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ANIMAL PRODUCTION

Effect of growth and carcass traits on likelihood of early pregnancy in Nellore heifers raised at intensive nutritional plan

Rones Goulart de Paula Júnior[1*], Joanis Tilemahos Zervoudakis[1] and Felipe Gomes da Silva[2]

[1]Programa de Pós-Graduação em Ciência Animal, Faculdade de Agronomia e Zootecnia, Universidade Federal de Mato Grosso, Cuiabá, Rua Quarenta e Nove, 2367, 78060-900, Cuiabá, Mato Grosso, Brazil. [2]Departamento de Zootecnia, Instituto de Ciências Agrárias da Universidade Federal de Minas Gerais, Montes Claros, Minas Gerais, Brazil. *Author for correspondence: E-mail: rones-junior@hotmail.com

ABSTRACT. This study evaluated the influence of the quantitative traits measured by real-time ultrasound (adjusted longissimus muscle area [AdjLMA], adjusted rump fat thickness [AdjRFT], and adjusted marbling [AdjMAR]) as well as age at first breeding [AFB] and adjusted weight [AdjWeight], on the probability of occurrence of early pregnancy (EP) in 55 Nellore heifers, and also performed an economic analysis. All calves received supplementation in creep-feeding (*ad libitum*), and at weaning (average age= 210 ± 30 days; average weight= 241 ± 33 kg) until first breeding by artificial insemination (May to November) all heifers were managed in the same group (two paddocks of 25 ha each evenly covered with *Urochloa Marandu* Grass) and received protein-energy supplementation (1% of average BW per animal/day). The quantitative variables were collected immediately after timed artificial insemination (average age= 392 ± 27 days; average weight= 431.90 kg), and the pregnancy diagnosis was completed at 30 days following insemination. For economic analysis, two systems were compared (age at first breeding at 13 and 24 months). The greater adjusted weight on the first breeding increased the probability of occurrence of early pregnancy, while the greater adjusted longissimus muscle area reduced. In addition, intensive meat production systems provide greater economic return throughout cow-calf operation.

Keywords: longissimus muscle area; marbling; reproductive efficiency; protein-energy supplementation; rump fat; age at first breeding.

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Introduction

One of the main causes of low economic results of cattle farming systems in tropical regions is due to the advanced age at first calving (AFC) in Zebu heifers (Freitas, Souza, & Moreira, 2011). Thus, the selection of matrices able to start breeding early is one of the requirements for increasing the profitability of the cattle, as it allows the production of an extra calf throughout its lifetime productivity. In addition, a reduction in the required area for cattle rearing is noted, reducing maintenance costs and shortening the generation time, which enhances genetic progress (Endecott, Funston, Mulliniks, & Roberts, 2013).

However, there is now a greater concern towards the growth traits in breeding programs for beef cattle, probably due to the fact that they are easier to be measured and present higher heritability estimates in relation to reproductive characteristics (Laureano et al., 2011). Consequently, sexual precocity traits are used in the background as a selection criterion, slowing the identification of animals with this genetic potential which is closely related to productivity and profitability in beef cattle.

Therefore, the selection of sexual precocity traits which are easy to be measured are necessary, aiming to obtain information that can be incorporated into cattle breeding programs for the purpose of optimizing the accuracy of predicted genetic values for reproductive traits and identifying the animals with potential for early pregnancy as soon as possible. What is more, factors affecting the reproductive performance in young heifers can be better understood, and thus propose modifications in the management system to provide better conditions so that the genetics related to reproductive precocity is manifested (Chiaia et al., 2015; Ferraz et al., 2017).

In this context, studies have demonstrated that certain traits obtained through ultrasound (longissimus muscle area, fat thickness and marbling) and that are connected with muscularity and the animal body condition scoring are associated with sexual precocity (Caetano et al., 2013). Nevertheless, there are a few studies relating growth and carcass traits with the likelihood of early pregnancy in Nellore heifers.

Notwithstanding, it is necessary to perform a holistic economic assessment of the implementation of intensive nutritional plans for early mating, because in most cases the specific analysis only reflects the increase of nutritional costs, not demonstrating the potential economic return throughout the reproductive cycle of matrices submitted to early breeding (Day & Nogueira, 2013).

This study aimed to conduct an economic simulation and verify the influence of quantitative traits: age at first breeding, adjusted weight, adjusted longissimus muscle area (AdjLMA), adjusted rump fat thickness (AdjRFT), subcutaneous rump fat thickness (AdjSRFT), and adjusted marbling (AdjMAR), over the likelihood of early pregnancy in Nellore heifers kept on pasture after weaning, in intensive systems of supplementation during periods of drought and dry-rainy transition season.

