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ANIMAL PRODUCTION

Energy supplements for beef heifers on cool season pastures – a database analysis

Amanda Carneiro Martini[1] **Fernando Forster Furquim**[1*] **Camille Carijo Domingues**[1] **Paula de Oliveira Severo**[1] **Tuani Lopes Bergoli**[1] **Marta Gomes da Rocha**[1] **Luciana Pötter**[1]

[1]Laboratório de Pastos & Suplementos, Departamento de Zootecnia, Universidade Federal de Santa Maria (UFSM), 97150-900, Santa Maria, RS, Brasil. E-mail: ff.furquim@gmail.com. [*]Corresponding author.

ABSTRACT: Pooled data analysis is an analytical method that combines results from multiple studies. This technique provides a more robust estimate of the effects of an investigation. We performed a database analysis from seventeen experiments developed at Federal University of Santa Maria, Rio Grande do Sul state, Brazil, between 1999 and 2017 to characterize individual performance per area and stocking rate with or without supplementation of replacement heifers grazing winter pastures. Data were separated into two groups: with and without energy supplement provision, and into five subgroups based on supplement levels. Heifers from both groups were maintained under similar forage biomass and leaf blade allowance. Statistical analyses were run on R software using a 'meta' package. Supplement supply increased average daily gain and gain of body condition scores by 11.1% and 20.0%, respectively. Supplement levels higher than 1.2% of body weight resulted in higher weight gain per area, with the stocking rate increasing with higher supplement levels.
Key words: average daily gain, meta-analysis, ryegrass, stocking rate, supplement conversion.

Uso de suplemento energético para novilhas de corte em pastagens de estação fria - análise de banco de dados

RESUMO: Análise conjunta de dados é um método analítico que integra os resultados de muitos estudos. Essa técnica fornece uma estimativa mais robusta sobre os efeitos de uma investigação. Com o objetivo de caracterizar o desempenho individual, por área e a taxa de lotação com uso ou não de suplementos para novilhas de reposição mantidas em pastagem de inverno, foi realizada uma análise de banco de dados de dezessete experimentos conduzidos na Universidade Federal de Santa Maria (UFSM), RS, Brasil, entre 1999 e 2017. Os dados foram estratificados em dois grupos: com e sem suplemento energético e cinco subgrupos de acordo com o nível de suplemento. As novilhas de ambos os grupos foram mantidas em similar massa de forragem e oferta de lâminas foliares. As análises estatísticas foram executadas no software R, pacote 'meta'. O fornecimento de suplemento aumentou o ganho médio diário em 11.1% e em 20.0% o ganho no escore de condição corporal. Níveis de fornecimento maiores que 1.2% do peso corporal proporcionaram o maior ganho de peso por área e a taxa de lotação aumenta à medida que os níveis de suplemento aumentam.
Palavras-chave: azevém, conversão de suplemento, ganho médio diário, meta-análise, taxa de lotação.

INTRODUCTION

Breeding systems require selection and contention of beef heifers to maintain herd size and productivity, ensuring livestock sustainability (HENLEY et al., 2021). In Southern Brazil, grasslands are the main forage source for herd; however, their production decreases during the winter season (MEZZALIRA et al., 2012), affecting the energy and protein intake essential to meet animal requirements (BERETTA et al., 2000, TITTONELL et al., 2016). During feed scarcity season, improving animal energy balance is possible by establishing cultivated grasses adapted to climate conditions and tolerant to grazing that can extend grazing period, increasing nutritional forage value and decreasing seasonal variations (VENDRAMINI et al., 2006, VENDRAMINI & MORIEL, 2020). Furthermore, the use of supplementation can enhance the growth and reproductive performance of heifers (MARTIN et al., 2007), making it a useful tool to achieve ideal body weight and improve reproductive results (MULLINIKS et al., 2013).

Cool-season pastures are used to reduce negative effects of low temperatures on forage quality and productivity by establishing high nutritional

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pastures with frost-tolerant species (SALGADO et al., 2013). However, these pastures can limit animal performance through their heterogeneity along the productive cycle (PARIS et al., 2012). In this sense, supplementation can be used as a strategy to intensify rearing of heifers by providing nutrients that are not available in pastures, extending grazing season, and thus optimizing forage use, reducing reproductive cycles, and increasing animal performance (DIXON & STOCKDALE, 1999; BARBERO et al., 2015). In-field grazing experiments are of primary importance to assess the effects of supplementation on animal performance on winter pastures, but they are expensive and time-consuming. One alternative approach is the use of meta-analysis combining results from different related studies and estimating the effects of treatments with higher precision, consequently providing useful information for future livestock practices with lower costs and higher financial incomes (LOVATTO et al., 2007, RODRIGUES & ZIEGELMANN, 2010).

