Carcass Traits, Meat Characteristics, and Economic Viability of Grazing Nellore Cattle Produced Under Different Supplementation Strategies in the Tropics

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Abstract

This study explored the effects of different supplementation strategies in the dry and rainy seasons in the tropics on the carcass traits, meat quality, and economic viability of Nellore cattle produced under grazing conditions. For this purpose, twenty-eight non-castrated male animals (18 months) with an initial body weight of 327.93 ± 4.22 kg were used. The animals were equitably distributed in a randomized complete design thorough four supplementation strategies as follows: i) mineral supplementation (MS) in both dry and rainy seasons (MS/MS), ii) MS in the dry season and concentrate supplementation (CS) in the rainy season (MS/CS), iii) CS in the dry season and MS in the rainy season (CS/MS), and iv) CS in both dry and rainy seasons (CS/CS). Thereafter, carcass traits, primary carcass cut yields, meat quality traits, chemical composition of meat, and economic viability of cattle production across different supplementation strategies were determined. Data revealed that animals under CS/CS showed the greatest ($P < 0.01$) hot carcass weights among the other supplementation strategies evaluated. Conversely, supplementation strategy did not affect ($P > 0.05$) carcass traits (the ribeye area, final pH, and forequarter), meat quality traits (shear force, myofibrillar fragment index, sarcomere length, and color), and meat chemical composition (crude protein, fat, and moisture) of the animals. The effective operational cost, total cost, gross revenue, and profit of animals under CS/CS showed the greatest values, whereas the lowest ones were obtained for the animals under MS/MS. In conclusion, data suggest that concentrate supplementation during at least one season (dry or rainy) produces similar meat quality traits and chemical composition of meat, but different hot carcass weight, backfat thickness and hindquarter proportion to those observed when animals were supplemented with concentrate in both seasons. Additionally, CS/CS animals, despite having a higher total cost, have greater profitability when raised in tropical pasture.

Introduction

Beef cattle raised under tropical conditions use the pasture as the main feed source across the whole year (Lobato et al., 2014); however, even when forage is well managed, there are variations in its quality and quantity due to changes in climate conditions, which are characterized by the occurrence of the dry and rainy seasons in the tropics (Pezzopane et al., 2018). In this context, the amount of digestible nutrients ingested by grazing animals may change across the year, which may infer in their developmental stage, carcass traits, and beef quality (De Paula et al., 2019).

To overcome the variations in nutrient inputs, grazing tropical beef cattle is commonly supplemented with concentrate in intensive production systems (Detmann et al., 2014); however, beyond supplementation level, the choice for an adequate supplementation strategy during the dry and rainy seasons may differentially infer in the growth rate of the animals (Sampaio et al., 2017). In general, a restriction of nutrients occurs in the dry season, whereas an increase of nutrient supply to animals goes in the rainy season; hence, the dynamics of nutrient across these seasons influences the body composition and weight gain (Modzelewska-Kapituła and Nogalski, 2016; Oksbjerg and Therkildsen, 2017; Silva et al.,

2020). Therefore, the selection of a correct supplementation strategy may positively affect the carcass characteristics of cattle, thereby influencing the cattle production economic viability as well.

Studies with beef cattle under tropical conditions have focused on the evaluation of the effects of supplementation levels during the dry season and its potential effects on growth and performance parameters during the subsequent rainy season (Roth et al., 2017; Sampaio et al., 2017; Roth et al., 2018). Nevertheless, to date, no studies have yet conducted evaluating the effects of different supplementation strategies considering the dry and rainy seasons, on the carcass traits, meat quality, and economic viability of Nellore beef cattle production. This information may be valuable for designing sustainable cattle nutrition strategies in the tropics to meet world market preferences across the year, considering that cattle production in this region accounts for half of cattle worldwide (Rubio Lozano et al., 2021). Thus, this study evaluated the effects of different supplementation strategies across the dry and rainy seasons in the tropics on the carcass characteristics, meat quality, and economic viability of grazing Nellore steers. The hypothesis of this study focused on that concentrate supplementation during at least one season (dry or rainy) produces similar carcass traits, meat quality traits, and chemical composition of meat to those observed when animal are supplemented with concentrate in both seasons.

Material And Methods

Location, animals, treatments, and experimental diets

The experiment was conducted at the beef cattle station of the Federal Rural University of Amazon/UFRA–Parauapebas Campus, Para, Brazil (6° 4'25.53"S; 49°48'54.57"W).

Twenty-eight young Nellore bulls, 18 months of age and 327.93 ± 4.22 kg body weight were equitably distributed in the treatments represented in Table 1. The experimental area consisted of eight paddocks of one hectare each, composed by *Urochloa brizantha*, cv. Marandu, which was not grazed during 60 days before the beginning of the experiment. Animals were continuously moved through four paddocks in the entire experiment. Each treatment group of animals was sequentially moved from one paddock to the next every 7 days to minimize potential effects of different paddock conditions on the response to supplementation strategies.

