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Relationship between body weight and reproductive efficiency in Nelore (*Bos taurus indicus*) heifers submitted to TAI

[Relação entre peso corporal e eficiência reprodutiva em novilhas Nelore (*Bos taurus indicus*) submetidas à IATF]

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Abstract: The present study aimed to evaluate the influence of body weight and weight change on conception rate and pregnancy loss rates in Nelore heifers subjected to timed artificial insemination (TAI). A total of 1,927 pasture-raised heifers, 24 months-old on average were used. Hormonal protocols were carried out between October 2024 and March 2025. Heifers were weighed at three time points: 50 days before the protocol (D–50), at the beginning of TAI (D0), and at pregnancy diagnosis at 30 days post-AI (PD30). Body weight and average daily gain (ADG) were categorized into quartiles (Q1 = lightest; Q4 = heaviest) and associated with conception and pregnancy loss rates. Statistical analyses were performed using SAS Studio. Initially, a generalized logistic regression model was used, followed by a quartile-categorized model, with a significant level of 5 %. Conception rates of 51.3 % (988/1927) at PD30 and 48.1 % (926/1927) at PD60 were observed. Conception rates were higher ($p<0.001$) in Heifers with a corpus luteum at the beginning of the protocol. Absolute body weight at D0 was positively associated with conception rates ($p < 0.05$), as was periconceptional ADG, which influenced both fertility and pregnancy maintenance. Heifers with higher ADG showed a conception rate of 51.3 % (236/460) and a lower pregnancy loss rate of 3.7 % (9/245). Greater body weight performance and the presence of ovarian cyclicity improve conception rates and pregnancy maintenance in Nellore heifers submitted to TAI.

Keywords: ADG; CL; Conception; Pregnancy Loss.

Resumo: O presente estudo teve como objetivo avaliar a influência do peso corporal e do desempenho ponderal sobre a taxa de concepção e perda gestacional em novilhas Nelore submetidas à inseminação artificial em tempo fixo (IATF). Foram utilizadas 1.927 novilhas criadas a pasto, com idade média de 24 meses. Os protocolos hormonais foram realizados entre outubro de 2024 e março de 2025. As novilhas foram pesadas em três momentos: 50 dias antes do protocolo (D–50), início da IATF (D0) e no diagnóstico de gestação aos 30 dias após a IATF (DG30). As variáveis peso corporal e ganho médio diário (GMD) foram classificadas em quartis (Q1 mais leve e Q4 mais pesado) e associadas às taxas de concepção e perda gestacional. Análises estatísticas foram realizadas no SAS Studio. Primeiramente, utilizou-se um modelo de regressão logística generalizada ajustado, e

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posteriormente um modelo categorizado por quartil, com nível de significância de 5 %. Observou-se taxa de concepção de 51,3 % (988/1927) em DG30 e 48,1 % (926/1927) em DG60. As taxas de concepção foram maiores (p<0,001) em novilhas com corpo lúteo no início do protocolo. O peso corporal no D0 foi positivamente associado às taxas de concepção (p<0,05), assim como o GMD no período periconcepcional, que influenciou tanto a fertilidade quanto a manutenção da gestação. A concepção em novilhas com maior GMD foi de 51,3 % (236/460) e a perda gestacional de 3,7 % (9/245). Maior desempenho ponderal e presença de ciclicidade ovariana favorevem as taxas de concepção e manutenção da gestação em novilhas nelore submetidas a IATF.

Palavras-chave: CL; GMD; Perda Gestacional; Concepção.

1. Introduction

Brazilian beef cattle production stands out globally due to its scale and competitiveness, positioning the country as the world's largest exporter of beef, with more than 2.89 million tons exported in 2024 to over 157 countries [1]. Despite this international prominence, average productivity indices remain below those observed in competing countries, reinforcing the need for sustainable intensification strategies focused on productive and reproductive efficiency [2]. Projections by the Organization for Economic Co-operation and Development (OECD/FAO) [3] indicate a 12 % increase in global meat demand by 2029, requiring sustainable intensification of national production. Strategies such as the use of superior genetics, nutritional management, sanitary control, and assisted reproduction have been fundamental in increasing productivity without expanding the production area [4].

In this context, the cow–calf segment plays a strategic role, as it is responsible for producing the calves that supply the post-weaning and finishing phases. Approximately 60 % of livestock operations are involved in this stage [5]. The efficiency of this activity depends primarily on improvements in reproductive indices, such as pregnancy rate and age at first calving, factors that directly impact system costs and profitability [6]. The early and well-planned introduction of heifers into reproductive management in cow–calf herds can reduce the age at first calving, shorten the generation interval, and allow greater incorporation of superior genetics [7]. However, this category still presents significant challenges in achieving optimal efficiency. Data from Baruselli et al. [8] indicate an average conception rate per fixed-time artificial insemination (FTAI) of 43 % in zebu heifers, lower than that observed in multiparous cows (54 %), highlighting the need for improvements in selection, reproductive protocols, and specific pre-breeding management applied to young females.

Several factors influence heifer fertility, including parity, ovarian cyclicity, body condition, nutrition, and hormonal response [8,9]. Nutrition, in particular, exerts a direct influence on reproductive performance, as previously demonstrated by Wiltbank et al. [10]. Contemporary studies highlight that the metabolic environment during gestation, combined with weight gain and body condition before puberty, decisively impacts future reproductive capacity [11,12]. Adequate post-weaning nutrition can advance the age at first service, even in heifers genetically predisposed to late puberty [4]. Puberty in *Bos indicus* heifers generally occurs between 22 and 36 months, with first calving around 44 to 48 months [13]. Strategies that increase weight gain and improve body condition, with greater adipose tissue deposition, favor leptin secretion, a hormone involved in activating the reproductive axis and initiating cyclicity [14,15]. Adequate body maturity is associated with a better response to FTAI protocols, promoting higher conception rates. Thus, heifers with better body condition tend to exhibit earlier ovarian cyclicity and a more efficient hormonal response [14–16].

Thus, we hypothesized that animals with greater body weight and higher average daily gain (ADG) would present better reproductive performance and higher pregnancy maintenance rates. The objective of this study was to evaluate the relationship between heifer body weight during the ovulation induction and synchronization period and the conception rates and pregnancy losses obtained by FTAI. It is expected that the results may support strategic decision-making regarding the management of heifers exposed to the breeding season, promoting greater productive efficiency.

2. Material and Methods

2.1 Ethics Committee

All procedures performed in this study were previously evaluated and approved by the Animal Ethics Committee (CEUA) of the Federal University of Goiás, under protocol no. 055/24, in accordance with national ethical guidelines for animal experimentation.

2.2 Study Location

The experiment was conducted at Fazenda Nova Piratininga, located in the municipality of São Miguel do Araguaia, state of Goiás, Brazil. The activities were carried out between October 2024 and March 2025. The heifers were maintained on *Andropogon gayanus* Kunth pastures with *ad libitum* access to water and mineral salt. Throughout the entire experimental period, the animals remained under a continuous grazing system and were handled in corrals only for the application of hormonal protocols and sample collection.