In this context, our objective was to examine the effects of supplementation on the performance of beef heifers and pasture-supporting capacity in winter pastures from the Southern Brazil region. We hypothesized that the use of supplements will increase: (1) average daily gain, (2) stocking rate, and consequently (3) average gain per area. The intent was to develop the first suite of information that would be useful for prediction of supplementation benefits on beef heifers' performance and pasture productivity for this region.

MATERIALS AND METHODS

Experiments description and dataset construction

Datasets were constructed based on results from 17 experiments developed at Laboratório Pastos & Suplementos (Departamento de Zootecnia, Universidade Federal de Santa Maria) from 1999 to 2017 (Table 1). These experiments assessed 589 beef heifers (Angus breed and Charolais/Brahman crossbreed), with initial age and corporal weight average of 8 months and 160.9 ± 22.6 kg, respectively. Established pastures were ryegrass (*Lolium multiflorum* Lam.) by itself or in a mixed consortium with black oat (*Avena strigosa* Schreb.), arrowleaf clover (*Trifolium vesiculosum* Savi), or red clover (*Trifolium pratense* L.). The average winter pasture use was 106 days, from May to September, and grazing management was continuous or rotational

Table 1 - Works from Pastos & Suplementos laboratory database with year of conduction, pasture utilization days (PUD), and supplements characterization.

Work	Year	PUD	n*	------Supplement------	
				Type	% BCS**
FRIZZO, 2003	1999	126	30	Rice bran + citrus pulp	0.7; 1.4
ROCHA, 2003	2000	132	20	Sorghum	1.0
SANTOS, 2005	2001	88	12	Ground corn and soybean hulls	0.9
PILAU, 2005	2001	131	30	Sorghum	0.7
PILAU, 2005	2002	115	45	Wheat meal	0.5; 1.0; 1.5
MACARI, 2005	2005	95	24	Commercial ration	0.3; 0.6; 0.9
ROSO, 2007	2005	70	9	Commercial ration	1.0
ROSA, 2010	2007	74	12	Commercial ration	1.0; 1.4
ROSO, 2011	2008	105	24	Extruded ration	0.15; 0.3
ROSA, 2011	2009	108	16	Extruded ration Triturated corn	0.2 0.65
OLIVEIRA, 2012	2010	114	16	Whole corn and steam-rolled corn	1.0
FONSECA NETO, 2013	2011	110	24	Rice bran Rice bran + ionophore	0.8
ALVES, 2014	2012	130	28	Oat; whole corn	0.8
GAI, 2015	2013	118	30	Corn Grounded corn + glycerol	0.9 0.9+0.2
AMARAL NETO, 2016	2014	105	12	Rice bran	0.5; 1.0
AMARAL NETO & BAYER, 2016	2016	85	12	Rice bran	0.5
VICENTE, 2017	2017	100	18	Whole corn	0.8

*Number of repetitions; **Daily quantity of supplement (% of body weight (BW)).

stocking rate, with variable put-and-take animals to maintain forage mass and height of canopy according to experimental criteria. Two or three repetitions were done per area with three tester animals. The average of supplement provision was 0.8% (ranging from 0.15 to 1.5) of liveweight being offered daily at 0200 pm. Data were compiled on Microsoft® Office Excel® 2013 and separated into two groups with and without supplement, and into five subgroups according to daily quantity of offered supplement (Table 2). The average and standard deviation of variables were obtained from the raw data from each experiment.

Forage and animal variables

The selected variables from pasture attributes were: forage biomass (FB, kg DM ha-1), forage accumulation rate (FAR, kg DM ha-1 day-1), forage allowance (FA, kg DM per 100 kg BW), leaf blade allowance (LBA, kg DM per 100 kg BW), and canopy height (H, cm). Additionally, we included the following forage variables obtained by grazing simulation: crude protein (CP, %), neutral detergent fiber (NDF, %), and organic matter digestibility (OMD, %). Variables related to animal performance were: average daily gain (ADG, kg BW day-1), gain of body condition score (BCS), final body weight (FBW, kg), stocking rate (SR, kg BW ha-1), supplement conversion to body weight (SC, kg ha-1), and gain per area (GPA, kg BW ha-1 day-1). The GPA was obtained by average of SR divided by beef heifers' weight, multiplied by average daily gain of tester animals. The SC was obtained from supplement intake per hectare divided by the GPA difference between animals that received and did not receive supplements.

