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Research article

Effect of the performance, calving date and lactation period on the probability of pregnancy in beef cows

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ABSTRACT: Determining what and how much each environmental factor affects pregnancy is crucial to the sustainability and management of beef cow herds. The study evaluated through logistic regression the effect of environmental variables on the increase or reduction in the pregnancy rate of beef cows. The average pregnancy rate in the cows was 73 %, with an average age for the herd of 3.7 years. An increase in age of one year represented a 30 % increase in pregnancy, while a reduction of one year reduced the odds of pregnancy in the cows by 23 %. During the lactation period, an extra seven days' lactation reduced the odds of pregnancy by 12 %. For every seven days that weaning was brought forward, the cows' pregnancy odds increased by 14 %. An increase of 0.1 kg in average daily gain represented an increase of 17 % and 15 % in the odds of pregnancy during the first 60 days post-partum and 60 days to the end of the reproductive period. On the other hand, the loss of 0.1 kg in average daily gain resulted in a 14 % and 13 % reduction in the cows' pregnancy odds, respectively. Factors such as age, the precocity of calving in the calving season, the time the calf remains with the cow and better performance in cows between calving and the end of the mating are strategies that increase the chances of pregnancy in beef cows.

Keywords: body condition score, cow age, mating calving interval, post-partum weight gain, calving weight

Introduction

The pregnancy rate in cattle is a variable that strongly impacts the productive efficiency of breeding herds (Burns et al., 2010; Pacheco et al., 2020). The intensification of production systems passes through stages requiring an increase in the pregnancy rate (Mulliniks et al., 2020) and reproductive physiology related to herd management and nutrition (Klein et al., 2021).

Reproduction in beef cattle can be influenced by genetic and environmental factors to which the herds are subjected during the production cycle. Factors such as weight and body condition scores (Bohnert et al., 2013); weight gain, post-partum and during the breeding period (Cerdótes et al., 2004); the age of the cow (Bitencourt et al., 2020); lactation period (Vaz and Lobato, 2010; Orihuela and Galina, 2019); and the period between calving and the start of the mating (Pacheco et al., 2020), among others, govern the success or failure of reproduction in breeding herds.

In beef cattle, lactation predominates over other physiological activities. The cow prioritises milk production over reproduction, primarely due to a low intake of nutrients relative to the nutritional requirements for adequate production (Montiel and Ahuja, 2005). Based on its severity, a negative energy balance influences the production and release of hormones related to reproduction and the determination of the anoestrus period in beef cows.

Due to the complexity inherent in each production system, reproduction in beef cattle has yet to be fully understood, and it is important to quantify how much each factor might influence the reproductive performance of a herd. Information on how management affects nutrition and reproduction, especially in pasture conditions, is still scarce (Eloy et al., 2022).

The study aimed to integrate potential environmental variables that might affect reproductive performance and quantify the odds ratio of increasing or decreasing the pregnancy rate in beef cows using the response curves of the most important predictors.

Materials and Methods

The experiment was conducted in the district of Itaqui, Rio Grande do Sul, Brazil, located at –29°15′40″ S, 55°59′47″ W, altitude 166 m. The deep soils of the region are naturally acidic, and are classified as xeric dystrophic oxisoils. According to the Köppen classification, the climate is subtropical (cfa). The annual average relative humidity is 73 %, with an average rainfall of 1600.0 mm (Alvares et al., 2013). All procedures were approved by the Ethics Committee on the Use of Animals (CEUA) of UFSM under Process n° 2388280122.

Reproductive performance was evaluated using 284 lactations of Braford cows, 134, 85 and 65 three, four and five years old, respectively. Cows were evaluated for three consecutive years, being primiparous at three years of age, secondiparous at four years of age and terceirparous at five years of age. The cows were managed as a single group, kept during all pregnancies and when primiparous on natural pasture (with an animal load of 320 kg ha^{-1}). During lactations, as secundiparous and terceriparous, cows were kept on Brachiaria Brizantha 'Marandu'and *Brachiaria Humidicola (Rendle) Shweick*, respectively. The only management that differsed between cows was the weaning age of the calves.

For mating, natural breeding was used at a bull/cow ratio of 1:25, with bulls being previously approved by libido assessment and andrological examination. Pregnancy was diagnosed by ultrasound 30 days after the end of each mating. Calving took place from 7 Sept to 16 Oct, 10 Sept to 1 Dec, and 5 Oct to 25 Nov for years one, two and three, respectively. Weaning occurred from Dec to Mar, and was carried out in stages, with the lactation periods of the cows varying between 55 and 178 days, this variation being distributed over the three years.

