thus, the greater ME intake for LO vs. HI cows,

explained by a lower stocking rate, was used for maintenance in detriment of greater production (calf birth weight or RE in body tissue).

Previous research has indicated that the energy expenditure for walking and grazing was greater than for ruminating and resting (Susenbeth et al., 1998, 2004). During winter, HI cows walked less than LO cows (5 vs. 24 ± 11 minutes per day, $P \leq 0.05$; Machado et al., 2017) and although they did not present differences in the probability of grazing or in grazing time, they had a reduced bite rate than LO cows (43 vs. 56 ± 4 bite/min, $P = 0.05$; Machado et al., 2017). In fact, Di Marco and Aello (2001) indicated bite rate is considered the most expensive component in grazing activity (Di Marco and Aello, 2001; Brosh et al., 2006) showed in Aberdeen Angus steers grazing cultivated pastures that HP can increase between 8 and 52% above basal metabolism depending on grazing conditions (herbage mass and height). On the other hand, Piaggio et al. (1995) showed that greater HA, increased selectivity that in turn, increased forage digestibility. Approximately 50% of maintenance costs are related to the mass and metabolic activity of the gastrointestinal viscera and liver due to the processes of feeding, chewing, fermentation and digestion, as well as the absorption and metabolism of digested nutrients; therefore, as food digestibility increases, maintenance costs decrease (Nkrumah et al., 2006; Reynolds et al., 2011). Thus, it could be suggested that in winter, the better management of grazing intensity for HI than LO, was reflected in a higher herbage mass with equal HA and a higher sward structure (Machado et al., 2017; Do Carmo et al., 2018) that allowed cows to decrease grazing time and increased selectivity for higher-quality - more digestible - forage, decreasing energy maintenance requirements, therefore, RE was equal for HI and LO cows.

Energy partitioning during the spring and summer lactation

Along with the increase in energy requirements for lactation, herbage production and its energy concentration are maximum during spring and summer as *Campos* grasslands are dominated by C4 species (Do Carmo et al., 2018). In the present study, rainfall in early spring was below the historical average (22 vs. 102 mm in November), thus, herbage mass accumulation was delayed, reaching maximum in summer. However, HA for both, HI and LO treatments, was the greatest in spring when compared with the other seasons, which probably allowed cows to maximize herbage intake. Cow BCS and BW were greater in spring and summer than in fall-winter in agreement with greatest HA (Do Carmo et al., 2018). Moreover, RE-tissue, measured as both MJ/d or $\text{kJ/BW}^{0.75}$ per day, indicated that cows for both, HI and LO, were in positive energy balance. Total RE was greater in spring-summer than in fall-winter due to RE-milk as milk peak yield occurred in early lactation for beef cows grazing *Campos* (Espasandín et al., 2016). In agreement with the increased total RE, cow ME intake was almost 42% greater in spring and summer than in fall and winter as both, energy demands due to lactation and HA, increase. In contrast to winter, both, RE- milk and ME intake were greater for HI than LO, especially during spring, and they were greater than the reported previously for Laporta et al. (2014; 62 and 53 MJ/d of ME intake and 4.9 and 4.0 ± 0.3 kg/d of milk with milk production at day +60 for HI and LO cows, respectively).

Although during lactation in spring and summer, total HP ($\text{kJ/kg BW}^{0.75}$ per day) increased as ME intake increased, it was less than the reported previously for grazing lactating beef cows (Brosh et al., 2004; 2006; Brosh, 2007). The lower total HP of the present study was associated with a reduced cow HR, without changes in their O2P. The

lower HR and total HP was associated with reduced ME intake (300-700kg MS/ha of herbage allowance; Brosh 2006; and quality 6.28-10.5 MJ; 40-170gr /kg MS PC).

In contrast with Brosh et al. (2006), although LO cows had an increased O2P, greater intensity of pasture grazing did not affect total HP. However, total RE was 1.5-fold greater for HI than LO cows, thus, it could be expected that HPp was increased while HPm was decreased for HI than LO cows during this period, and that greater proportion of the increased ME intake was partitioned towards production – body and milk RE - instead maintenance.

Energy efficiency during the gestation-lactation cycle

Consistent with the greater total RE and decreased maintenance costs (Ferrell and Jenkins, 1985), gross energy efficiency calculated as the ratio of total RE to ME intake, tended to be greater in HI than LO cows, especially during lactation, explained by the greater milk yield of the former ones (Gutierrez et al., 2013). However, the biological production efficiency calculated as the relationship between the grams of calf with the ME consumption per unit of $BW^{0.75}$, was not different between the treatments.

This discrepancy was probably associated, among other factors, with calf milk consumption vs. cow milk production, either due to later weaning, when calves were already grazing and were not totally dependent on lactation (Wright and Russel, 1987) or when their growth potential decreased (Greenwood and Cafe, 2007). The young calves can start consuming forage at a very young age; they learn foraging skills from their peers, and intake of forage increases with reduced milk supply around weaning (Tedeschi and Fox, 2009). Besides, previous reports indicated biological efficiency was 2.7 and 3.7 g/MJ for Hereford and Aberdeen Angus, respectively, with an intake of

3000 kg of dry matter per year which represents 77.4 MJ per day (Jenkins and Ferrell, 1994), and between 3.6 and 5.7 g/MJ with an ME intake of 455 and 473 kJ/kg BW^{0.75} per day, respectively (Do Carmo et al. 2016). It could be suggested that the ME intake reported in the present study (1.5 fold greater than Do Carmo et al., 2016) allowed to reach greater efficiencies.