Material and methods

This experiment was carried out in a commercial property, specialized in the selection of Polled Nellore breed, located in Inaciôlandia-GO, from May to November (dry period and dry-rainy transition season). In order to evaluate the productive and reproductive performance, 55 Nellore heifers were used, with initial age and average weight of 7 months and 241 ± 33 kg at weaning, respectively. All animals belonged to the same group during breeding phase, receiving supplementation via creep-feeding (Fosbovinho Proteico ADE®, DSM; 26.60 and 60.20% crude protein – CP and total digestible nutrients -TDN based on dry matter – DM, respectively) provided *ad libitum* 45 days after birth, aiming at an average daily weight gain of 1.0 kg animal^{-1} day^{-1} (Valadares Filho et al., 2016).

Immediately after weaning, all animals were placed in two paddocks with 25ha each, both evenly covered with *Urochloa brizantha* cv. *Marandu* (35% DM; 7% de CP; 51% TDN; 71% neutral detergent fiber - NDF), providing covered drinking fountains and troughs for supplementation. Continuous grazing was used, with trained workers rotating the animals between paddocks aiming at a minimum forage canopy height of 25 cm.

Due to the need to obtain high rates of weight gain for early mating, all animals received protein-energy supplementation (1% of average body weight/animal/day based on DM) from weaning to the breeding season. The supplement (Table 1) was formulated to meet the nutritional requirements of Nellore heifers with an average body weight of 336 kg and a weight gain of 1.0 kg animal^{-1} day^{-1}, aligned with the nutritional requirements proposed by Valadares Filho et al. (2016).

The evaluation of the chemical composition of the available forage for animals consumption was carried out through manual grazing simulation, and the samples were sent for analysis in a commercial laboratory (SOLOCRIA - Laboratório Agropecuário) according to methodologies proposed by Association of Official Analytical Chemists [AOAC] (1990).

Table 1. Percentage composition of the supplement based on natural matter.

Item	%	CP[1] %	TDN[1] %
Ground grain sorghum	58	5.60	48
Soybean meal	12	5.85	9,50
DDGS[2]	15	4.8	9.70
Núcleo[3]	12	-	-
Urea	3	8.45	-
Total	100	24.70	67.20

[1]Estimated value using the '*Tabela de composição de alimentos para bovinos*' (Valadares Filho, Machado, Furtado, Chizzotti, & Amaral, 2015). [2]Distillers dried grains with solubles. [3]Commercial nucleous: levels of assurance: calcium: 190 g; phosphor: 60 g; magnesium: 20 g; sodium: 70 g; sulfur: 20 g; cobalt: 15 mg kg^{-1}; copper: 700 mg kg^{-1}; iodine: 40 mg kg^{-1}; manganese: 1.600 mg kg^{-1}; Selenium: 19 mg kg^{-1}; zinc: 2.500 mg kg^{-1}.

Heifers were weighed at weaning in May, and at the moment of fixed-time artificial insemination in November, without previous fasting, aiming to measure weight gain due to the level of supplementation. We used the cattle's average weight at birth as the initial value to calculate performance during breeding phase.

The cattle consumption of forage dry matter was estimated according to the equations proposed by Valadares et al. (2016), based on the average body weight, average daily gain, bromatological composition of the supplement and forage, and average daily consumption of supplement during the experimental period.

Prior to the synchronization of ovulation protocol for fixed-time artificial insemination (FTAI), heifers were submitted to a puberty induction protocol lasting 12 days, and on day - 12 all heifers received an intravaginal progesterone device 4th use (CIDR®, Zoetis) and on day 0 the device was removed (Rodrigues et al., 2013).

According to a study conducted by Rodrigues et al. (2014), the protocol for fixed-time artificial insemination (D0- 2.0 mg of estradiol benzoate + bovine intravaginal device with 1.0 g progesterone, D9- implant removal + 250 µg of cloprostenol sodium + 300 IU equine chorionic gonadotropin + 0.5 mg of estradiol cypionate, D11- FTAI) started 12 days after the puberty induction protocol, due to the fact that it is the best interval to optimize pregnancy rates.

Heifers were inseminated at 392 ± 27 days of age, using a single Nellore bull semen conducted by the same inseminator. Immediately after FTAI, ultrasound images of longissimus muscle area (LMA), subcutaneous rump fat thickness (SRFT), marbling (MAR) were collected and heifers' weight were registered. Pregnancy diagnosis was carried out through ultrasound 30 days after FTAI.

The ultrasound images were collected and recorded with the ALOKA 500 V device, with a 3.5 MHz linear probe measuring 17.2 cm and an acoustic coupler, in conjunction with an image capture system (Blackbox, Biotronics Inc., Ames, IA, USA). Afterwards, these images were interpreted by the laboratory in charge of data quality assurance (Aval Serviços Tecnológicas S/S), using the 'Biosoft Toolbox software' (Biotronics Inc., Ames, IA, USA), which is an appropriate program with precision to two decimal places.