To adjust the grazing capacity, the cows were weighed during the first 24 h after calving, on each weaning date, at the beginning and end of each mating, and every 28 days during the remaining periods. Daily weight gain was determined by the difference in body weight of the cows between each weighing divided by the number of days between each weighing. When weighing, the body condition score of the cow was evaluated (on a scale of 1 to 5, with 1 = very thin and 5 = fat; Nazhat et al., 2021).

The following variables were tested: lactation period (days); interval between calving and the end of the mating (days); the weight of the cow (kg) and body score (points) - at calving, at 60 days post-partum and at the end of the mating; the average daily gain (kg) from calving to 60 days post-partum, and 60 days post-partum until the end of the mating, and the age of the cow at calving.

The SAS statistical package (Statistical Analysis System, v. 9.2) was used to prepare the models and statistical analysis. The pregnancy rate response variable was given the number one for a pregnant female and zero for a non-pregnant female and was analysed employing logistic regression using the LOGISTIC procedure. Among the predictor variables, multicollinearity was diagnosed by analysing the Pearson correlation matrix and measuring the variance inflation factor, condition index, eigenvalues (λ), and proportion of the variance associated with each λ (Khalaf and Iguernane, 2016; Sari et al., 2018). The variables tested in the mathematical model must present a significant Pearson correlation for pregnancy rate and have low multicollinearity with the other variables. The variables cow weight (kg) and body score (points) - at calving, at 60 days postpartum, and the end of mating were not significantly correlated ($p < 0.05$) by Pearson's correlation test with pregnancy rate or increased multicollinearity and were therefore not included in the models tested. After a diagnosis of multicollinearity, the set of covariates used to build each model was selected based on the significance of each covariate as determined by the likelihood-ratio test. The selection employed several multiple regression models with linear, and linear and quadratic effects. The interactions were tested using the stepwise method. The probability threshold for inclusion and remaining in the model was 0.25 and 0.30, respectively (Hosmer et al., 2013). The Hosmer-Lemeshow goodness-of-fit test was used to choose the best model to be adopted, considering $p > 0.30$ (Hosmer et al., 2013). The Hosmer and Lemeshow test associates the data with their estimated probabilities from lowest to highest, followed by a chi-square test to determine whether the estimated frequencies are close to those observed so that the closer to one, the better the fit of the model to the data.

After fitting the model (estimation of the β*i's* parameters), the significance of the variables resulting from the model was tested to determine whether the independent variables were influencing the odds of pregnancy of the cows. The Wald test and the score test were used to determine the quality of the fitted model and the individual significance of the set of model parameters.

The following equation express the adjusted multiple regression model for the pregnancy rate of the cows:

$$Pi = \frac{\exp(yi)}{1+\exp(yi)} = [1+\exp(-yi)]^{-1}$$

where Pi in the model is the odds of the i-th cow being diagnosed as pregnant;

$$yi = \mu + \beta 1X1i + \beta 2X2i + \beta 3X3i + \beta 4X4i + \beta 5X5i + \varepsilon i$$

where μ is a constant; X1i, age at calving (years) of the i-th cow; X2i, calving interval at the end of the breeding period (days) of the i-th cow; X3i, lactation period (days) of the i-th cow; X4i, average daily gain from calving to weaning of the i-th cow; X5i, average daily gain (kg) from weaning to the end of the reproductive period (kg) of the i-th cow; and εi, random error associated with the i-th cow.

To interpret the coefficients, the odds ratio (OR) was used, estimated by OR = exp (bk), which is the ratio between two possible outcomes, i.e., the ratio between success (ϖj) and failure (1-ϖj) of the cow becoming pregnant. The odds ratios were based on the mean denominator of the data set for each model. The units of change for the regression variables were: one year for age; seven days for the interval between calving and the end of the reproductive period; seven days for the lactation period; 0.100 kg for the average daily gain from birth to weaning; 0.100 kg for the average daily gain from weaning to the end of the breeding season.