2.3 Experimental Design

The experimental study was conducted with 2,000 Nellore heifers (*Bos indicus*), all at their first breeding service. The females were maintained under the farm's routine sanitary protocol, including vaccination against important reproductive diseases, according to the health calendar adopted by the farm. The animals were distributed into 16 experimental groups (± 33.3 ha), divided according to group weight and number of animals.

Artificial inseminations were performed by two experienced technicians who regularly participate in training courses and had the highest conception rates in heifers on the farm, using conventional semen from eight bulls with proven fertility. The average age of the heifers at the beginning of the experiment (D−50; 50 days before day 0 of the FTAI protocol) was 24.68 ± 2.07 months, with an average body weight of 277.08 ± 18.36 kg.

The heifers underwent gynecological examination by transrectal ultrasonography at D0 (day 0 of the FTAI protocol) to assess ovarian cyclicity (presence or absence of corpus luteum—CL), as well as pregnancy diagnosis at 30 days and confirmation of conception at 60 days (DG30 and DG60) after FTAI. In addition, body weight was recorded at D−50, D0, and DG30.

Gynecological evaluations were performed by two experienced farm veterinarians using transrectal ultrasonography with a Mindray DP10 device equipped with a 7.5 MHz linear transrectal transducer (DP10, Mindray, China). For weight measurements, animals were not fasted and were weighed individually as they were restrained in the chute using an integrated scale (S3, Tru-Test, United States).

After DG30, pregnant females were allocated to paddocks separate from non-pregnant ones, while remaining within the same paddock rotation system used at the beginning of the experiment, and both groups received equivalent nutritional supplementation.

2.3.1 Reproductive Management and Pregnancy Diagnosis

On D−50, the females were brought to the corral for body weight evaluation. Hormonal protocols were conducted by the farm team. On D−24 (24 days before day 0 of the FTAI protocol), the heifers began the ovulation induction protocol with the insertion of a 500 mg intravaginal progesterone device (Repro One®, GlobalGen vet science).

On D−12, the device was removed, and 0.5 mg of estradiol cypionate (Cipion®, GlobalGen vet science) was administered intramuscularly (IM). On D0, the animals received 2 mg of estradiol benzoate (Syncrogen®, GlobalGen vet science) IM, along with a new intravaginal progesterone implant. Females presenting a corpus luteum (CL) on D0 received 0.530 mg of cloprostenol (Induscio®, GlobalGen vet science) IM, and body weights were recorded.

After eight days (D8), the implant was removed, and the heifers received 0.530 mg of cloprostenol, 0.5 mg of estradiol cypionate, and 200 IU of equine chorionic gonadotropin (ECGen®, GlobalGen vet science) IM. On D10, at the time of artificial insemination, 8.4 µg of buserelin (Maxrelin®, GlobalGen vet science) was administered IM.

Pregnancy diagnoses were performed 30 days after FTAI and confirmed at 60 days (Figure 1). Finally, body weight data were collected at DG30.

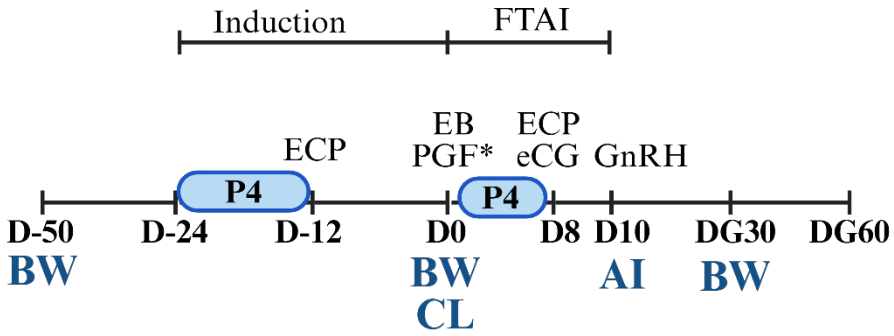

Figure 1. Representation of the experimental design with the protocol used for FTAI, indicating the periods in which body weight measurements and pregnancy diagnoses were performed in Nelore heifers on a farm in the state of Goiás, Brazil. P4 corresponds to a 500 mg intravaginal progesterone implant; EC to 0.5 mg estradiol cypionate; EB to 2 mg estradiol benzoate; PGF2α to 0.530 mg prostaglandin F2α administered to animals presenting a corpus luteum (CL); eCG to equine chorionic gonadotropin; and GnRH to 8.4 µg buserelin. Pregnancy diagnosis and body weight evaluation were performed at 30 (DG30) and 60 (DG60) days after artificial insemination (AI).

2.4 Statistical Analysis

Statistical analyses were performed using SAS Studio (SAS Institute Inc., Cary, NC, USA). Initially, the data were imported from the “SAS” worksheet of an Excel spreadsheet, and incomplete records were excluded, retaining only animals with valid information (1,927 animals) for pregnancy at 30 days (DG30), 60 days (DG60), presence of corpus luteum (CL0), and body weights (BW D−50, BW D0, BW DG30, and BW change over 80 days).

The influence of body weight on reproductive performance was evaluated in two ways:

1. Continuous models: A generalized logistic regression model was fitted using PROC GLIMMIX to investigate the association between DG30 and DG60 and the continuous variables BW D−50, BW D0, and BW DG30, adjusting for the fixed effects of CL0 and inseminator. Adjusted means were estimated using LSMEANS, and multiple comparisons among inseminators and CL0 categories were performed with Tukey adjustment (ADJUST=TUKEY). Adjusted probabilities were obtained using the ILINK option.

2. For a categorical analysis of the influence of body weight, animals were classified into quartiles based on weight variables (BW D−50, BW D0, BW DG30) and the difference between BW DG30 and BW D−50 (ΔBW). Classification was performed using PROC RANK with the GROUPS=4 option, generating the variables Q_BW D−50, Q_BW D0, Q_BW DG30, and Q_ DELTA.

For each of these classifications, frequency analyses were performed (PROC FREQ) to compare the proportion of pregnant females across quartiles at DG30, DG60, and pregnancy loss (positive pregnancy at DG30 and negative at DG60), using the chi-square test.

Additionally, logistic regression models were fitted using PROC GLIMMIX, considering the binary outcome (pregnancy or loss) and body weight quartiles as fixed effects (Q_BW D−50, Q_BW D0, Q_BW DG30, or Q_DELTA, depending on the analysis). For the outcome of positive pregnancy at 30 days (DG30), models were adjusted for the covariates presence of corpus luteum (CL0), batch, and inseminator. For the outcomes of positive pregnancy at 60 days (DG60) and pregnancy loss, models included only batch as a covariate.

Adjusted means by quartile were obtained using the LSMEANS statement, and comparisons among groups were performed using the DIFF option with Tukey adjustment for multiple comparisons (ADJUST=TUKEY). P-values were obtained using PDIFF, and differences among quartiles were indicated by letters (LINES option), allowing the identification of statistically distinct groups at a 5 % significance level ($\alpha = 0.05$).