Statistical analyses

All statistical analyses for the meta-analysis were performed using R (R CORE TEAM, 2018) and the 'metacont' function within the package 'meta' (SCHWARZER, 2007), which produces both fixed- and random-effects estimates with continuous outcome data. The standardized mean difference (SMD) was used to obtain mean differences across groups, and selected experiment results were pooled using inverse variance weighting. The effect size on variable measure unit was obtained by multiplying the average of the standard deviation from animals that received supplement by the analysis standardized mean difference. The choice of model (fixed-effect or random-effect) was based on heterogeneity by I2 test (HIGGINS et al., 2003), which quantifies the impact of heterogeneity on meta-analysis through mathematical criteria independent of number of studies and treatment metric effect. Variable stocking rate (SR) was modelled as a function of supplement levels using the 'metareg' function from the 'meta' package, and variance estimates between studies were done using the restricted maximum likelihood (REML) method. Supplement conversion (SC) was analyzed by regression analysis according to supplement levels and its model was chosen based on coefficients (linear, quadratic, and cubic) significance using Student's t-test with $\alpha = 0.05$ as the probability limit for rejection of null hypothesis. These analyses were made using the 'lm' function and were plotted using the 'ggplot2' package (WICKHAM, 2016).

Table 2 - Subgroups created according to supplement level (% of BSC) and number of works of each (n) from Pastos & Suplementos Laboratory database.

Subgroups	% BSC*	n
1	> 0 to 0.3	4
2	> 0.3 to 0.6	4
3	> 0.6 to 0.9	9
4	> 0.9 to 1.2	7
5	> 1.2 to 1.5	3

*Daily quantity of supplement (% of BSC).

RESULTS AND DISCUSSION

Based on heterogeneity analysis, the fixed-effect model was chosen for the FB, FAR, FA, LBA, H, CP, NDF, and OMD variables, while the random-effect model was used for the ADG, BCS, FBW, GPA, and SR variables.

All heifers, supplemented or not, were maintained under similar conditions of FM (1574.1 ± 306.9 kg DM ha^{-1}, I2 = 0 %, P = 0.6244), FAR (49.2 ± 19.2 kg DM ha^{-1} day^{-1}, I2 = 0 %, P = 0.1783), H (14.5 ± 2.9 cm; I^2= 8 %, P= 0.9944), and LBA (3.8 ± 2.1 kg DM per 100 kg BW, I2 = 0 %, P = 0.1961). Furthermore, results from the grazing simulation were similar among groups for CP (20.2 ± 4.4 %, I^2 = 0 %, P = 0.2325), NDF (47.2 ± 7.3 %, I^2 = 0 %, P = 0.7787), and OMD (67.5 ± 8.3 %. I^2 = 0 %, P = 0.8617) variables. Forage allowance was higher for heifers maintained exclusively on cool-season pastures (10.4 ± 2.4 kg de DM per 100 kg BW, P <0.0001), and the difference among groups with or without supplement use was 1.2 kg DM per 100 kg BW (I^2 = 0 %, P < 0.0001).

Variables ADG, BCS, and FBW did not show differences among subgroups; however, the use of supplement, independent of level, increased individual performance (Table 3). Heifers that received supplements had an ADG of 1.0 ± 0.2 kg day^{-1}, which was 11.1% higher than that of heifers that did not receive supplements.

Heifers that received supplements had ADG, BCS, and FBW 11.1%, 20%, and 5.3%, higher than heifers fed only with cool-season pastures, respectively (Table 3).

Supplement level influenced SR (SR = −0.1 + 351 × supplement level; P = 0.0047; R2 = 86.3%), wherein level changes increased by 1.0 standard-deviation. The average of SR standard-deviation when heifers were supplemented was 351.0 kg ha^{-1}, which increased in 35.1 BW ha^{-1} when supplement level increased 0.1% (Figure 1). Supplement conversion was fitted to the crescent linear regression model (SC = 1.9 + 5.9 × supplement level; P < 0.0001; SE = 1.2; R2 = 77.0%). When increasing the supplement level by 0.1%, an increase of 0.6 kg of supplement resulted in an increase of 0.1 kg of BW ha^{-1} (Figure 2). While all subgroups showed an increase in GPA, differences were observed among subgroups (P = 0.0177) (Figure 3).