To obtain the LMA and MAR images the transducer was placed perpendicularly to the spine, transversely on the *longissimus dorsi* muscle, between the 12 and 13th ribs, on the left side of the calf, using an acoustic coupler (standoff). To obtain the SRFT image, the transducer was placed at the intersection of the *gluteus medius* e *biceps femoris* muscles, located between the ilium and ischium, without using the acoustic coupler. In order to collect images, vegetable oil was used as coupler to ensure the acoustic contact between the linear probe and heifer's body.

Weight and other evaluated carcass traits were adjusted to the average age of the lot (392 ± 27 days) at the moment of data collection, allowing the comparison of animals within it and also with other cattle, as suggested by Waldner et al. (1992).

Two breeding systems based on the age at first breeding were considered for economic simulation (Traditional – 24 months and Super early – 13 months), the additional revenue with the implementation of the super early system was estimated based on studies (Day & Nogueria, 2013) that demonstrate additional profit in calves throughout the matrices lifetime reproductivity, when compared with the traditional system.

As an indication of a more efficient system, return on invested capital was used, dividing the profit margin by the investment with supplementation, considering an additional of 0.9 calves at the end of 48 months for the super early mating system (Day & Nogueira, 2013), which corresponds to a period in which the matrices of the two systems will have an average age of 6.5 years.

Thus, the additional revenue was obtained considering the average price of a calf in the region (R$ 1,650.00 – 10%), resulting in R$ 1,485.00, and the expenses were obtained through the total cost of nutrition (supplement + mineral salt for the traditional system and creep-feeding + supplement for the super early one), supplement costs were calculated in kilograms (R$ kg^{-1}) according to the pricing practice in the state of Goiás.

The relation between the quantitative traits and early pregnancy were carried out by the logistic regression analysis, testing the influence of independent variables (age at first breeding, adjusted weight, AdjLMA, SRFT e AdjMAR) on early pregnancy, through the *Forward* method for inclusion of significant variables ($p < 0.5$), followed by the *Backward* method for removing the non-significant variables ($p > 0.1$), using the option *Stepwise* of the *software* SAS University Edition® (Statistical Analyses System [SAS], 2013).

The ratio between likelihood $\left(\frac{s(success)}{u(unsuccess)}\right)$ associated with each regression variable was estimated through ($e^{\hat{\beta}_h}$) and defines the change in the ratio between probabilities when there is an alteration of a regression variable unit, where ($\hat{\beta}_h$) is the estimate of parameters obtained through the maximum likelihood estimation (Freund & Littell, 2000).

Results and discussion

Table 2 shows the descriptive statistics for all studied independent variables.

The AFB, AdjSRFT and AdjMAR variables were removed from the model for not meeting the significance criteria ($p < 0.1$). Other studies (Morrison, Feazel, Bagley, & Blouin, 1992; Perry, 2012) have not found effect of age at first breeding (AFB) over early pregnancy in young heifers as well, suggesting that the body weight at first breeding is the most important variable in the event of heifers reproductive activity, as it is decisive for the onset of puberty.

Table 2. Number of observations (n), mean, standard deviation (SD), maximum and minimum values and coefficient of variation (CV) for the studied traits in precocious Nellore heifers.

Variable	N	Mean	SD	Maximum	Minimum	CV (%)
AFB (days)	55	392.14	27.14	448.00	338.00	6.92
AdjWeight (kg)	55	431.89	37.38	512.00	308.00	8.65
AdjLMA (cm²)	55	58.83	4.48	65.91	45.81	7.61
AdjSRFT (mm)	55	7.28	1.72	11.74	3.35	23.71
AdjMAR (%)	50	3.75	0.95	5.65	1.84	25.46

AFB= age at first bred; AdjWeight= adjusted weight; AdjLMA= adjusted longissimus muscle area; AdjSRFT = adjusted subcutaneous rump fat thickness; AdjMAR = adjusted marbling.

Therefore, in intensive systems aiming at early pregnancy, the nutritional plan to which the animals will be submitted, becomes important, since puberty must be hastened, so that it results in progressive changes in brain development which provide sexual maturity and early reproductive ability of heifers managed under intensive production systems (Schillo, Hall, & Hileman, 1992).

In traditional breeding systems consisting of a large part of Brazilian properties, where heifers are mated at 24 months, there is great flexibility regarding the goal of weight gain from weaning to mating, making it possible to distribute these gains throughout the breeding season (Menegassi, 2013).

In general, the objective is to wean with at least 150 kg, which can be supplemented in the post-weaning period, ensuring a better development of heifers, and reaching one year with a minimum weight of 210 kg. Thus, completing two years and reaching 320 kg, having an average gain of 0.350 kg per day along breeding.

Nevertheless, in intensive systems as in this study, heifers were submitted to a dietary strategy to enable high weight gain after weaning (1.0 kg day^{-1}) and increase weight at first breeding, aiming at an increase in the growth speed and development, in order to hasten puberty and, therefore, enhance the likelihood of early pregnancy (Ferraz et al., 2017). The average supplement intake (1.0% BW) provided 0.830 kg day^{-1} of CP and 2.25 kg day^{-1} of TDN, which is close to the recommendations of Valadares Filho et al. (2016) to meet the requirements of protein (0.855 kg day^{-1}) and 55% under the recommended TDN (5.0 kg day^{-1}) to achieve the targeted weight gain.