The variables inseminator and presence of corpus luteum (CL) at the beginning of the protocol were included in the statistical model as fixed effects in the analysis performed using the GLIMMIX procedure. Interactions between weight quartiles and these variables were evaluated in preliminary analyses; however, they were not statistically significant and were therefore not retained in the final model.

Finally, to evaluate the relationship between body weight at the beginning of the protocol (day 0) and early conception rate (positive pregnancy diagnosis at 30 days, DG30), a logistic regression stratified by the presence of corpus luteum (CL0) was used. The analysis was conducted in SAS Studio using the PROC LOGISTIC procedure, with DG30 (0 = non-pregnant, 1 = pregnant) as the outcome variable and BW D0 as the continuous predictor. The presence of CL was included as a categorical variable in the model. Prediction curves were generated for each stratum (CL0 = 0, absent; CL0 = 1, present) with 95 % confidence intervals, allowing visualization of the interaction between body weight and CL presence.

3. Results

Figure 2 presents the general descriptive data for the 2,000 animals initially considered in the study (incomplete records were excluded, retaining only animals with valid information), including the mean and standard deviation (Mean ± SD) of body weights (kg) of Nellore heifers obtained at three distinct time points of the experiment, as well as the average daily gain (ADG) during the 80-day evaluation period (D−50 to DG30).

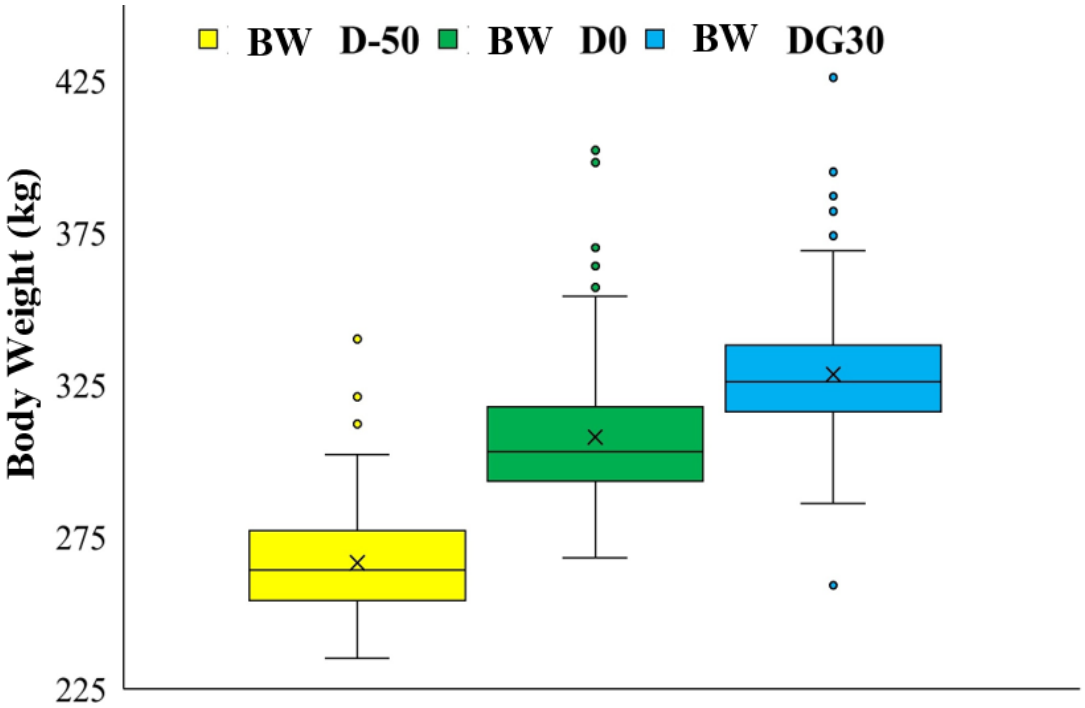

Figure 2. Boxplot of body weights (kg) of Nelore heifers evaluated at three experimental time points. 50 days before FTAI (D−50), at the beginning of the FTAI protocol (D0), and 30 days after artificial insemination (DG30). The boxes represent the interquartile range (Q1–Q3), the horizontal line within the box indicates the median, the "X" represents the mean, the whiskers indicate the minimum and maximum values within 1.5 times the interquartile range, and points outside these limits correspond to outliers.

At the initial weighing, 50 days before the start of the protocol (D−50), the heifers had an average body weight of 277.08 ± 18.36 kg. At D0 and D30, the average body weights were 306.40 ± 21.36 and 330.52 ± 21.71 kg, respectively, indicating a continuous increase over time. Based on these data, the ADG for the entire period was calculated as 0.668 ± 0.190 kg/day.

The conception rate of the heifers at DG30 was 51.3 %, corresponding to 988 pregnant heifers out of a total of 1,927 evaluated. At DG60, the final conception rate decreased to 48 %, with 926 heifers confirmed as pregnant. Considering the number of heifers diagnosed as pregnant at DG30, the overall pregnancy loss in the group was 6.3 % (62/988; Figure 3).

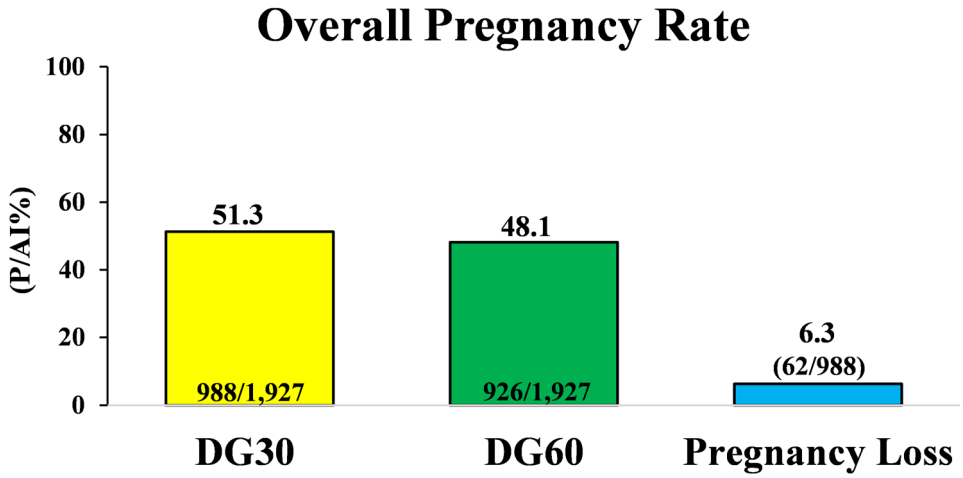

Figure 3. Overall pregnancy rate (%) of Nelore heifers evaluated at 30 days (DG30) and 60 days (DG60) after FTAI, as well as pregnancy loss. The values presented correspond to the proportion of pregnant females relative to the total number evaluated at each diagnostic time point: 988/1,927 (DG30) and 926/1,927 (DG60), and females with pregnancy loss at DG60 of 62/988 (Pregnancy loss).

Initially, after applying the generalized logistic regression model (GLIMMIX), a significant effect of the inseminator on conception rate per AI was observed. Inseminator A exhibited a rate of 54.2 % (520/953), whereas inseminator B showed 48.4 % (470/971) (p = 0.0178). These results indicate that the individual skill or technique of the inseminator may influence AI efficiency.