The FB correlates directly with available forage to animals, being considered one of the most relevant and utilized factors in grazing management (CONFORTIN et al., 2013). The average of forage biomass in our study was within the intended values for analyzed experiments (Table 3). According to ROMAN et al. (2007), the ideal values of FB for maximum animal performance in temperate climate zones range from 1100 to 1800 kg ha^{-1} of DM. For ryegrass pastures, canopy height should be maintained from 10 to 15 cm to optimize biomass fluxes and provide conditions for pasture growth that will allow animals to have higher forage intake and better performance results (PONTES et al., 2004). In this sense, when heifers were fed solely with cool-season pastures, FA was 11.5% higher than for supplemented heifers; however, despite this difference, both had higher values (3.4 and 3.1, respectively, for non- and supplemented heifers) than the 3% estimated by the National Research Council (NRC, 2000). BARGO et al. (2003) suggested that appropriate values for animals fed solely with pastures range from 3 up to 5 times more than that estimated for dry matter intake, and 2.5 times higher when animals receive supplements. Furthermore, FA values from experiments analyzed in the present study were within the range indicated by GRAMINHO et al. (2019), from 6 to 12 kg of DM per 100 kg of BW for ryegrass management, without jeopardizing foliar tissue fluxes and efficiency of pasture use. The sum of the average supplement intake and forage allowance totaled 10 kg of DM per 100 kg of BW, similar to the forage allowance of heifers maintained only on pastures. Additionally, it was not inferior to NRC (2000) estimates and probably was not a limiting factor of forage intake.

Chemical composition and digestibility are the main factors that influence pasture quality (SOLLENBERGER & CHERNEY, 1995). Beef heifers require 13.5% of crude protein for high animal performance (NRC, 2000); our study successfully exceeded this value. Content of NDF has an inverse relation with forage intake, with values ranging from 55 to 60% not limiting intake, according to VAN SOEST (1994). However, in our study, values were below this range and were thus considered as intake limiters. The average OMD was within the 65–70% range indicated by POPPI et al. (1994) for high digestibility diets and in these cases, voluntary intake is restricted by metabolic mechanisms, such as animal capacity to use absorbed nutrients. According to DIXON & STOCKDALE (1999), digestibility has a linear correlation with NDF, being higher in forages that have lower NDF and higher protein content. Therefore, our results for CP, NDF, and OMD characterized cool-season pastures as having high nutritional quality for heifers.

The highest ADG observed could be explained by the supplement additive effect, which

Table 3 - Additional values in average daily gain (ADG, kg day^{-1}), gain of body condition score (BSC, scores), and final body weight (FBW, kg) of heifers managed on pastures receiving supplements from Pastos & Suplementos Laboratory database.

Variable	SMD[1]	MD[2]	I2[*]	P[**]	P[***]
ADG	0.5	0.1	48.70	<.0001	0.8261
BCS	1.3	0.1	85.20	0.0017	0.7341
FBW	0.9	13.1	91.50	0.0007	0.5747

[1]Standardized difference of means; [2]Mean difference between heifers supplemented or not in variable unit of measure; [*]% heterogeneity between experiments measured by I2 statistic; [**]probability for statistic difference between groups calculated by inverse variance weighting; [***]probability for statistic difference between subgroups calculated by inverse variance weighting.

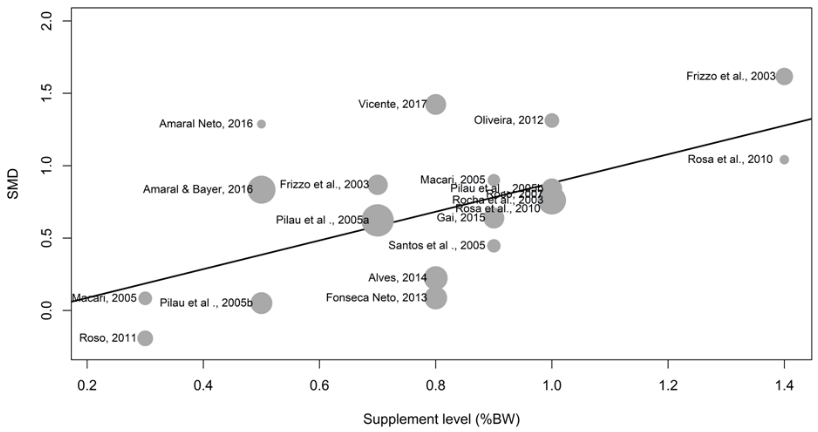

Figure 1 - Bubble chart graphics: Y-axis represents the effect size using the standardized mean difference (SMD) method from meta-regression analysis. Size of dots represents analysis participation of each study.

