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Beef heifer weight loss during gestation and its effects on progeny performance

Perda de peso da novilha de corte durante a gestação e seus efeitos no desempenho da progênie

Pérdida de peso de novillas de carne durante el embarazo y sus efectos en el rendimiento de la progenie

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Abstract
The objective of the present study was to evaluate the intensity of weight loss in beef heifers during gestation and its effects on progeny performance up to 205 days of age. Sixty pregnant heifers aged 3 or 4 years, born between 2015 and 2017, from the rotational cross between Charolais and Nellore breeds were used. Females were divided according to the intensity of weight loss in the gestation period (7, 14, and 21%) and age at first calving (3 and 4 years), in a completely randomized design in a 3 x 2 factorial scheme. Lost up to 21% (T21) of body weight during gestation and had higher body conditions at the end of the breeding season (3.12 vs 3.02 and 3.04 points) and lower body weight at calving (341.96 vs 386.26 and 362.95 kg) about T7 and T14 heifers. The birth weight of the calves showed a tendency to increase as the weight loss of the pregnant heifers increased, with values of 29.46, 30.60 and 32.76 kg for treatments T7, T14 and T21, without reflections on the post-weaning performance of the progeny. In general, the loss of 14 or 21% of the heifer's body weight during pregnancy reduces the weight at the first calving, while heifers calved at 4 years of age are heavier and give rise to progeny with greater productive potential up to 205 days of age.
Keywords: Fetal programming; Food restriction; Nutrition.

Resumo

O objetivo do presente estudo foi avaliar a intensidade da perda de peso da novilha de corte durante a gestação e seus reflexos no desempenho da progênie até os 205 dias de idade. Foram utilizadas 60 novilhas gestantes com 3 ou 4 anos de idade, nascidas entre 2015 e 2017, oriundas do cruzamento rotativo das raças Charolês e Nelore. As fêmeas foram divididas de acordo com a intensidade da perda de peso no período gestação (7, 14 e 21%) e da idade ao primeiro parto (3 e 4 anos), num delineamento inteiramente casualizado em esquema fatorial 3 x 2. Novilhas que perderam até 21% (T21) do peso corporal na gestação apresentaram maior condição corporal ao final da estação reprodutiva (3.12 vs 3.02 e 3.04 pontos) e menor peso corporal ao parto (341.96 vs 386.26 e 362.95 kg) em relação às novilhas T7 e T14. O peso ao nascimento dos bezerros apresentou tendência para aumentar à medida que se intensificou a perda de peso das novilhas gestantes, com valores de 29.46, 30.60 e 32.76 kg para os tratamentos T7, T14 e T21, sem reflexos no desempenho pós-desmame da progênie. De modo geral, a perda de 14 ou 21% do peso corporal da novilha durante a gestação reduz o peso ao primeiro parto, enquanto que novilhas paridas aos 4 anos de idade são mais pesadas e originam uma progênie com maior potencial produtivo até os 205 dias de idade.

Palavras-chave: Nutrição; Programação fetal; Restrição alimentar.

Resumen

El objetivo del presente estudio fue evaluar la intensidad de la pérdida de peso en novillas de carne durante la gestación y sus efectos en el comportamiento de la progenie hasta los 205 días de edad. Se utilizaron 60 novillas preñadas de 3 o 4 años de edad, nacidas entre 2015 y 2017, provenientes del cruce rotacional entre las razas Charolais y Nellore. Las hembras se dividieron según la intensidad de la pérdida de peso en el período de gestación (7, 14 y 21%) y la edad al primer parto (3 y 4 años), en un diseño completamente al azar en un esquema factorial 3 x 2. Perdieron hasta El 21% (T21) de peso corporal durante la gestación presentó mayor condición corporal al final de la época de servicio (3,12 *vs* 3,02 y 3,04 puntos) y menor peso corporal al parto (341,96 *vs* 386,26 y 362,95 kg) en relación a las novillas T7 y T14. El peso al nacer de los terneros mostró una tendencia a aumentar a medida que aumentaba la pérdida de peso de las vaquillas preñadas, con valores de 29,46; 30,60 y 32,76 kg para los tratamientos T7, T14 y T21, sin reflejos en el comportamiento posdestete de las novillas. De modo geral, a perda de 14 ou 21% do peso corporal da novilha durante a gestação reduz o peso ao primeiro parto, enquanto que novilhas paridas aos 4 anos de idade são mais pesadas e originam uma progênie com maior potencial produtivo até os 205 dias de edad.