Similarly, the presence of a corpus luteum (CL) at the beginning of the hormonal protocol (D0) had a positive effect on conception rate (p = 0.0003), indicating that these females had already reached sexual maturity, with better responses to the hormonal protocol and, therefore, higher chances of conceiving compared to other heifers. Among animals with CL present at D0 (n = 1,295/1,927; 67.2 %), the conception rate was 54.85 % (711/1,295), whereas among those without CL (n = 632/1,927; 32.8 %), it was 45.15 % (285/632).

No influence of bulls on conception rate at 30 days post-AI (P/AI) was observed (p = 0.18). These results reinforce the importance of the presence of a corpus luteum, that is, the use of females that have reached puberty at the beginning of the protocol, for reproductive success.

Although the categorical variable batch and the continuous variables BW D−50, BW D0, and BW DG30 were included in the logistic regression model, none showed an effect on conception rate when evaluated individually (p > 0.30). These findings indicate that, in isolation, body weight at the different evaluated time points was not associated with conception at DG30.

However, considering the possibility of non-linear patterns or threshold effects not captured by continuous analyses, animals were subsequently classified into quartiles based on body weight at days −50, 0, and 30 in order to explore potential associations between different weight ranges and conception rates.

In the first model, females were divided into four quartiles based on body weight measured at D−50: Q1 (254.53 ± 7.9 kg), Q2 (270.91 ± 3.77 kg), Q3 (283.69 ± 3.77 kg), and Q4 (301.08 ± 8.79 kg). Figure 4 illustrates the results of conception rates at DG30 and DG60, as well as pregnancy losses between these periods. No differences were observed (p > 0.05) for any of the analyzed variables.

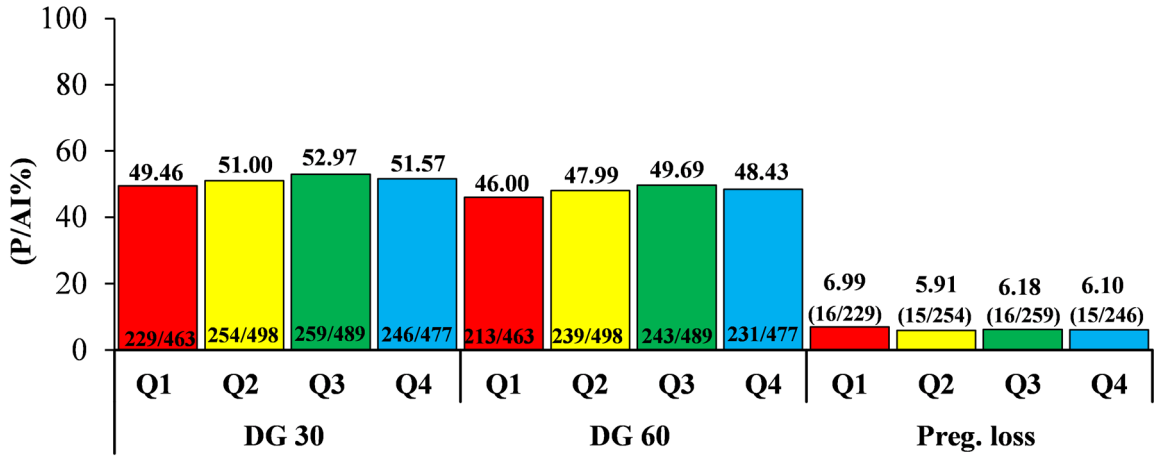

Figure 4. Conception rates at 30 days (DG30) and 60 days (DG60), and pregnancy loss (%) in Nelore heifers classified by body weight quartiles at D−50. The columns represent the groups Q1 (254.53 ± 7.9 kg), Q2 (270.91 ± 3.77 kg), Q3 (283.69 ± 3.77 kg), and Q4 (301.08 ± 8.79 kg). The bars represent the conception rate (%) for each quartile (Q1 to Q4), with the number of pregnant females over the total number of inseminated animals indicated at the base of each bar. No differences were observed among groups (p > 0.05).Source: Author.

Subsequently, in the second model, animals were divided into four quartiles based on body weight measured at D0: Q1 (280.5 ± 12.61 kg), Q2 (300.17 ± 3.75 kg), Q3 (313.3 ± 3.97 kg), and Q4 (333.49 ± 12.23 kg). Figure 5 shows the conception rates at DG30 and DG60, as well as pregnancy loss in heifers grouped into quartiles (Q1 to Q4).

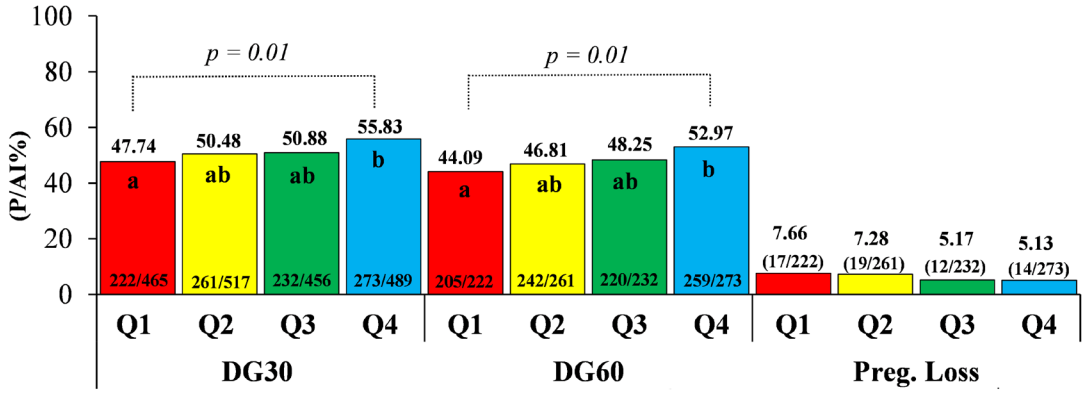

Figure 5. Pregnancy rates at DG30 and DG60, and pregnancy loss between diagnoses, in heifers distributed into quartiles according to body weight at D0. The columns represent the conception rate (%) for each quartile (Q1 to Q4), with the number of pregnant animals over the total number of inseminated animals indicated at the base of each bar. The mean body weights (kg) of the quartiles were: Q1 (280.5 ± 12.61), Q2 (300.17 ± 3.75), Q3 (313.3 ± 3.97), and Q4 (333.49 ± 12.23). Bars with different letters indicate significant differences ($p < 0.05$), with p-values presented within the boxes.

At DG30, conception rates ranged from 47.74 % in Q1 to 55.83 % in Q4. The Q4 group, composed of the heaviest animals, showed a higher rate compared to Q1 ($p = 0.01$), indicating that greater body weight at the beginning of the protocol was associated with higher conception rates at 30 days. At DG60, this pattern was maintained, with Q1 showing 44.09 % conception and Q4 reaching 52.97 %, again with a significant difference between the lowest and highest weight groups ($p = 0.01$). This suggests that greater body weight is also associated with pregnancy maintenance up to 60 days.