increased dry matter intake and, consequently, provided higher amounts of energy to animals. Furthermore, this result can be linked with diet equilibrium provided by supplement use, which is a degradable carbohydrate source for rumen that optimizes volatile fatty acids and propionic acid production, hence increasing glycose availability for muscular, uterine, and fatty tissues storage (NOVIANDI et al., 2014). Supplementation of heifers on ryegrass pastures increases ADG and anticipates reproductive system development of 13-month-old heifers (GONZALEZ et al., 2016).

BCS of higher supplemented animals was determined by weight gain composition by the end of the grazing period. Animals that fed on pastures with high protein content and received energy supplements tended to accumulate more fat faster than animals maintained without supplements. High protein and energy relations in consumed nutrients have potential to alter animal BCS (POPPI & MCLENNAN, 1995).

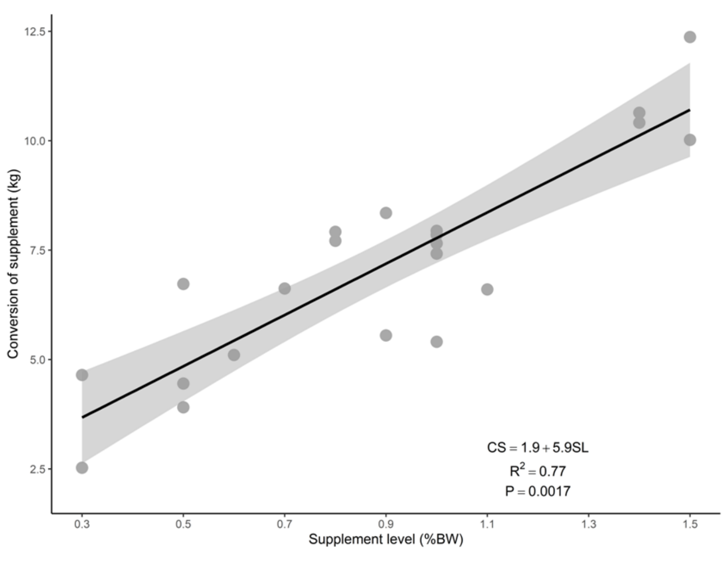

Figure 2 - Supplement conversion (SC, kg ha^{-1}) according to supplement level (% BW) from Pastos & Suplementos Laboratory database.