However, protein is the most limiting nutrient of pastures in this period coinciding with drought, which turns the use of supplementation to optimize microbial activity and allow the fermentation of non-fibrous carbohydrates trivial, consequently increasing forage consumption, extraction of latent energy in NDF and finally, animals' performance (Reis, Melo, Bertipaglia, & Oliveira, 2005).

This way, the achieved average daily gain (1.035 kg day^{-1}) at weaning demonstrates that the provided level of supplementation enabled the targeted gains for calves kept in *Urochloa brizantha* cv. *Marandu* pasture (estimated consumption of 4.10 kg animal^{-1} day^{-1} based on DM), being validated as a nutritional strategy that can be recommended for intensive systems which need optimization of weight gain for early mating.

Although previous studies (Foldager & Sejrsen, 1987) suggest hastening the rates of pre-mating gain (above 0.600 kg day^{-1}) aiming to increase weight and hasten puberty might reduce from 10 to 25% the subsequent milk yield. In a recent study conducted with beef heifers, Schubach et al. (2019) verified that heifers weaned at 7 months, submitted to a diet to achieve gains of 0.800 kg day^{-1}, had their age at puberty hastened without damaging milk yield. Therefore, this reinforces the fact that intensive dietary plans may be implemented without future damages to production.

Notwithstanding, it must be considered that the greater the heifers' weight at calving, the less the need of nutrient partitioning for growth, enabling the reduction of supplementation costs in this period in order to meet the nutritional requirements to improve the reproductive efficiency. Yet, a higher weight at calving allows to minimize the incidence of dystocia, which is mostly associated with inadequate development at pre-calving (Short, Staigmiller, Bellows, & Greer, 1994; Hansen, Lund, Pedersen, & Christensen, 2004).

Furthermore, since the nutritional requirements during pre-puberty are lower when compared with pregnancy (Valadares Filho et al., 2016), the implementation of intensive nutritional strategies in this period is biologically and economically more efficient, especially when agribusiness co-products (DDGS) are used to reduce costs of supplement.

Reiterating the importance of optimizing development, heifers' weight at first breeding ($p < 0.0083$), and the ratio between likelihood of 1.032 shows that the increase in a unit of AjdWeight (kg) is related with the increase of 3.2% in the likelihood of early pregnancy (Table 3).

Table 3. Estimate of parameters used in the model of probability of early pregnancy according to independent variables.

Regression variable	Ration between likelihood	Confidence interval	p-value
AdjLMA (cm^2)	0.861	0.723-1.025	0.0923*
AdjWeight (kg)	1.032	1.008-1.056	0.0083*

AdjLMA = adjusted longissimus muscle area; AdjWeight= adjusted weight. *Significant $p < 0.1$.

Other studies working with Nellore matrices (Semmelmann, Lobato, & Rocha, 2001; Freitas et al., 2011) have also reported positive association between weight at the beginning of reproduction and likelihood of pregnancy in heifers mated between 15 and 18 months, and heifers with greater weight at the beginning of the breeding season had better chances of becoming pregnant.

In this study, the average of adjusted weight of heifers mating between 12 and 14 months, who became pregnant, was 441.3 kg, which represent 80% of the mean weight of adult cows of this cattle (550 kg). On the other hand, the heifers that were not diagnosed with positive pregnancy had an average of adjusted weight of 417.7 kg, accounting for 76.4% of all evaluated animals in the study.

According to Vaz et al. (2012), the higher the body weight at insemination, the greater the obtained pregnancy, observing that heifers weighing 316 kg or more (70% of adult weight), had 100% of estrus manifestation and 93.8% of pregnancy. Therefore, in similar breeding systems nutritional levels providing greater weight gain is recommended, aiming to increase body weight at first mating and consequently, pregnancy rates.

In this study, this difference of weight at first breeding can be justified by the use of creep-feeding during breeding phase (pre-weaning) intending to optimize the calves' development and increase weight at weaning, whereas Vaz et al. (2012) used creep-feeding for the animals at rearing period.

Supplementation via creep-feeding started at around 45 days of age, because based on the National Research Council [NRC] (2001) and average body weight at birth of 35 kg, the nutritional requirements of these animals for the targeted gain of 1.0 kg day^{-1} are met being milk-fed until the 7th week (49 days) of life, when body weight achieves 84 kg and the total net energy demand account for 5.18 Mcal day^{-1} (2.39 Mcal day^{-1} for maintenance e 2.79 Mcal day^{-1} for gain), reinforcing the need to adopt supplementation for the maintenance of this weight gain.