Results

Predicting the pregnancy rate in beef cattle requires statistical procedures of multivariate analysis with the aid of logistic regression. One of the premises of such statistical analysis is the absence or low presence of multicollinearity in the statistical model (Khalaf and Iguernane, 2016; Sari et al., 2018). The present analysis, therefore, included the recommendations of Khalaf and Iguernane (2016), who suggest critical values for the Variance inflation factor (VIF) when greater than 10, for the Eigenvalue (λ) when less than 0.01, and for the Condition index (CI) when greater than 50, indicating significant multicollinearity. The descriptive analysis of the independent variables and the pregnancy rate show the averages over which the pregnancy probabilities were estimated (Table 1).

Multicollinearity value and the logistic regression equation

After a diagnosis of multicollinearity adjusted for the intercept (Table 2), considering only the significant variables, the logistic regression equation was constructed (Table 3).

The effects of the age of the cow, lactation period, interval between birth and the end of the mating, average daily gain between delivery and 60 days post-partum, and average daily gain from 60 days post-partum to the end of the mating were entered into the logistic regression equation to explain the probability of pregnancy. From the value found for the Variance Inflation Factor (VIF), the eigenvalue (λ), the condition index (CI) and the proportion of the variance associated with the eigenvalues, no adjustments were made to reduce multicollinearity. Based on the Hosmer-Lemeshow statistic (2013), there is no evidence for a lack of model fit (p = 0.5294) (Table 3).

The variables in weight and body score at calving, at 60 days, and at the beginning and end of the mating were inserted into the model and later removed due to the occurrence of multicollinearity with the age of the cows, which is a premise for either not existing or being almost non-existent. The choice to leave age in the model is due to its greater significance in fitting the equations.

Cow age effect

From the odds ratio statistic, based on the mean age of this herd of 3.7 years, an increase in one year

Table 1 – Descriptive statistics of the characteristics evaluated in the cows.

Variable	N	Mean	SD	Min	Max
Age	284	3.7	0.8	3.0	5.0
Body weight (kg d^{-1})					
At calving	284	351.0	56.6	265.0	526.0
At 60 days post-partum	284	371.9	54.2	265.0	526.0
At the end of the mating	284	388.5	56.6	278.2	560.0
Body condition score (points)					
At calving	284	2.8	0.6	2.0	4.5
At 60 days post-partum	284	3.2	0.5	2.0	4.7
At the end of the mating	284	3.4	0.6	2.3	4.9
Average daily gain (kg d^{-1})					
Calving to 60 days post-partum	284	0.233	0.255	–0.707	1.273
Weaning to the end of the mating	284	0.248	0.248	–1.030	1.119
Lactation period (days)	284	102	39.6	55	178
Calving to the end of the mating	284	133	12.9	77	154
Pregnancy rate (%)	284	72.9	4.4	-	-

N = Number of observations; SD = Standard deviation; Min = Minimum; Max = Maximum.

Table 2 – Diagnosis of multicollinearity between the coefficients of the variables included in the model.

Variable	VIF	λ	CI	Proportion of variance decomposition associated with the eigenvalues				
				Age	Weaning	CIBS	Average Daily Gain	
							C-60d	60d-EBS
Age	1.36	0.531	2.99	0.0048	0.0062	0.0001	0.7227	0.1042
Lactation	1.78	0.447	3.27	0.0003	0.0284	0.0004	0.0492	0.6461
CIBS	1.30	0.217	4.68	0.0029	0.0927	0.0001	0.0507	0.0335
Average daily gain (kg d^{-1})								
C-60d	1.14	0.029	12.73	0.5791	0.8342	0.0537	0.1609	0.1116
60d-EBS	1.22	0.004	33.98	0.0028	0.0358	0.9454	0.0051	0.0937

VIF = Variance inflation factor; λ = Eigenvalue; CI = Condition index; CIBS = Calving interval and end of the mating; C-60d = Calving to 60 days post-partum; 60d-EBS = 60 days to the end of the mating.

represented an increase of 30 % in pregnancy, while a reduction of one year reduced the odds of pregnancy by 23 % (Table 4).

Effect of lactation period on pregnancy probability

During the lactation period, an increase of seven days in the time the calf remained with the cow reduced the odds of pregnancy by 12 %, while anticipating weaning by seven days increased the odds of pregnancy by 14 %, based on a mean lactation period of 102 days (Table 4).

Interval between parturition and the end of mating

An increase of seven days in the mean interval of 133 days between calving and the end of the mating represented a 28 % more chance of the cows becoming pregnant. In contrast, a reduction of seven days promoted a reduction of 21 % in the probability of pregnancy (Table 4).