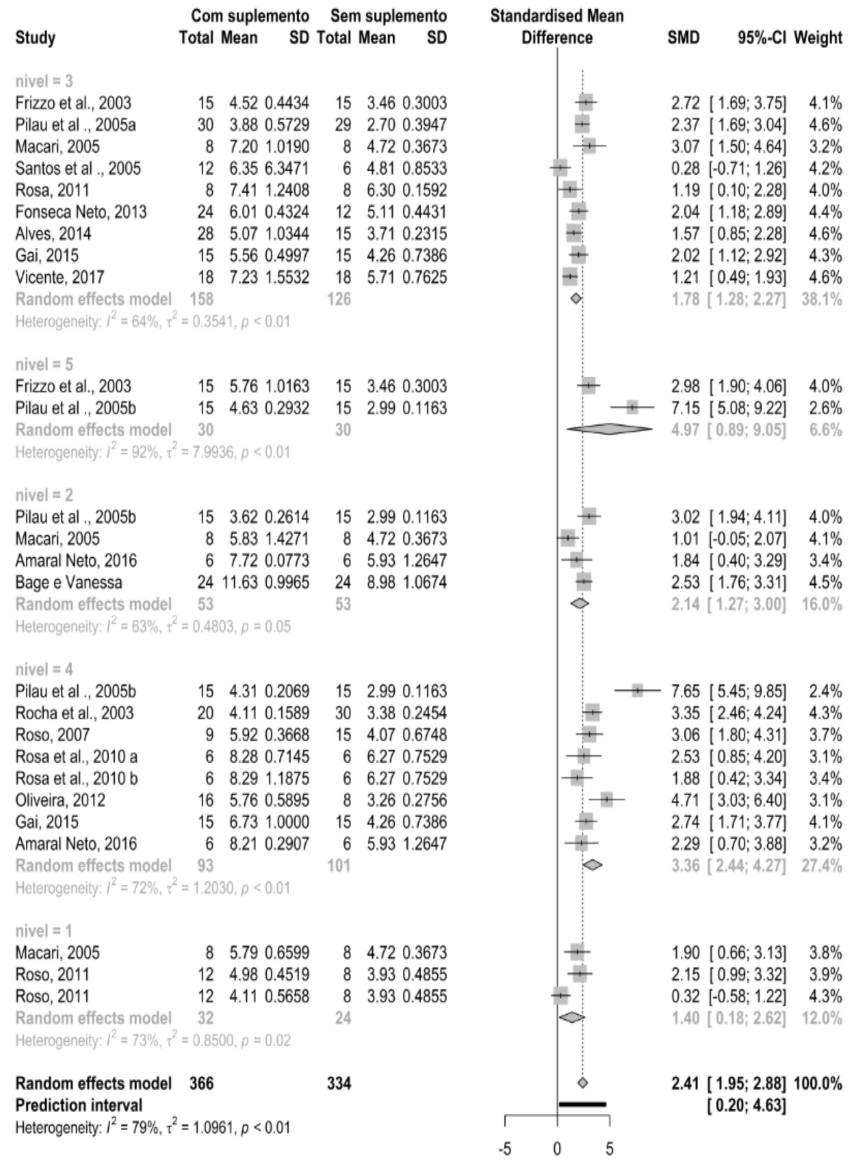

Figure 3 - Dashed vertical line represents standardized mean difference of supplemented animals. The size of squares represents participation weight of each study on analysis and horizontal line indicates standard deviation of studies.

In a study of the development of beef heifers, SILVA et al. (2018) showed that the main factors altering conception rate of 14-months-old heifers were BCS at the beginning and the end of the reproductive season. Furthermore, weight gain intensification was necessary to increase the nutrient levels of the diets of animals, aiming to reach a BSC of 4.0 ± 0.1, which had a higher conception rate.

Heifers that received supplementation reached 59.2% of the 450 kg of mature weight. According to LARDNER et al. (2014), heifers did not have their reproductive performance affected and became more productive by reaching 55% of BW for their first mating when compared to heifers raised to reach 62% of BW, which are nutritionally more demanding, thus increasing financial investment. This weight change is linked to genetic modifications that aim to decrease the age of heifers' puberty (FUNSTON et al., 2012).

In accordance with our results, PÖTTER et al. (2010a) reported similar relations between SR and supplement levels that were due to the effect of substitution of pasture intake by supplement consumption. Supplementation can decrease forage intake due to substitution, wherein higher levels of supplement favor substitution of pasture intake for supplements that increase stocking rate (KLEIN et al., 2015). Additionally, when supplement consumption substitutes part of forage intake, it improves diet quality due to higher energy levels, which allows higher bovine selectivity during grazing (LISBINSKI et al., 2018). The lower SC with an increase of the supplement amount can be associated with greater response of SR to higher levels than the individual gain of the heifers, which is characteristic of the supplement substitution effect. When heifers were supplemented with levels equivalent to subgroup 5 (6.2 ± 0.7 kg BW ha^{-1} day^{-1}), they showed additional production of 3.5 kg BW ha^{-1} day^{-1}, 83.3% higher than results from heifers maintained only by pastures, as a consequence of combining higher animal weight gain and lower stocking rate. The GPA is determinant of finance balance, even when the livestock production system aim is not the slaughter of animals; thus, reduction of the age of first mating and having a large number of heifers able to reproduce can indicate higher utilization efficiency of pastures (PÖTTER et al., 2010b).

CONCLUSION

Energy supplementation of beef heifers in the central portion of Rio Grande do Sul State, increases average daily gain and gain of body condition during cold season, which is a critical period for livestock production due to low forage availability and quality associated with low animal performance. Supplementation levels higher than 1.2% of body weight can achieve a higher gain per area and higher stocking rate.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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