No differences were observed among groups regarding pregnancy loss, which ranged from 5.13 % (Q4) to 7.66 % (Q1) ($p > 0.05$).

In the third analysis, females were divided into four quartiles based on body weight measured at D30: Q1 (303.44 ± 11.07 kg), Q2 (323.89 ± 3.96 kg), Q3 (336.79 ± 3.91 kg), and Q4 (358.31 ± 11.96 kg). Figure 6 presents the conception rates at DG30 and DG60, as well as pregnancy loss rates.

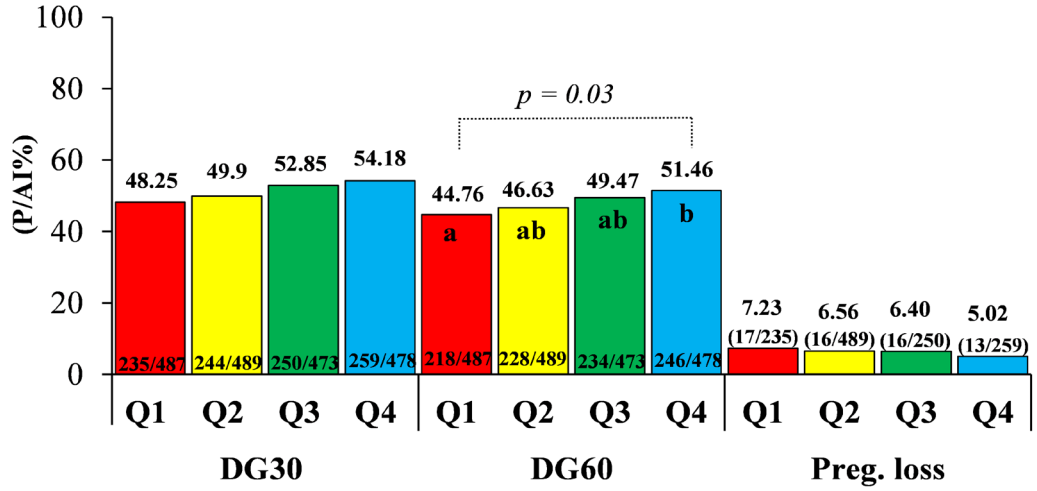

Figure 6. Pregnancy rates at 30 days (DG30) and 60 days (DG60), and pregnancy loss between DG30 and DG60 in heifers classified into quartiles based on mean body weight at DG30. Q1 (303.44 ± 11.07 kg), Q2 (323.89 ± 3.96 kg), Q3 (336.79 ± 3.91 kg), and Q4 (358.31 ± 11.96 kg). The columns represent the pregnancy rate (%) for each quartile (Q1 to Q4), with the number of pregnant animals over the total number of inseminated animals indicated at the base of each bar. Different letters (a, b) indicate statistically distinct groups.

No differences were observed (p > 0.05) in conception rates at DG30 among quartiles, with values ranging from 48.25 % (Q1) to 54.18 % (Q4). For DG60, lighter animals (Q1, 44.76 %) showed lower conception rates (p = 0.03) compared to heavier animals (Q4, 51.46 %), while the other groups did not differ from each other (p > 0.05).

No differences were identified (p > 0.05) among quartiles regarding pregnancy loss between DG30 and DG60, which ranged from 7.23 % in the lightest group (Q1) to 5.02 % in the heaviest group (Q4).

Finally, in the last quartile-based analysis, females were classified according to body weight change, defined as the difference between body weight at D−50 and D30: Q1 (34.89 ± 9.00 kg), Q2 (50.45 ± 2.62 kg), Q3 (58.73 ± 2.65 kg), and Q4 (71.86 ± 8.79 kg). Figure 7 presents the conception rates at 30 and 60 days, as well as pregnancy loss rates, for the four evaluated quartiles.

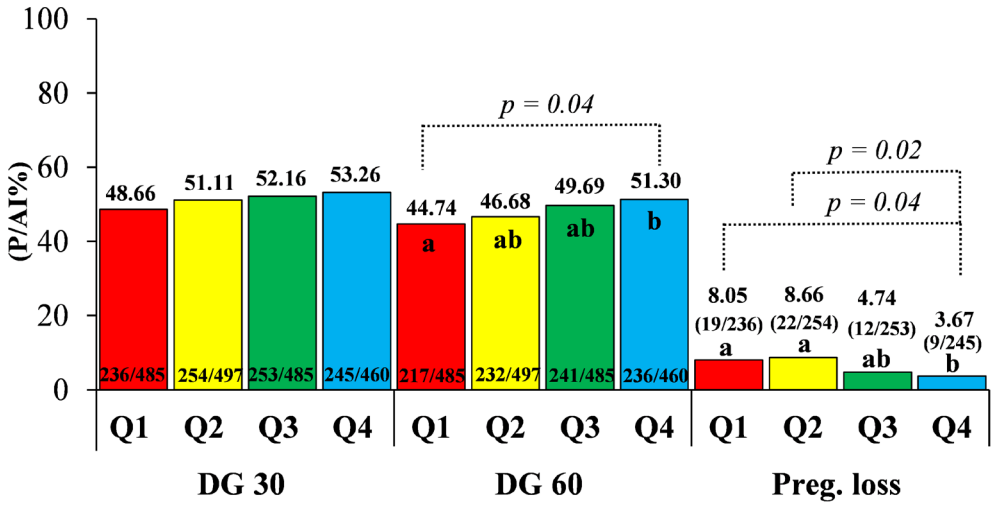

Figure 7. Pregnancy percentage in relation to average daily gain (ADG) across quartiles, with Q1 representing the lowest ADG and Q4 the highest, evaluated at pregnancy diagnoses at 30 days (DG30) and 60 days (DG60), as well as pregnancy loss percentage, distributed by performance quartiles. Q1 (34.89 ± 9.00 kg), Q2 (50.45 ± 2.62 kg), Q3 (58.73 ± 2.65 kg), and Q4 (71.86 ± 8.79 kg). The columns represent the conception rate (%) for each quartile (Q1 to Q4), with the number of pregnant animals over the total number of inseminated animals indicated at the base of each bar. Bars with different letters indicate significant differences (p < 0.05), with p-values presented within the boxes.

Regarding pregnancy at 30 days, no differences were observed (p > 0.05) among groups, with rates ranging from 48.6 % in animals with lower weight gain (Q1) to 53.26 % in those with higher weight gain (Q4). At DG60, in addition to a numerical increasing trend in conception rates across weight gain quartiles—Q1 (217/485, 44.74 %), Q2 (232/497, 46.68 %), Q3 (241/485, 49.69 %), and Q4 (236/460, 51.30 %)—it was observed that animals with lower weight gain (Q1) had a lower conception rate (p = 0.04) compared to those with higher weight gain (Q4). However, the other groups did not differ from each other (p > 0.05). Furthermore, animals with lower weight gain, Q1 (19/236, 8.05 %) and Q2 (22/254, 8.66 %), showed higher (p < 0.05) pregnancy loss rates compared to animals with higher weight gain (Q4 = 9/245, 3.67 %).