Postpartum body weight gains

Based on an average daily gain of 0.233 and 0.248 kg d^{-1} for the first 60 days post-partum, and between 60 days post-partum to the end of the mating, an increase of 0.100 kg represented an increase of 17 % and 15 % in the odds of pregnancy, respectively. On the other hand, a reduction of 0.100 kg during the first 60 days post-partum and then to the end of the mating promoted a respective reduction of 14 % and 13 % in the odds of pregnancy (Table 4).

Discussion

The cows' weights and body condition scores from calving to the end of the mating, even when increased, played no part in the pregnancy probability equation due to multicollinearity with the age of the animals. The parameters of weight and body condition score increase from calving to the end of the mating due to the better nutritional conditions made available to the cows, with the greater nutrient intake, providing in addition to maintening the nutritional conditions for weight gain and an increase in body score which are positively correlated with reproductive performance (Vaz et al., 2020; Klein et al., 2021). The body condition score represents the available body reserves that will be used for lactation and reproduction; when nutrition is inadequate, body reserves are depleted, reducing the body condition score (Diskin and Kenny, 2016), leading to low ovulation. Cows with higher body condition scores usually perform better (Bohnert et al., 2013). The mean body condition score, at calving, at 60 days post-partum, and at the end of the mating in the present study can be considered appropriate for determining reproduction in beef cows. On the other hand, the body condition score, which is analysed regardless of the size or physiological state of the animal, and is related to pregnancy (Bohnert et al., 2013), may be incorrect, as there might be differences in the ability of the cows to adapt to the environment, interfering in their metabolic, hormonal and reproductive behaviour.

Table 3 – Regression variables and confidence limits on the pregnancy rate of beef cows.

	Estimate	Standard Error	95 % Confidence Limits	*p*-value	HLT
Intercept	–2.9142	1.7911	–6.4244 to 0.5964	0.1038	0.5294
Age	0.2647	0.2198	–0.1661 to 0.6956	0.2285	
Weaning	–0.0181	0.0048	–0.0275 to –0.0087	0.0002	
CIBS	0.0327	0.0127	0.0078 to 0.0576	0.0100	
Average daily gain (kg d^{-1})					
C-60d	1.5236	0.7189	0.1146 to 2.9325	0.0341	
60d-EBS	1.3868	0.6882	0.0380 to 2.7357	0.0439	

HLT = Hosmer-Lemeshow Test; CIBS = calving interval and end of the mating; C-60d = calving to 60 days post-partum; 60d-EBS = 60 days to the end of the mating.

Table 4 – Estimate of the odds of each regression variable in the equation on the pregnancy rate of beef cows.

Intercept	PE	95 % CL	Increase		Reduction	
			Unit	Estimate	Unit	Estimate
Age	1.303	0.847 to 2.005	1 year	1.303	1 year	0.767
Lactation	0.982	0.973 to 0.991	7 days	0.881	7 days	1.135
CIBS	1.033	1.008 to 1.059	7 days	1.257	7 days	0.795
Average daily gain (kg d^{-1})						
C-60d	4.588	1.121 to 18.775	0.100 kg	1.165	0.100 kg	0.859
60d-EBS	4.002	1.039 to 15.421	0.100 kg	1.149	0.100 kg	0.871

PE = Point estimate; CL = Confidence limits; CIBS = calving interval and end of the mating; C-60d = calving to 60 days post-partum; 60d-EBS = 60 days to the end of the mating.

Cow age effect

In this study, the increase in the rate of reproduction with the increasing age of the cows is due to their having borne their first, second or third calf during years one, two and three of the evaluation, calving at three, four and five years of age, respectively. Cows of an advanced age, which might limit their performance, were not evaluated. Adult cows show superior reproductive performance compared to younger cows (Vieira et al., 2005; Bitencourt et al., 2020), as they are physiologically developed and do not require a large nutritional intake, unlike young cows who need different management to meet the requirements of maintenance, growth, lactation and reproduction (Bitencourt et al., 2020). Vieira et al. (2005), working with a herd of Nellore in the cerrado, found quadratic behaviour for the reproductive performance of the cows, with the pregnancy rate increasing up to the seventh calving, and decreasing as the number of births increased. When evaluating the determinant effects of pregnancy in heifers and primiparous cows in 43 experiments conducted on farms, Eloy et al. (2022) found greater ease of pregnancy in heifers associating lower primiparous pregnancy with calving stress and the effects of the first lactation while still growing. When evaluating both growing and adult cows, Bitencourt et al. (2020) found that adult cows were 66 % more reproductive than growing cows, and when stratified by calving precocity within the calving season, adult cows, even when calving at the end of the season, showed better reproductive performance than growing cows, even though the latter gave birth earlier.