The average gain of animals during rearing period was of 0.980 kg day^{-1}, which is closer to the planned performance of 1.0 kg day^{-1} based on the nutritional requirements proposed by Valadares Filho et al. (2016), demonstrating that it is essential to use this nutritional management when the aim is to increase weight gain to maximize weight at weaning. The average consumption of 1.5 kg $animal^{-1}$ day^{-1} of Fosbovinho Proteico ADE (26.60 % CP and 60.20% TDN based on DM) provided 0.399 kg day^{-1} of CP and 0.900 kg day^{-1} of TDN, which represents 72.5 and 32.25% of the recommendation of CP (0.550 kg day^{-1}) and TDN (2.79 kg day^{-1}) respectively, for suckling calves weighing 165 kg on average (Valadares Filho et al., 2016).

Notwithstanding, Patterson et al. (1992) highlight that, in production systems which advocate the super early mating, the pre-weaning period is greater in percentage than the post-weaning period, which is verified in this study, presenting values of 53.8 and 46.2%, respectively, working with mating age of 13 months.

Therefore, as the productive system is intensified and younger heifers are mated, the pre-weaning period increases its influence on development and consequently, on the reproductive performance of beef heifers, since recent studies have demonstrated that the increase of weight gain at this period with supplementation results in hastening of puberty since it promotes the maturation of the neuroendocrine reproductive axis (Cardoso et al., 2014).

According to Owens, Dubeski, and Hanson (1993) zebu heifers achieve puberty with nearly 65% of adulthood weight, and therefore, the group of Nellore heifers that managed to anticipate pregnancy in this study had body weight compatible with their physiological age at the beginning of the reproductive period, allowing early mating. Thus, the increase of body weight proved to be effective to maximize the reproductive efficiency, underlining the need of adequate body development of zebu heifers for reproductive performances compatible with a more profitable beef cattle.

However, it is important to consider that the growth traits must not be assessed in isolation in production strategies to anticipate pregnancy in zebu heifers. Thus, it is evident that carcass characteristics should also be evaluated, and in this study the longissimus muscle area significantly influenced ($p < 0.0923$) the likelihood of early pregnancy. The ration between likelihood of 0,861 indicated that the increase in a unit of AdjLMA (cm^2) is related with a reduction of 13.9% in the likelihood of early pregnancy (Table 3).

According to Schafhäuser Jr. et al. (2004), heifers presenting a greater longissimus muscle area had more muscle and demonstrated lower reproductive efficiency during breeding season, (confirming the tendency that animals with a better body development tend to achieve puberty later and present lower reproductive efficiency (Patterson et al., 1992).

In addition, the selection exclusively focused on a greater longissimus muscle area can culminate with matrices production with a bigger frame, which present greater demand of maintenance, and in an environment of lower nutrients supply, can have their puberty delayed, negatively affecting the reproductive rates (Caetano et al., 2013).

According to Randel and Welsh (2013), heifers that are more efficient from a feed standpoint (less residual food consumption), present delayed puberty and conception due to a greater muscle development and a decrease in the deposition in adipose tissue, aligned with the results found in this study, in which traits connected with muscle (greater AdjLMA) negatively affected the likelihood of early pregnancy in Nellore heifers.

Nevertheless, the EGP8Ajust did not affect the reproductive performance in this study, although Caetano et al. (2013) claim that it is important to select this trait to increase sexual precocity in heifers. According to Cunningham, Clifton, and Steiner (1999), leptin is a hormone produced by the adipose tissue, which can act as a metabolic signal to indicate that energy reserves are enough to trigger the onset of puberty and reproduction.

In this specific studied case, the non-influence of the fat thickness over sexual precocity can happen due to the fact that animals belong to the same group and do not present differences for this trait (7.49 and 6.97 mm of AdjSRFT for heifers with positive pregnancy and heifers with negative pregnancy, respectively).

Regarding AdjMAR, the absence of effect over the likelihood of early pregnancy is also verified in other studies (Splan, Cundiff, & Van Vleck, 1998; Smith & Greiner, 2013) suggesting that the selection for this characteristic will not have a significant effect over the heifers' sexual precocity. Notwithstanding, the majority of these studies are conducted with taurine breeds, hindering the comparison due to the high variability between zebu and taurine breeds concerning marbling (Ladeira et al., 2018).

As important as observing metrics of gain and carcass characteristics, are the economic evaluations, which become the cattle breeder's benchmark to disseminate and continue these nutritional strategies for early mating.

Thus, it is important to consider the additional cost with supplementation to increase weight at first breeding and consequently, the reproductive efficiency, and what is the economic return of this strategy throughout the reproductive life of matrices for the rearing system.

The implementation of the intensive nutritional strategy for mating at 13 months needs a better investment with supplementation (Table 4), which can initially be an impediment to the adoption of this strategy, considering that many cattle breeders are undercapitalized. However, it is necessary to carry out an economic analysis throughout the production cycle, since in this study the super early strategy provided a greater economic return at the end of the fourth year (Table 4), when matrices of both systems would be 6.5 years old on average, and the additional gain in calves for the most intensive system (13 months) would be of 0.9 (Day & Nogueira, 2013).