To evaluate the interaction between body weight and ovarian status at day 0 (beginning of the synchronization protocol), the heifers were stratified based on the presence or absence of a corpus luteum (CL) at the start of the synchronization protocol.

In females without CL at D0, a positive association was observed between body weight and the probability of pregnancy at 30 days after FTAI, with higher conception likelihood as body weight increased (p = 0.027; n = 632), indicating that these heifers were more delayed in terms of physiological maturity and, therefore, required higher body weights to reach sexual maturity. In contrast, in females with CL at D0, no effect of body weight on the probability of conception was observed (p = 0.294; n = 1,295), suggesting that these heifers had already reached sexual maturity at the beginning of the protocol, regardless of their body weight (Figure 8).

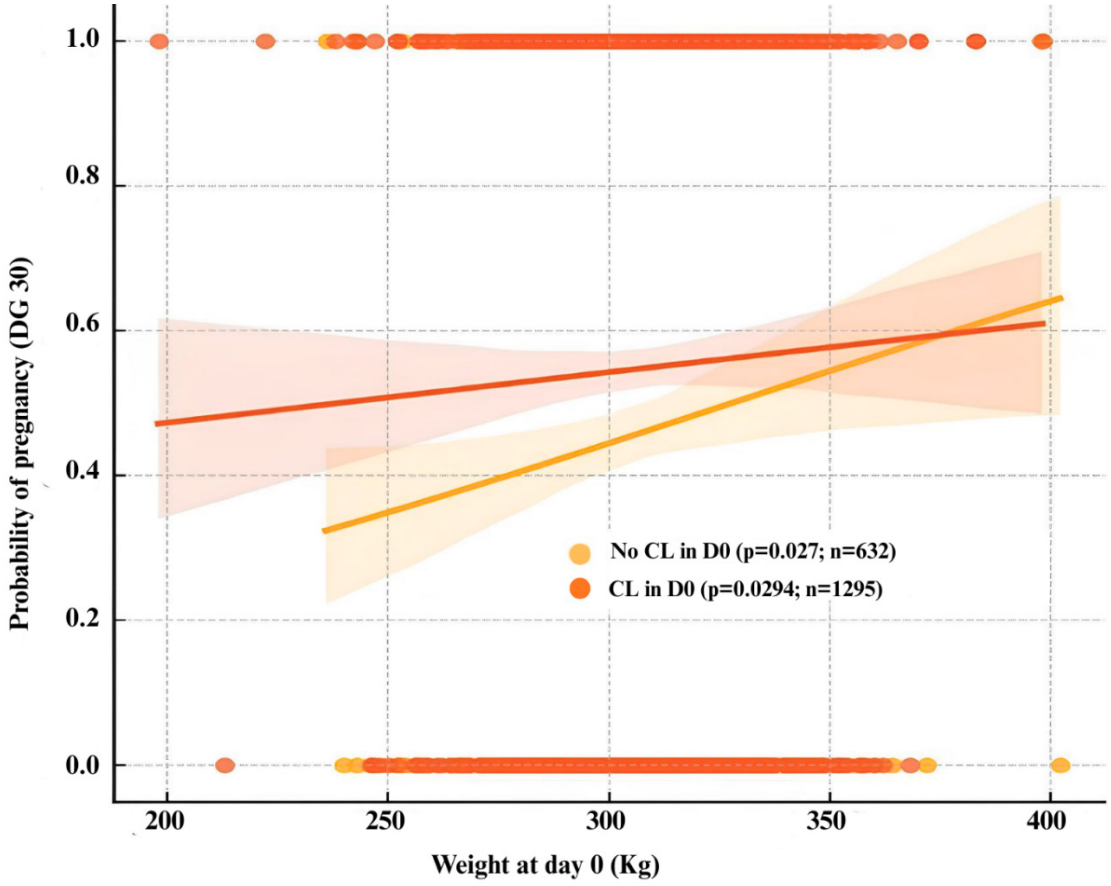

Figure 8. Relationship between body weight at day 0 and the probability of pregnancy at 30 days in Nelore heifers. Stratified by the presence or absence of a corpus luteum (CL) at the beginning of the protocol.

4. Discussion

The results obtained in this study highlight the inherent complexity of reproductive dynamics in Nellore beef heifers, particularly in the context of fixed-time artificial insemination (FTAI). The conception rate recorded at 30 days (51.3 %) is higher than the expected standards for *Bos indicus* heifers raised on pasture, as reported in the literature, but still reflects the challenge that this category represents compared to multiparous females, whose average conception rate following FTAI often exceeds 54 % [8]. These findings reinforce that, in heifers, factors such as physiological immaturity, lower ovarian activity, and greater sensitivity to nutritional and environmental variations influence reproductive success [15,17–19].

The pregnancy loss rate of 6.3 % between 30 and 60 days after FTAI is also within the ranges reported in the literature [20], but should not be overlooked. Pregnancy maintenance is strongly influenced by embryo quality and the uterine environment, both of which are sensitive to maternal metabolic status, especially in heifers that are still growing [21, 22].

The absence of an effect of body weight as a continuous variable at D−50, D0, and D30 on conception suggests that, in isolation, absolute body weight is not a reliable indicator for assessing sexual maturity in heifers. This finding is consistent with Ayres et al. [23], who highlight the limitations of univariate evaluation of body weight as a predictor of conception. However, when the data were stratified into quartiles, important associations emerged.

Greater body weight at D0 (Q4 = 333.49 ± 12.23 kg) was associated with higher conception rates at both DG30 (55.8 %) and DG60 (52.9 %) compared to Q1 (mean body weight of 280.5 ± 12.6 kg; DG30 = 47.7 %; DG60 = 44.1 %). This finding is consistent with previous studies indicating that females with greater body weight within an appropriate range for their age and physiological stage tend to show a better hormonal response and a higher probability of reproductive success [16, 24, 25].

Importantly, average daily gain (ADG) during the 80-day evaluation period (overall mean of 0.668 ± 0.190 kg/day) had a relevant impact when analyzed across performance categories. Animals with greater gains (Q4 = 71.9 ± 8.7 kg) showed higher pregnancy rates at 60 days (51.3 %) and lower pregnancy losses (3.7 %) compared to animals with lower gains (Q1 = 34.9 ± 9.0 kg), which exhibited 44.7 % pregnancy and 8.1 % loss ($p < 0.05$). These results indicate that, more than absolute body weight, body performance during the periconceptional period has a direct effect on embryo viability and pregnancy maintenance, corroborating D'Occhio, Baruselli, and Campanile [17] and Funston et al. [11], who associated maternal metabolic environment with physiological maturity, body weight, and, consequently, embryo survival.

The role of ovarian cyclicity was also confirmed in this study. The presence of a corpus luteum (CL) at the beginning of the protocol was associated with a higher pregnancy rate (54.9 % vs. 45.1 % in females without CL; $p = 0.0003$), as also described by Sá Filho et al. [26] and Stevenson et al. [27]. This reinforces that prior activation of the reproductive axis is a determining factor for the success of hormonal protocols.