Palabras clave: Nutrición; Programación fetal; Restricción alimentaria.

1. Introduction

Recent studies have demonstrated the effects of the nutritional status of the pregnant female on fetal formation and consequently on the performance of the progeny after birth (Du et al., 2010; Bohnert et al., 2013; Castro-Rodriguez et al., 2020; Ramírez et al., 2020). Changes in fetal formation caused by nutritional insults to the pregnant uterus are called fetal programming or developmental programming. Changes in fetal formation, according to Reynolds et al. (2019), serve to provide a rapid fetal adaptation to the uterine environment of formation programming the individual to the future environment of creation.

In general, challenging conditions during pregnancy cause negative changes in the fetal formation of individuals (Castro-Rodríguez et al., 2020). The nutrition of cows can be evaluated by body condition or by the weight variation of the female during pregnancy. Bohnert et al. (2013) obtained higher performance of calves up to 205 days of age when they were born from cows with higher body scores at calving. Similarly, Marques et al. (2016) evaluated the effects of body score variation during pregnancy on offspring performance. The authors obtained superior gains in calves born to cows that gained body scores in the final stage of gestation, the results being superior to those obtained in the offspring of cows with high body scores throughout pregnancy.

In a meta-analytic study, Klein et al. (2021b) observed higher performance of calves in the early months of life, when they were born to cows that gained body weight compared to those that lost less or more than 10% of body weight during pregnancy. In a similar study, Rodrigues et al. (2021) did not observe any effect of the weight variation of the pregnant cow on the progeny performance variables, however, the authors observed losses in the carcass and meat characteristics of the offspring when the cow lost weight during pregnancy. The results of fetal programming are very dispersed and inconclusive, since there may be metabolic adaptations of cows to maintain gestation.

Assessing the reproductive history of the cow, Klein et al. (2021a) obtained better performance from the offspring of cows that had not calved in the previous year and had a higher body score in reproduction, the result being justified by the greater mobilization of body reserves and the ability to maintain pregnancy in these cows. In the hypothesis that heifers have a higher maintenance requirement in the first pregnancy and lower body reserves, the objective of the study was to evaluate the intensity of weight loss during pregnancy of heifers and the effects on the performance of the progeny up to 205 days of age.

2. Methodology

The methodologies used in the present study follow the ethical protocols described and approved by the Ethics Committee for the Use of Animals, under registration number 6157161121 of the Federal University of Santa Maria.

The study was carried out at the Animal Science Department of the Federal University of Santa Maria, municipality of Santa Maria - RS, Brazil. The experimental area is located at an average altitude of 95 m, with 29° 43' south latitude and 53° 42' west longitude. According to Alvares et al. (2014), the climate of the region is "Cfa" (humid subtropical), according to the Köppen's classification, with average annual rainfall between 1600 and 1900 mm, a temperature of 18.8°C, with a minimum average of 9.3 °C and maximum average of 24.7 °C.

Sixty pregnant beef heifers belonging to the 5th and 6th generations of the rotational cross between the Charolais and Nellore breeds were used. Females were divided according to the intensity of weight loss in the gestation period (7, 14 and 21%) and age at first calving (3 and 4 years) in a factorial scheme. Body weight variation was calculated by the ratio between calving weight and the final weight of the breeding season in which the heifer was pregnant for the first time (3 or 4 years of age), where: T7, loss of 0 to 7% of Weight; T14, 8 to 14% weight loss and T21, 15 to 21% weight loss.