Therefore, the strategy of heifers mating at 13 months represents an economic viable alternative, because it enables greater economic return, in addition to adding indirect gains such as less need of area to non-productive heifers rearing (mating at 24 months) and increase in genetic gain. Thus, the selection of heifers with potential for weight gain is extremely important, as well as more intensive nutritional plans aiming to achieve greater body weight to a better precocity at the beginning of reproductive life, since it influences the onset of puberty and early pregnancy likelihood.

Yet, this study suggests the need to consider the carcass traits such as longissimus muscle are, as it affected early pregnancy in Nellore heifers, and if selected as the only criterion for matrices replacement, it can result in the production of animals with more muscles and elevated weight at maturity, which will be late in relation with puberty and early pregnancy. Notwithstanding, the additional costs with supplementation to optimize weight gain aiming to improve reproductive efficiency in super early systems must be considered as investment, since it enables greater economic return throughout the production cycle of matrices in rearing activity.

Table 4. Economic analysis according to the additional of calves of two production systems with different nutritional strategies for age at first mating.

Economic indicators	Traditional system 24 months	Super early system 13 months
Weight at birth (kg)	35	35
Average daily weight gain -Calf (kg day^{-1})[1]	0.55	0.98
Female weight at weaning (kg)	150	241
Body weight gain (kg 210^{-1} dias)	115.5	205.8
Supplement intake-Calf (kg dia^{-1})	0	1.5
Supplement cost (R$ kg^{-1})	0	1.7
Supplement investment - Calf (R$)[2]	0	420.75
Average daily weight gain - Rearing (kg day^{-1})[1]	0.350	1.035
Weight at the end of Rearing[3]	320	431
Body weight gain (kg)	170	190
Supplement-Rearing Intake (kg day^{-1})	0.350	3.36
Mineral Supplement Intake - Rearing (kg day^{-1})	0.10	0
Supplement Cost (R$ kg^{-1})	1.50	0.78
Mineral Supplement Cost(R$ kg^{-1})	2.70	0
Supplement investment - Rearing (R$)[4]	170.50	482.25
Total supplementation cost (R$)[5]	170.50	902.98
Additional revenue at the end of the 4th year (R$)[6]	0	R$ 1,485.00
Additional gross profit (R$)[7]	-170.50	R$ 582.02
Invested capital remuneration (%)[8]	0	3.43

[1]Performance in mating systems at 24 months (traditional) according to Menegassi, 2013; [1]Performance obtained in this study (mating at 13 months – super early) [2]Intake*supply period (165 days)*supplement cost; [3]Traditional system (17 months= 488 days*0.350 kg day^{-1}) + weight at weaning (150 kg); [3]Super early system (6 months= 184 days*1.035 kg day^{-1}) + weight at weaning (241 kg); [4]Traditional system (supplement intake in 152 days*supplement cost (R$ kg^{-1}) + mineral salt intake in 336 days*Mineral Supplement cost (R$ kg^{-1}); [4]Super early system (supplement intake in 184 days*supplement cost (R$ kg^{-1}); [5]Supplementation investment (Calf) + Supplementation investment (Rearing); [6]Additional in calves (0.9 more calves according to Day & Nogueira, 2013) considering average price of calf (R$ 1,650.00 – 10% of calf's price= R$ 1,485.00); [7]Additional revenue – Total cost with supplementation; [8](Additional gross profit/Total cost with supplementation*100)/cycle (48 months).

Conclusion

The greater adjusted body weight increased the likelihood of early pregnancy in Nellore heifers while the greater longissimus muscle are reduced, suggesting the importance of multiple analysis of body traits for the selection of matrices and increase of reproductive efficiency. What is more, the early mating system provides better economic return throughout the production cycle when compared with the traditional system.

References

Association of Official Analytical Chemists [AOAC]. (1990). *Official methods of analysis* (15th ed.). Washington, DC: AOAC International.

Caetano, S. L., Savegnago, R. P., Boligon, A. A., Ramos, S. B., Chud, T. C. S., Lôbo, R. B., & Munari, D. P. (2013). Estimates of genetic parameters for carcass grow thand reproductive traits in Nellore cattle. *Livestock Science, 155*(1), 1-7. DOI: https://doi.org/10.1016/j.livsci.2013.04.004

Cardoso, R. C., Alves, B. R. C., Prezotto, L. D., Thorson, J. F., Tedeschi, L. O., Keisler, D. H., & Williams, G. L. (2014). Use of a stair-step compensatory gain nutritional regimen to program the onset of puberty in beef heifers. *Journal of Animal Science*, *92*(7), 2942-2949. DOI: https://doi.org/10.2527/jas.2014-7713