Additionally, in females without CL, body weight at D0 influenced the probability of pregnancy, whereas this effect was not observed in cycling females. This interaction suggests that, in acyclic heifers, greater body development and live weight at the time of the protocol may partially compensate for the absence of cyclicity, possibly by promoting a better response to the exogenous hormones used for ovulation induction. These results indicate that these females, due to their later physiological development, need to reach higher body weights to attain puberty and express greater reproductive potential [14,28].

Body maturity not only influences the onset of puberty but also the physiological capacity to sustain pregnancy. Animals with delayed physiological maturity and limited adipose tissue reserves exhibit lower leptin secretion, a hormone directly linked to the hypothalamic–pituitary–ovarian axis and the induction of reproductive activity [15,29]. Thus, the association between greater body weight and improved reproductive success, observed in the higher weight and gain quartiles, supports the importance of nutritional management strategies aimed at achieving physiological maturity in females prior to the breeding season.

Additionally, the influence of the inseminator on pregnancy rate ($p = 0.0178$) highlights the need for technical standardization and continuous training of professionals involved in FTAI procedures. Variability among inseminators, even under controlled experimental conditions, may reflect subtle differences in skill, precision, or adherence to the protocol, directly impacting reproductive outcomes. These findings are consistent with the recommendations of Baruselli et al. [8], who emphasize the importance of periodic training and quality control in reproductive

biotechnologies as a means to ensure greater reproducibility and efficiency in fixed-time artificial insemination programs. In summary, the results of this study demonstrate that both physiological status (ovarian cyclicity) and growth performance (especially ADG) exert synergistic effects on the fertility of Nellore heifers. Management strategies that promote adequate physiological maturity prior to the breeding season, combined with the identification of ovarian status, represent valuable tools for maximizing reproductive indices. The integrated adoption of these criteria may significantly contribute to reducing embryonic losses and increasing reproductive efficiency in beef cattle production systems.

5. Conclusion

The results of this study demonstrate that the reproductive performance of Nellore heifers subjected to FTAI is strongly associated with physiological maturity at the beginning of the protocol, particularly the presence of a corpus luteum and weight gain during the period prior to insemination. Although absolute body weight was not an isolated predictor of conception, heifers with greater development and better growth performance showed higher conception rates and lower pregnancy losses. These findings reinforce the importance of integrated nutritional and reproductive management strategies aimed at achieving physiological maturity in heifers before the breeding season to improve productive efficiency in cow–calf systems. In addition, the critical role of ovarian cyclicity as a physiological marker of sexual maturity, as well as the technical qualification of inseminators, is highlighted for the effectiveness of FTAI programs.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Data availability statement

The complete dataset supporting the results of this study is available upon request from the corresponding author.

Author contributions

Conceptualization: Sales Filho, G., Déo, P. H., Melo, L. F., Consentini, C. E. C., Sprícigo, J. F. W.; Data curation: Castro, A. C. S., Carneiro, M. C., Imai, L. S., Consentini, C. E. C., Sprícigo, J. F. W.; Formal analysis: Imai, L. S., Sprícigo, J. F. W.; Funding acquisition: Carneiro, M. C., Sprícigo, J. F. W.; Investigation: Castro, A. C. S., Carneiro, M. C., Sales Filho, G., Moura, G. H. C.; Methodology: Castro, A. C. S., Carneiro, M. C., Melo, L. F., Consentini, C. E. C., Sprícigo, J. F. W.; Project administration: Castro, A. C. S., Carneiro, M. C., Sales Filho, G.; Resources: Sales Filho, G., Déo, P. H., Consentini, C. E. C.; Software: Imai, L. S.; Supervision: Melo, L. F., Consentini, C. E. C., Sprícigo, J. F. W.; Validation: Imai, L. S., Consentini, C. E. C., Sprícigo, J. F. W.; Visualization: Castro, A. C. S.; Writing – original draft: Castro, A. C. S.; Writing – review & editing: Sprícigo, J. F. W.

Declaration of Generative AI Use

The authors did not use generative artificial intelligence tools or technologies in the creation or editing of any part of this manuscript.

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References

1. Brasil bate recorde nas exportações de carne bovina em 2024 [Internet]. 2025 [cited 2025 May 23]. Available from: https://abiec.com.br/brasil-bate-recorde-nas-exportacoes-de-carne-bovina-em-2024/

2. Ondei V. Que desfrute foi esse? • Portal DBO [Internet]. Portal DBO. 2020 [citado 23 de maio de 2025]. Available from: https://portaldbo.com.br/que-desfrute-e-esse/

3. FAO: América Latina e Caribe vão responder por mais de 25 % das exportações agrícolas globais até 2028 | As Nações Unidas no Brasil [Internet]. [citado 29 de julho de 2025]. Available from: https://brasil.un.org/pt-br/83643-fao-am%C3%A9rica-latina-e-caribe-v%C3%A3o-responder-por-mais-de-25-das-exporta%C3%A7%C3%B5es-agr%C3%ADcolas-globais

4. Ferraz MVC, Pires AV, Santos MH, Silva RG, Oliveira GB, Polizel DM, et al. A combination of nutrition and genetics is able to reduce age at puberty in Nelore heifers to below 18 months. Animal [Internet]. 1o de janeiro de 2018 [citado 20 de maio de 2025];12(3):569–74. Available from: https://doi.org/10.1017/S1751731117002464

5. Issuu [Internet]. 2025 [citado 16 de julho de 2025]. Revista ABCZ 126. Available from: https://issuu.com/abcz.pmgz/docs/revista_abcz_126

6. Caixeta DG, Carmo JP do. CRIAÇÃO DE BEZERROS NEONATOS: manejo e bem estar. Scientia Generalis [Internet]. 20 de outubro de 2020 [citado 19 de maio de 2025];1(3):92–103. Available from: http://scientiageneralis.com.br/index.php/SG/article/view/v1n3a10

7. Wathes DC, Pollott GE, Johnson KF, Richardson H, Cooke JS. Heifer fertility and carry over consequences for life time production in dairy and beef cattle. Animal [Internet]. 1o de janeiro de 2014 [citado 20 de maio de 2025];8:91–104. Available from: https://doi.org/10.1017/S1751731114000755

8. Baruselli PS, Ferreira RM, Colli MHA, Elliff FM, Sá_Filho MF, Vieira L, et al. Timed artificial insemination: current challenges and recent advances in reproductive efficiency in beef and dairy herds in Brazil. Anim Reprod [Internet]. 2017 [citado 20 de maio de 2025];14(3):558–71. Available from: http://dx.doi.org/10.21451/1984-3143-AR999

9. Consentini CEC, Alves RLOR, Silva MA, Galindez JPA, Madureira G, Lima LG, et al. What are the factors associated with pregnancy loss after timed-artificial insemination in *Bos indicus* cattle? Theriogenology [Internet]. 15 de janeiro de 2023 [citado 26 de maio de 2025];196:264–9. Available from: https://doi.org/10.1016/j.theriogenology.2022.10.037