Heifers were weighed at 24 months of age, at the end of each breeding season, and at calving. On these occasions, the assessment of the body condition score was performed, using a scale from 1 to 5 points (1 - very thin; 2 - thin; 3 - average; 4 – fat, and 5 - very fat).

Measures of male and female progeny performance were taken at birth, at early weaning, and at seven months of age. Due to the birth interval of 90 days, the weights were adjusted for 75 and 205 days of the age of the animals. The daily weight gain was obtained through the quotient of the total weight gain by the interval of days between the subsequent weighings, and these results were used to calculate the adjusted weight for the referred ages.

The experimental design used was completely randomized in a 3 x 2 factorial design, with three levels of weight loss during gestation and two ages at first calving. The normality of the residues was analyzed by the Shapiro-Wilk test, with no need for any statistical transformation. The data were submitted for analysis of variance by the F-test, through the PROC GLM procedure, and when significance was found, the means were compared using the Tukey-test at a 5% significance level. Statistical analyzes were performed using the SAS® Studio University Edition statistical package (2016), using the following mathematical model:

$$Y_{ijkl} = \mu + VP_i + IP_j + (VP*IP)_{ij} + S_k + Z_l + \varepsilon_{ijkl}$$

Where Y_{ijkl}: dependent variables; μ: mean of all observations; VP_i: effect of the *i*-th weight during gestation; IP_j: effect of the *j*-th age at first birth; $VP*IP_{ij}$: interaction between the i-th weight loss during gestation and the *j*-th age at first delivery; Sk: effect of the covariate calf sex; Z_l: effect of the covariate percentage of Nellore breed in cows; ε_{ijkl}: effect of residual random error (error b).

3. Results and Discussion

We did not observe any interaction between the study factors for the variables evaluated, and the results were presented and discussed separately. The performance of heifers during the gestation period is shown in Table 1, where, in general, beef heifers that have greater body reserves in the breeding season end up mobilizing more body tissues to maintain gestation. The performance of heifers during growth until the end of the breeding season was similar between treatments (P>0.05), with an average weight at 24 months of heifers of 292.19 kg for T7, T14 and T21 heifers. Even with the desired weight for coverage (61%, considering an adult herd weight of 480 kg), some females did not conceive in the first production year and were mated again at 36 months of age. Heifers that calved at 4 years were lighter at 24 months of age, with values of 270.63 and 302.13 kg for females that calved at 3 or 4 years (Table 1).

Table 1. Productive performance of heifers according to weight variation during the first gestation.

Performance of pregnant heifers	Weight loss in gestation*			Age at first birth**		SD
	7 (*19*)	14 (*22*)	21 (*19*)	3 (*40*)	4 (*20*)	
Weight at 24 months, kg	304.22	287.24	285.11	302.13a	270.63b	44.19
Body weight at final of the breeding season, kg	418.16	411.32	408.53	398.00b	441.98a	47.68
Body score at final of the breeding season, pts***	3.02b	3.04b	3.12a	3.01b	3.17a	4.64
Calving weight, kg	386.26a	362.95ab	341.95b	352.53b	386.00a	41.66
Escore at calving, pts***	2.33	2.16	2.17	2.12b	2.43a	13.99

Means followed by different letters on the same line differ from each other by Tukey's Test (P<0.05);* Weight loss in gestation (7, 14 or 21% or T7, T14 and T21); ** Age at first birth (3 or 4 years of age); *** 1 - very thin; 2 - lean; 3 - average; 4 - fat and 5 - very fat. Source: Authors (2022).

The intensity of body weight loss of heifers during the gestational period influenced body weight at calving, with values of 386.26, 362.95 and 341.95 kg, for treatments T7, T14 and T21, respectively (Table 1). Weight losses were 31.90, 48.37 and 66.58 kg, values that represent the equivalent of 7, 13 and 18% of the weight in relation to the end of the breeding season. Rodrigues et al. (2021), evaluated the weight variation of pregnant cows and observed that the loss of 10 or 20% of the weight during gestation influenced the weight of the cows at calving, with losses of 23.31 and 60.22 kg, respectively.