Chiaia, H. L. J., Lemos, M. V. A., VenturinI, G. C., Aboujaoude, C., Berton, M. P., Feitosa, F. B., ... Baldi, F. (2015). Genotype × environment interaction for age at first calving, scrotal circumference, and yearling weight in Nellore cattle using reaction norms in multitrait random regression models. *Journal of Animal Science*, 93(4), 1503-1510. DOI: https://doi.org/10.2527/jas.2014-8217

Cunningham, M. J., Clifton, D. K., & Steiner, R. A. (1999). Leptin's actions on the reproductive axis: perspectives and mechanisms. *Biology of Reproduction*, *60*(2), 216-222. DOI: https://doi.org/10.1095/biolreprod60.2.216

Day, M. L., & Nogueira, G. P. (2013). Management of age at puberty in beef heifers to optimize efficiency of beef production. *Animal Frontiers*, *3*(4), 6-11. DOI: https://doi.org/10.2527/af.2013-0027

Endecott, R. L., Funston, R. N., Mulliniks, J. T., & Roberts, A. J. (2013). Joint Alpharma-Beef Species Symposium: implications of beef heifer development systems and lifetime productivity. *Journal of Animal Science*, *91*(3), 1329-1335. DOI: https://doi.org/10.2527/jas.2012-5704

Ferraz, M. V. C., Polizel, D. M., Miszura, A. A., Oliveira, G. B., Bertoloni, A. V., Sartori, R., ... Pires, A. V. (2017). Genetics is the essential factor for the precocious puberty in Nellore heifers. *Journal of Animal Science*, 95(4), 153-154. DOI: https://doi.org/10.2527/asasann.2017.310

Foldager, J., & Sejrsen, K. (1987). Mammary gland development and milk production in dairy cows in relation to feeding and hormone manipulation during rearing. In A. Neimann-Sørensen, *Research in cattle production: danish status and perspectives* (p. 102-116). Frederiksberg, DK : Landhusholdningsselskabets Forlag.

Freitas, A. R., Souza, J. F., & Moreira, A. (2011). Predição da precocidade sexual em bovinos da raça Nelore por meio de componentes principais. *Revista de Ciências Agrárias, 54*(2), 153-158. DOI: https://doi.org/10.4322/rca.2012.009

Freund, R. J., & Littell, R. C. (2000). *SAS® system for regression*. Cary, NC: SAS Institute Inc.

Hansen, M., Lund, M. S., Pedersen, J., & Christensen, L. G. (2004). Genetic parameters for stillbirth in Danish Holstein cows using a Bayesian threshold model. *Journal of Dairy Science*, *87*(3), 706-716.

Ladeira, M. M., Schoonmaker, J. P., Swanson, K. C., Duckett, S. K., Gionbelli, M. P., Rodrigues, L. M., & Teixeira, P. D. (2018). Nutrigenomics of marbling and fatty acid profile in ruminant meat. *animal*, *12*(s2), s282-s294. DOI: https://doi.org/10.1017/S1751731118001933

Laureano, M. M. M., Boligon, A. A., Costa, R. B., Forni, S., Severo, J. L. P., & Albuquerque, L. G. (2011). Estimativas de herdabilidade e tendências genéticas para características de crescimento e reprodutivas em bovinos da raça Nelore. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 63*(1), 143-152. DOI: https://doi.org/10.1590/S0102-09352011000100022

Menegassi, S. R. O. (2013). *Manejo de sistemas de cria em pecuária de corte*. Guaíba, RS: Agrolivros.

Morrison, D. G., Feazel, J. I., Bagley, C. P., & Blouin, D. C. (1992). Postweaning growth and reproduction of beef heifers exposed to calve at 24 or 30 months of age in spring and fall seasons. *Journal of animal science*, *70*(3), 622-630. DOI: https://doi.org/10.2527/1992.703622x

National Research Council [NRC]. (2001). *Nutrient requirements of dairy cattle*. Washington, DC: National Academic Press.

Owens, F. N., Dubeski, P., & Hanson, C. F. (1993). Factors that alter the growth and development of ruminants. *Journal Animal Science, 71*(8), 3138-3150. DOI: https://doi.org/10.2527/1993.71113138x

Patterson, D. J., Corah, L. R., Brethour, J. R., Higgins, J. J., Kiracofe, G. H., & Stevenson, J. S. (1992). Evaluation of reproductive traits in *Bos taurus* and *Bos indicus* cross bred heifers: relations hip of age at puberty to leng tho fthe post partuminterval to estrus. *Journal of Animal Science, 70*(5), 1994-1999.

Perry, G. A. (2012). Harnessing basic knowledge of factors controlling puberty to improve synchronization of estrus and fertility in heifers. *Journal of Animal Science*, *90*(4), 1172-1182.