Effect of lactation period on pregnancy probability

The probability of pregnancy was highly sensitive to a reduction in the lactation period. Milk production is important in breeding systems due to its positive correlation with the weaning weight of the calves. However, milk production and the physical presence of the suckling calf inhibit the hormonal trigger responsible for reproduction in cows (Montiel and Ahuja, 2005; Orihuela and Galina, 2019) due to the increase in the nutritional requirement for milk production, which is the most significant requirement of the beef cow during the reproductive cycle (NRC, 2016). Thus, weaning the calves early (at 76 days) allows the cows to regain their body weight, resulting in increases in the pregnancy rate than when the cows nurse their calves for longer periods (Vaz and Lobato, 2010; Orihuela and Galina, 2019). In primiparous beef cows, early weaning greatly improves reproduction (Vaz and Lobato, 2010), with higher body weights at calving influencing the pregnancy rate (Vaz et al., 2020). The calving interval was reduced by 17 days, afforded by the reduction of 21 days in the weaning age of the calf from 63 to 42 days postpartum (Cerdótes et al., 2004).

Interval between parturition and the end of mating

Early calving during the calving season is fundamental to reproductive success in beef cows due to the extended recovery period between calving and the next mating. Early pregnancy in the breeding season increases the overall production efficiency of herds (Eloy et al., 2022). However, cows that calve early in the season, in addition to better reproductive performance, tend to be more efficient due to their consuming better-quality pasture (Castilho et al., 2018) during lactation, weaning heavier calves (Bitencourt et al., 2020) and producing more kilogram of calf per kilogram of cow at weaning (Vaz et al., 2020).

Higher pregnancy rates were seen in cows that calved earlier in the season, explaining that the results were due to cows that calved earlier benefitting from a more extended period to the start of the mating, and despite being lighter at calving because of the quality of the forage offered during the post-partum period, showing more significant gains in body weight at the start of the mating (Castilho et al., 2018; Vaz et al., 2020).

Postpartum body weight gains

Gains in the body weight of the cow after calving and during the mating are fundamental to performance (Castilho et al., 2018). In the present study, even with no variations in nutrition, various animals showed better performance, which was reflected in higher rates of reproduction. Ideal nutrition levels promote better reproductive performance in beef cows, while at non-ideal feeding levels, weight loss and a negative daily variation in weight are typical (Trindade et al., 2016). Beef cows under inadequate nutrition conditions deplete their body reserves, losing body condition score (Vieira et al., 2005), resulting in a low ovulation rate due to the decrease in glucose and insulin levels and growth factor I (IGF-I) non-potentiating godonotropins luteinizing hormone (LH) and follicle-stimulating hormone (FSH) responsible for ovulation (Eloy et al., 2022). Therefore, for better reproductive response during mating, the cow must be in a nutritional state consistent with a positive daily variation in weight which will favor the hormonal trigger responsible for reproductive success. For heifers and primiparous cows, body weight at the beginning of the breeding season and average daily gains during the breeding season were determinants that explain the pregnancy rate (Eloy et al., 2022). However, multiple factors can determine the pregnancy rate and may be closely related to body weight, animal category or breed (Eloy et al., 2022).

Conclusion

As young cows progress to adulthood the odds of pregnancy increase. Reducing the time the calf remains with the cow, increasing the interval between calving and the end of the mating, and promoting better performance in the cows between calving and the end of breeding are strategies that increase the odds of pregnancy in the beef cow.

Authors' Contributions

Conceptualization: Reis, N.P.; Lobato, J.F.P.; Restle, J.; Vaz, R.Z. **Data curation**: Reis, N.P.; Sartori, D.B.S.; Vaz, R.Z. **Formal analysis:** Reis, N.P.; Pacheco, R.F. **Investigation:** Reis, N.P.; Sartori, D.B.S. **Methodology:** Lobato, J.F.P.; Pacheco, R.F.; Vaz, R.Z. **Supervision:** Vaz, R.Z. **Writing-original draft:** Reis, N.P.; Vaz, R.Z. **Writing-review & editing:** Reis, N.P.; Lobato, J.F.P.; Vaz, R.Z.; Nuñez, A.J.C.; Restle, J.

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