Heifers that lost up to 21% of body weight during gestation (T21) had a higher body score at the end of the breeding season (3.12 *vs* 3.02 and 3.04 points, respectively for T21, T7 and T14). Greater body reserves may indicate a greater ability to sustain fetal growth during a nutritional challenge in gestation. Assessing the female's reproductive history, Klein et al. (2021a) observed that cows that did not conceive in the previous year had a higher body score in the breeding season and consequently had a greater ability to maintain gestation due to greater mobilization of body reserves, with positive effects on progeny performance after seven months of age.

Similarly, the females used in our study that did not become pregnant at 3 years old were mated again and calved at 4 years of age, with higher body weight and score at the end of the breeding season (441.98 *vs* 398.00 kg and 3.12 *vs* 3.01 points, respectively). Despite the weight loss during gestation (average of 45.47 and 55.98 kg for cows that calved at 3 or 4 years, respectively), cows that calved at 4 years of age were heavier and had a higher body score at calving, with values respectively of 386.00 *vs* 352.53 kg and 2.43 *vs* 2.12 points.

The body score of females T7, T14 and T21 at parturition were similar (P>0.05), with values of 2.33, 2.16 and 2.17 points, respectively. The similarity in body score at parturition is explained by the greater mobilization and weight loss of T21 heifers during gestation since these females had higher body scores at the beginning of gestation. The greater or lesser

mobilization of body reserves during gestation may be a consequence of the maintenance of physiological conditions during pregnancy, a concept known as homeorhesis (Bauman & Currie, 1980).

The best body condition at parturition may be related to better nutrition of the female during pregnancy, an aspect that in turn has been associated with better fetal development in a current concept called fetal programming. According to Funston et al. (2012), better nutrition and consequent gain in body score is an efficient strategy to stimulate fetal programming in beef cattle. Bohnert et al. (2013) observed that the higher weight and body score of cows at calving improved the birth weight of the progeny, and this superiority was maintained until the beginning of the finishing phase.

On the other hand, Marques et al. (2016) studied the period of gestation where weight loss, assessed by body score, has the greatest effect on fetal programming and progeny performance. The authors observed that the performance of calves until weaning was higher when the cows gained body scores in the second and third semesters of gestation, with the performance of the progeny being superior compared to cows that had a high or low score throughout gestation. Thus, we understand that weight gain and body condition during gestation act as environmental signs, an aspect that acts in the programming of the developing fetus. Working with different intensities of food restriction during pregnancy, Ramirez et al. (2020) observed a linear loss of weight and body condition of the cows as the nutrient restriction of the pregnant cow increased, with reflections mainly on the birth weight of the progeny.

Despite the greater mobilization of body reserves of pregnant females in treatments T14 and T21, the intensity of weight loss did not influence progeny performance until 205 days of age (Table 2), despite these progenies being 4.5 and 2.3 % heavier at 7 months of age compared to T7 progeny. However, a trend was observed for higher birth weight of calves as the weight loss of the female during pregnancy increased, with values of 29.46, 30.60 and 32.76 kg for treatments T7, T14 and T21 (Table 2). This result may be a response to the greater ability to maintain pregnancy and fetal growth in females that lost more weight in this physiological state. This theory corroborates the findings of Klein et al. (2021a), who observed higher performance of progeny born to cows that lost more weight during gestation. In addition, Broadhead et al. (2019) state that the ability of cows to adapt to nutritional insults during pregnancy influences the results of programming, with greater mobilization of body reserves generally associated with greater resilience of the female by the fetus.

According to Prezotto et al. (2016), the loss of score and body weight may indicate that cows and fetuses have the ability to adapt to periods of both restrictions and refeeding so that they alter energy use in an attempt to increase feed utilization or to change maintenance requirements to maintain fetal growth and development. The higher performance of the progeny of cows calved at 4 years of age (Table 2) can be somehow attributed to the greater capacity of these heifers to maintain pregnancy, since they have greater body reserves and lower nutritional requirements for growth (NRC, 1998). The progeny of these heifers showed higher average daily gain during lactation (0.773 *vs* 0.683 kg day^{-1}) and in the post-weaning period (0.549 *vs* 490 kg day^{-1}), demonstrating this superiority in daily weight gain may be the result of fetal programming.