10. Wiltbank JN, Rowden WW, Ingalls JE, Geegoey KE, Koch RM. Effect of Energy Level on Reproductive Phenomena of Mature Hereford Cows. Journal of Animal Science [Internet]. 1o de maio de 1962 [citado 20 de maio de 2025];21(2):219–25. Available from: https://doi.org/10.2527/jas1962.212219x

11. Funston RN, Martin JL, Larson DM, Roberts AJ. PHYSIOLOGY AND ENDOCRINOLOGY SYMPOSIUM: Nutritional aspects of developing replacement heifers1. Journal of Animal Science [Internet]. 1o de abril de 2012 [citado 21 de maio de 2025];90(4):1166–71. Available from: https://doi.org/10.2527/jas.2011-4569

12. Martin LC, Brinks JS, Bourdon RM, Cundiff LV. Genetic effects on beef heifer puberty and subsequent reproduction. Journal of Animal Science [Internet]. 1o de dezembro de 1992 [citado 30 de maio de 2025];70(12):4006–17. Available from: https://doi.org/10.2527/1992.70124006x

13. Rodrigues PF, Menezes LM, Azambuja RCC, Suñé RW, Barbosa Silveira ID, Cardoso FF. Milk yield and composition from Angus and Angus-cross beef cows raised in southern Brazil1. Journal of Animal Science [Internet]. 1o de junho de 2014 [citado 22 de maio de 2025];92(6):2668–76. Available from: https://doi.org/10.2527/jas.2013-7055

14. Chilliard Y, Delavaud C, Bonnet M. Leptin expression in ruminants: Nutritional and physiological regulations in relation with energy metabolism. Domestic Animal Endocrinology [Internet]. 1o de julho de 2005 [citado 23 de maio de 2025];29(1):3–22. Available from: https://doi.org/10.1016/j.domaniend.2005.02.026

15. Perry GA. Factors affecting puberty in replacement beef heifers. Theriogenology [Internet]. 1o de julho de 2016 [citado 23 de maio de 2025];86(1):373–8. Available from: https://doi.org/10.1016/j.theriogenology.2016.04.051

16. Freitas BG, Mingoti RD, Monteiro BM, Guerreiro BM, Crepaldi GA, Ramos L, et al. Relationship of body maturation with response to estrus synchronization and fixed-time AI in Nelore (*Bos indicus*) heifers. Livestock Science [Internet]. 1o de setembro de 2021 [citado 22 de maio de 2025];251:104632. Available from: https://doi.org/10.1016/j.livsci.2021.104632

17. D'Occhio MJ, Baruselli PS, Campanile G. Influence of nutrition, body condition, and metabolic status on reproduction in female beef cattle: A review. Theriogenology [Internet]. fevereiro de 2019 [citado 20 de maio de 2025];125:277–84. Available from: https://doi.org/10.1080/1828051X.2019.1600385

18. D'Occhio MJ, Baruselli ,Pietro S., and Campanile G. Metabolic health, the metabolome and reproduction in female cattle: a review. Italian Journal of Animal Science [Internet]. 2 de janeiro de 2019 [citado 23 de maio de 2025];18(1):858–67. Available from: https://doi.org/10.1080/1828051X.2019.1600385

19. Patterson DJ, Perry RC, Kiracofe GH, Bellows RA, Staigmiller RB, Corah LR. Management considerations in heifer development and puberty. Journal of Animal Science. 1o de dezembro de 1992;70(12):4018–35.

20. Reese ST, Franco GA, Poole RK, Hood R, Fernadez Montero L, Oliveira Filho RV, et al. Pregnancy loss in beef cattle: A meta-analysis. Animal Reproduction Science [Internet]. 1o de janeiro de 2020 [citado 1o de junho de 2025];212:106251. Available from: https://doi.org/10.1016/j.anireprosci.2019.106251

21. Bridges GA, Kruse SG, Funnell B, Perry GA, Gunn PJ, Arias RP, et al. Changes in body condition on oocyte quality and embryo survival. Proceedings Applied Reproductive Strategies in Beef Cattle Sioux Falls. dezembro de 2012;23:269–83. Available from : https://beefrepro.org/wpcontent/uploads/2020/09/2012ARSBC_21BridgesProceedings.pdf

22. Kruse SG, Bridges GA, Funnell BJ, Bird SL, Lake SL, Arias RP, et al. Influence of post-insemination nutrition on embryonic development in beef heifers. Theriogenology [Internet]. 1o de março de 2017 [citado 1o de junho de 2025];90:185–90. Available from: https://doi.org/10.1016/j.theriogenology.2016.11.021

23. Ayres H, Ferreira RM, Torres-Júnior JRS, Demétrio CGB, Sá Filho MF, Gimenes LU, et al. Inferences of body energy reserves on conception rate of suckled Zebu beef cows subjected to timed artificial insemination followed by natural mating. Theriogenology [Internet]. 1o de setembro de 2014 [citado 10 de junho de 2025];82(4):529–36. Available from: https://doi.org/10.1016/j.theriogenology.2014.04.026

24. Brooks AL, Morrow RE, Youngquist RS. Body composition of beef heifers at puberty. Theriogenology [Internet]. 1o de agosto de 1985 [citado 1o de junho de 2025];24(2):235–50. Available from: https://doi.org/10.1016/0093-691X(85)90188-8

25. Ferrell CL. Effects of Postweaning Rate of Gain on Onset of Puberty and Productive Performance of Heifers of Different Breeds. Journal of Animal Science [Internet]. 1o de dezembro de 1982 [citado 20 de maio de 2025];55(6):1272–83. Available from: https://doi.org/10.2527/jas1982.5561272x

26. Sá Filho MF, Prestes R, Medalha AG, Ayres H, Baruselli PS. Diferentes estímulos ovulatórios na indução de ciclicidade de novilhas *Bos indicus*. Resumos [Internet]. 2009 [citado 1o de junho de 2025]; Available from: https://doi.org/10.2527/jas.2005-636

27. Stevenson JS, Hill SL, Bridges GA, Larson JE, Lamb GC. Progesterone status, parity, body condition, and days postpartum before estrus or ovulation synchronization in suckled beef cattle influence artificial insemination pregnancy outcomes1. Journal of Animal Science [Internet]. 1o de maio de 2015 [citado 26 de maio de 2025];93(5):2111–23. Available from: https://doi.org/10.2527/jas.2014-8391

28. Gasser CL, Grum DE, Mussard ML, Fluharty FL, Kinder JE, Day ML. Induction of precocious puberty in heifers I: Enhanced secretion of luteinizing hormone1. Journal of Animal Science [Internet]. 1o de agosto de 2006 [citado 23 de maio de 2025];84(8):2035–41. Available from: https://doi.org/10.2527/jas.2005-636

29. Samadi F, Blache D, Martin GB, D'Occhio MJ. Nutrition, metabolic profiles and puberty in Brahman (*Bos indicus*) beef heifers. Animal Reproduction Science [Internet]. 1o de maio de 2014 [citado 23 de maio de 2025];146(3):134–42. Available from: https://doi.org/10.1016/j.anireprosci.2014.03.004