Randel, R. D., & Welsh, T. H. (2013). Interactions of feed efficiency with beef heifer reproductive development. *Journal of Animal Science, 91*(3), 1323-1328. DOI: https://doi.org/10.2527/jas.2012-5679

Reis, R. A., Melo, G. M. P., Bertipaglia, L. M. A., & Oliveira, A. P. (2005). Otimização da utilização da forragem disponível através da suplementação estratégica. In R. A. Reis, G. R. Siqueira, & L. M. A. Bertipaglia (Eds.), *Volumosos na produção de ruminantes* (p.187-238). Jaboticabal, SP: FUNEP.

Rodrigues, A. D. P., Peres, R. F. G., Lemes, A. P., Martins, T., Pereira, M. H. C., Day, M. L., & Vasconcelos, J. L. M. (2013). Progesterone-based strategies to induce ovulation in prepubertal Nellore heifers. *Theriogenology, 79*(1),135-141. DOI: https://doi.org/10.1016/j.theriogenology.2012.09.018

Rodrigues, A. D. P., Peres, R. F. G., Lemes, A. P., Martins, T., Pereira, M. H. C., Carvalho, E. R., & Vasconcelos, J. L. M. (2014). Effect of interval from induction of puberty to initiation of a timed AI protocol on pregnancy rate in Nellore heifers. *Theriogenology, 82*(5), 760-766. DOI: https://doi.org/10.1016/j.theriogenology.2014.06.008

Statistical Analyses System [SAS]. (2013) - *SAS/University edition, 9.4*. Cary, NC: SAS Institute Inc.

Schafhäuser Jr., J., Mancio, A. B., Fontes, C. A. A., Torres, C. A. A., Paulino, M. F., & Cecon, P. R. (2004). Desempenho reprodutivo de novilhas com diferente grau de musculosidade. *Revista da Faculdade de Zootecnia, Veterinária e Agronomia, 10*(1), p. 2-19.

Schillo, K.K., Hall, J.B., & Hileman, S.M. (1992). Effects of nutrition and season on the onset of puberty in beef heifer. *Journal Animal Science, 70*(12), 3994-4005. DOI: https://doi.org/10.2527/1992.70123994x

Schubach, K. M., Cooke, R. F., Brandão, A. P., Schumaher, T. F., Pohler, K. G., Bohnert, D. W., & Marques, R. S. (2019). Impacts of postweaning growth rate of replacement beef heifers on their reproductive development and productivity as primiparous cows. *Journal of Animal Science*, *97*(10), 4171-4181.

Semmelmann, C. E. N., Lobato, J. F. P., & Rocha, M. G. D. (2001). Effect of feeding systems on weight gain and reproductive performance of Nellore heifers bred at the age of 17/18 months. *Revista Brasileira de Zootecnia, 30*(3), 835-843. DOI: https://doi.org/10.1590/S1516-35982001000300032

Short, R. E., Staigmiller, R. B., Bellows, R. A., & Greer, R. C. (1994). Breeding heifers at one year of age: biological and economic considerations. In M. J. Fields, & R. S. Sand (Eds.), *Factors affecting calf crop* (p. 55-68). London, UK: CRC Press.

Smith, J. K., & Greiner, S. P. (2013). *Selection for marbling and the impact on maternal traits*. Blacksburg, VA: Department of Animal and Poultry Sciences; Virginia Polytechnic Institute and State University.

Splan, R. K., Cundiff, L. V., & Van Vleck, L. D. (1998). Genetic parameters for sex-specific traits in beef cattle. *Journal of Animal Science*, *76*(9), 2272-2278. DOI: https://doi.org/10.2527/1998.7692272x

Valadares Filho, S. C., Costa e Silva, L. F., Lopes, S. A. Prados L. F., Chizzotti M. L., Machado P. A. S., ... Furtado, T. (2016). *BR-Corte 3.0. Cálculo de exigências nutricionais, formulação de dietas e predição de desempenho de zebuínos puros e cruzados*. Viçosa, MG: UFV, DZO.

Valadares Filho, S. C., Machado, P. A. S., Furtado, T., Chizzotti, M. L., & Amaral, H. F. (2015). *Tabelas brasileiras de composição de alimentos para ruminantes.* Viçosa, MG: Editora UFV.

Vaz, R., Restle, J., Pacheco, P., Vaz, F., PascoaL, L., & Vaz, M. (2012). Ganho de peso pré e pós-desmame no desempenho reprodutivo de novilhas de corte aos quatorze meses de idade. *Ciência Animal Brasileira, 13*(3), 272-281. DOI: https://doi.org/10.5216/cab.v13i3.17527

Waldner, D. N., Dikeman, M. E., Schalles, R. R., Olson, W. G., Houghton, P. L., Unruh, J. A., & Corah, L. R. (1992). Validation of real-time ultrasound technology for predicting fat thicknesses, longissimus muscle are as, and composition of Brangus bulls from 4 months to 2 years of age. *Journal of Animal Science, 70*(10), 3044-3054. DOI: https://doi.org/10.2527/1992.70103044x