Table 2. Effect of heifer body weight variation during the first gestation on progeny performance.

Progeny performance	Weight loss in gestation*			Age at first birth**		SD
	7 (*19*)	14 (*22*)	21 (*19*)	3 (*40*)	4 (*20*)	
Birth weight, kg	29.46	30.60	32.76	30.45	31.88	16.26
Average daily gain to weaning, kg day^{-1}	0.687	0.739	0.710	0.683b	0.773a	21.04
Weight at 75 days, kg	81.01	86.11	86.03	81.76b	89.89a	14.84
Average daily gain at 205 days, kg day^{-1}	0.501	0.525	0.501	0.490	0.549	23.69
Weight at 205 days, kg	132.24	138.19	135.36	130.94b	144.35a	19.16

Means followed by different letters on the same line differ from each other by Tukey's Test (P<0.05);* Weight loss in gestation (7, 14 or 21%, or T7, T14 and T21); ** Age at first birth (3 or 4 years of age). Source: Authors (2022).

On the other hand, the absence of fetal programming effects on progeny performance after birth may be a result of the adaptation and compensatory growth of calves to the growth environment, as well as the consequences of the "economic" phenotype generated in situations of nutritional stress during pregnancy (Mohrhauser et al., 2015). Complementing this hypothesis, Klein et al. (2021b) found in a meta-analytic study that the effects of fetal programming are more noticeable in the early months of the progeny's life, with reflections, especially on the birth weight of the calves. Studying the severity of nutritional restriction in pregnant cows, Ramirez et al. (2020) observed a greater recovery in weight gain from birth to slaughter in the progeny of severely restricted cows, when compared to calves from unrestricted or moderately restricted cows.

In a similar study, Rodrigues et al. (2021) did not observe the effects of cow weight variation during gestation on progeny performance, but they found that the loss of 10 to 20% of body weight of the pregnant female negatively impacted the carcass and meat characteristics of the offspring, aspects not evaluated in our study. According to the authors, the weight gain of cows during gestation may have favored fetal formation, especially skeletal muscle tissue, which has a strong influence on fetal formation (Du et al. 2010). Working with different nutritional levels in the final third of pregnancy, Klein et al. (2022) observed that cows under feed restriction lost weight during this period, with negative effects on progeny productivity up to 12 months of age.

These changes in progeny performance can be permanent and can be observed in the adult life of the animal, although they are more noticeable in the initial months of the offspring's life (Klein et al., 2021b). In a meta-analytic study, Zago et al. (2020) observed that the progeny of cows that consumed energy and protein above the maintenance requirements showed greater weight gain at finishing, were slaughtered 5.5 days earlier and presented meat with a higher marbling content, an aspect much appreciated by consumers.

In general, our results indicate that heifers that lost up to 14 or up to 21% of body weight during pregnancy produced calves that were 3.87 and 11.17% heavier at birth compared to females that lost up to 7% of body weight, in the same way, that heifers calving at 4 years of age, and therefore with greater body reserves, develop more productive progeny after birth. Thus, we understand that the events that lead to fetal programming can be studied in two different ways, where, on the one hand, the pregnant female who loses more weight until delivery is more prepared and wears out more to maintain the pregnancy, while nutritional and consequently better body condition at delivery may also indicate a surplus of nutrients for better fetal formation.

4. Conclusions

Beef heifers that lose up to 14 or 21% of body weight during gestation are lighter at calving and tend to produce heavier calves at birth.

Heifers that calve at 4 years of age are heavier and have a higher body score in the breeding season and at calving. Hawover, birth weight is not influenced by age at first calving, but heifers calved at 4 years of age produce more efficient and productive calves up to 205 days of age.

More studies are needed to clarify the real effects of fetal programming on progeny performance, evaluating aspects related to female wear to maintain nutrient drainage and fetal formation, as well as nutritional systems adequate for the pregnant beef cow.

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