Brosh et al. (2004) related values of HP, ME intake (with values between 600 and 1900 kJ/kg BW^{0.75} per day) and RE in a prediction equation, where $HP = 0.375x + 328$ ($R^2=0.792$) and $RE = 0.625x - 328$ ($R^2=0.914$). When HP and total RE values obtained in this study for fall-winter gestation indicated fasting HP of 361 and 309 kJ/kg BW^{0.75} per day and km of 0.568 and 0.658, respectively; and for spring-summer lactation indicated fasting HP of 317 and 314 kJ/kg BW^{0.75} per day and km of 0.638 and 0.643, respectively. The values reported in the present study are similar than reported by NASEM (321 kJ/kg BW^{0.75} per day and 0.60 for fasting HP and km, respectively) and CSIRO (337 kJ/kg BW^{0.75} per day and 0.72 for fasting HP and km, respectively).

Conclusions

In the present study, HA did not improved ME intake in the annual production cycle, however, total RE was higher for HI cows explained by a decreased in energy maintenance requirements, through partitioning of cow ME intake towards RE tissue and/or milk instead of maintenance. Differences in the management of herbage allowance between treatments improved in HI-HA greater herbage mass and height in fall, therefore, with equal HA between treatments in winter, but with higher forage mass and stocking rate for HI than LO treatment, it allowed cows to be at maintenance with a lower ME intake compared with LO cows which could be probably associated to

differences in grazing activity. The greater gross energy efficiency for HI than LO treatment was not reflected in an increased biological efficiency (g calf per MJ of ME intake) for cows grazing increased herbage allowance. On the other hand, our results would indicate that energy requirements and energy efficiency of breeding beef cows grazing Campos grasslands are in agreement with international feeding systems (NASEM and CSIRO).

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Statements & Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose. The authors have no conflict of interest to declare.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Jimena Gómez, Alberto Casal, Martín Do Carmo and Mariana Carriquiry. The first draft of the manuscript was written by Jimena Gómez and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval

Animal procedures were performed according to protocol approved by the Animal Experimentation Committee of Universidad de la República (CHEA, UdelaR, Uruguay; expe ##021130-000818-14).

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Fig. 1. Least square means and s.e.m. for cow body condition score (BCS; 8-point scoring system, 1 = thin to 8 = obese); (a) and body weight (BW; b) throughout the gestation–lactation cycle (–145 to 175 days relative to calving) in beef cows grazing high (solid symbols and lines) and low (open symbols and dashed lines) herbage allowances (8 and 5 kg dry matter (DM)/kg BW of annual mean, respectively) of native grasslands (n = 46). Asterisks denote days in which cow BCS differed ($P < 0.05$), and cross denote days in which cow BW tended to differ ($P < 0.1$), between high and low herbage allowances.

Fig 2. Total retained energy (RE; a), total heat production (HP; b) and metabolized energy intake (MEI = Total RE + HP, c) in beef cows grazing high (black bars) and low (white bars) herbage allowances (8 and 5 kg dry matter (DM)/kg BW of annual mean, respectively) of native grasslands throughout the gestation-lactation cycle. Letters denote least square means differences ($P < 0.05$) and asterisks indicate a tendency ($P < 0.1$) for the interaction between treatments and days relative to calving.

Fig 3. Total retained energy (RE; a), total heat production (HP; b) and metabolized energy intake (MEI = Total RE + HP, c) per unit of metabolic BW in beef cows grazing high (black bars) and low (white bars) herbage allowances (8 and 5 kg dry matter (DM)/kg BW of annual mean, respectively) of native grasslands throughout the gestation-lactation cycle. Letters denote least square means differences ($P < 0.05$) and asterisks indicate a tendency ($P < 0.1$) for the interaction between treatments and days relative to calving.

Figures

Figure 1

Least square means and s.e.m. for cow body condition score (BCS; 8-point scoring system, 1 = thin to 8 = obese); (a) and body weight (BW; b) throughout the gestation–lactation cycle (–145 to 175 days relative to calving) in beef cows grazing high (solid symbols and lines) and low (open symbols and dashed lines) herbage allowances (8 and 5 kg dry matter (DM)/kg BW of annual mean, respectively) of native grasslands (n = 46). Asterisks denote days in which cow BCS differed (P < 0.05), and cross denote days in which cow BW tended to differ (P < 0.1), between high and low herbage allowances.

Figure 2

Total retained energy (RE; a), total heat production (HP; b) and metabolized energy intake (MEI = Total RE + HP, c) in beef cows grazing high (black bars) and low (white bars) herbage allowances (8 and 5 kg dry matter (DM)/kg BW of annual mean, respectively) of native grasslands throughout the gestation-lactation cycle. Letters denote least square means differences ($P < 0.05$) and asterisks indicate a tendency ($P < 0.1$) for the interaction between treatments and days relative to calving.

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