Table 1
Description of supplementation strategies evaluated in young Nellore bulls

Supplementation strategy ^a	Dry season	Rainy season
MS/MS	Mineral salt	Mineral salt
MS/CS	Mineral salt	Concentrate at 8 g/kg BW
CS/MS	Concentrate at 8 g/kg BW	Mineral salt
CS/CS	Concentrate at 8 g/kg BW	Concentrate at 8 g/kg BW
^a MS/MS: mineral supplementation during both, dry and rainy seasons; MS/CS: mineral supplementation during the dry season and concentrate supplementation during the rainy season; CS/MS: concentrate supplementation during the dry season and mineral supplementation during the rainy season; CS/CS: concentrate supplementation during both, dry and rainy seasons.		

The experimental period lasted 293 days, with 20 days for the animals' adaptation to paddocks and experimental diets. The first part of the experimental period was developed during the dry period (from 06/29 a 10/19, 112 days), and the second part during the rainy period (from 10/20 to 03/29, 161 days). The concentrate supplement was offered in amounts of 0.8% of the animals' body weight, while mineral supplement was provided at 0.10 kg/animal. Both supplements were formulated considering forage composition in each period (Table 2) and in accordance with cattle nutritional requirements for providing an average daily gain of 1 kg, in accordance with BR Corte (Valadares Filho et al., 2016) recommendations. Supplements (concentrate or mineral salt) for each treatment were provided daily at 10:00 am in a covered feeder (0.33 m/animal) located in each paddock and water was available *at libitum*.

Table 2

Ingredients and chemical composition of forage, concentrate, and mineral salts used during the dry and rainy seasons

Ingredient (% dry matter)	Dry season		Rainy season	
	Concentrate	Forage ^a	Concentrate	Forage ^b
Ground grain corn	76.68	-	81.79	-
Soybean meal	17.04	-	12.84	-
Mineral salt ^c	3.53	-	3.58	-
Urea	2.75	-	1.79	-
<i>Chemical composition (%DM)</i>				
Dry matter (% as fed)	89.96	88.82	88.46	90.67
Organic matter	92.32	88.81	94.51	90.86
Crude protein	22.86	8.68	19.10	11.28
Ether extract	2.99	1.68	4.55	2.17
Neutral detergent fiber	15.21	67.81	15.77	58.8
Lignin	1.68	4.64	0.82	2.81
^a Mean value of samples obtained by hand-plucking method during the dry season.				
^b Mean value of samples obtained by hand-plucking method during the rainy season.				
Mineral salt composition = 223 g Ca/kg; 74 g P/kg; 24 g S/kg; 100 mg Co/kg; 1250 mg Cu/kg; 1795 mg Fe/kg; 90 mg I/kg; 2000 mg Mn/kg; 15 mg Se/kg; 5270 mg Zn/kg; and 1740 mg F/kg.				

Chemical analysis of forage and supplements

Samples of forage and concentrate supplement (one-mm ground) were analyzed for dry matter (DM; Method 934.01), ash (Method 942.05), crude protein (CP, Method 984.13), and ether extract (EE; Method 920.39) in accordance with AOAC (2005) recommendations. Neutral detergent fiber (NDF) analysis was conducted following the procedure depicted by Van Soest et al. (1991) with modifications suggested by Mertens et al. (2002), and the lignin content was estimated as described by Van Soest and Robertson (1985). Mineral salt chemical composition was provided by the manufacturer (DSM®, Marabá, PA, Brazil). Table 2 shows the chemical composition of forage and supplements.

Slaughter, pH measurements, and carcass traits

At the end of the experimental period, cattle were fasted for 16 hours, weighed to determine the body weight at slaughter (BWS), and slaughter in a commercial slaughterhouse of Parauapebas City, following

the Sanitary and Industrial Inspection Regulations for Animal Origin Products (BRASIL, 1997). After animal slaughter, pH was measured in the *Longissimus* muscle in a section made at the 12th rib using a direct puncture pH meter (HI 99163 Model - Hanna Instruments). The carcass was separated into two half carcasses, whose weights were obtained to measure the hot carcass weight (HCW; kg), then cooled in a cold room for 24 hours. After cooling, the pH in the *Longissimus* muscle was again measured.

Determination of the yield of hot carcasses was performed in relation to BWS using the following equation: hot carcass yield (HCY; %) = (HCW/BWS) x 100. The ribeye area (cm²) and backfat thickness were measured on the left side of each carcass following the procedure suggested by Lacerda et al. (2021). The right half carcass of each animal was separated into the following primary cuts: forequarter (composed of the shoulder, neck, foreleg arm and five ribs), and hindquarter (composed of posterior part of the carcass, separated from the forequarter between the fifth and sixth ribs). The cuts were separately weighed, and their proportions were calculated with respect to the appropriate half of the cold carcass, in accordance with (Prado et al., 2015) recommendations.

Longissimus muscle processing and meat quality evaluation

A sample was taken from the left half carcass of each animal, between the 12th and 13th ribs comprising the *Longissimus dorsi* muscle for meat quality analysis. The 2.54 cm thick steaks were vacuum-packed and immediately frozen at -20 °C for further determination meat quality traits (shear force, myofibrillar fragmentation index, sarcomere length and color), and chemical composition of the meat (i.e., moisture, crude protein, and fat).

The shear force was determined following the procedures described by Lacerda et al. (2021), while the Myofibrillar fragmentation index was obtained as suggested by Culler et al. (1978), with modifications proposed by Hopkins et al. (2004). Sarcomere length was determined by using laser diffraction (indirect method), following the procedure described by Silva et al. (2017).

Meat color

Steaks were removed from packages under vacuum and exposed for 30 minutes in a refrigerated environment (4°C) to allow oxygenation. The parameters evaluated were L, a*, and b* using the CIELab scale, where L represents the luminosity (L = 0, black; and L = 100, white), a* represents the intensity of red (a* = 0 to -60, green; and a* = 0 to +60, red) and b* represents the intensity of yellow (b* = 0 to -60, blue; and b* = 0 to +60, yellow). Three determinations were made at different points on the *Longissimus* surface. The color evaluation was conducted using a colorimeter, with a D65 illuminant, 8° viewing angle, and 10° observer standard, according to the CIE (1986) specifications.

Chemical composition of meat

Samples from *Longissimus dorsi* were dehydrated in a freeze dryer for 48 h to determine the DM content. Thereafter, samples were defatted by successive washing with petroleum ether to obtain the pre-defatted

DM content. And finally, samples were processed in a ball mill (1 mm) and the DM (Method 934.01), CP (Method 984.13), and EE (Method 920.39) were performed in accordance with AOAC (2005) recommendations. The natural matter content (totaling 100% sample) was determined considering the protein and ether extract levels in the pre-defatted dry matter samples and the weight of the samples subjected to pre-defatting.

Economic feasibility assessments

An economic analysis of supplementation strategies was performed, using the budget analysis system developed by Shang (1990) as a reference. The following economic indicators were determined:

Supplementation cost in the dry and rainy seasons: Cost of the supplement consumed per animal per day.

Effective operational cost (EOC): Expenses related to machinery, labor, equipment, and supplement.

Total cost: EOC + purchase of animals.

Gross Revenue: Calculated according to the amount of carcass produced from each supplementation strategy and the sales price of the product (US \$ 2.65/kg carcass)

Profit: Gross revenue - total cost

Profit index = (Total cost/GR) × 100

All values were expressed in American dollars (USD). Prices of feedstuff were obtained from markets in the Para state of Brazil, during October 2017.

Statistical analyses

All statistical analysis were performed using the SAS® software (version 9.4; SAS Institute Inc., Cary, NC, USA). Data on variables related to meat carcass traits, meat quality traits, and chemical composition of meat were analyzed as a completely randomized design applying the proc MIXED of SAS, in accordance with the model described below:

$$Y_{ij} = \mu + T_j + \varepsilon_{ijk},$$

where Y_{ij} is the explored variable; μ is the overall mean; T_j is the treatment effect; and ε_{ij} is the residual error. The treatments means was compared performing a Tukey Test (Steel and Torrie, 1980) and the Least Squares Means of treatments were calculated by the LSMEANS statement of the proc MIXED. All treatment comparisons were conducted using a significance level of 0.05 ($P < 0.05$). Trends towards significance were considered when P value ranged from 0.05 and 0.10.

Data on economic variables (expenses and profitability) were analyzed by descriptive statistics using the proc MEANS of SAS.

Results

Carcass traits and primary carcass cut yields

Data revealed that cattle supplemented with concentrate in both dry and rainy seasons (CS/CS) showed the greatest hot carcass weights ($P < 0.01$) compared to animals under other supplementation strategies (Table 3). However, cattle supplemented with concentrate in at least one season (i.e., MS/CS and CS/MS) showed similar ($P > 0.05$) hot carcass weights (Table 3). Cattle without concentrate supplementation in both seasons (i.e., MS/MS) showed the lowest ($P < 0.01$) hot carcass weights among the supplementation strategies evaluated (Table 3). The type of supplementation strategy did not affect ($P \geq 0.05$) the final pH, hot carcass yield, and ribeye area (Table 3); however, there was a tendency ($P = 0.058$) to increase the backfat thickness for animals that were supplemented with concentrate during the dry season (i.e., CS/MS and CS/CS).

Table 3
Carcass traits and primary carcass cut yields from young bulls subjected to different supplementation strategies

Variables	Supplementation strategy ¹				SEM	P- value ²
	MS/MS	MS/CS	CS/MS	CS/CS		
<i>Carcass traits</i>						
Hot carcass weight, kg	231.21 ^C	247.51 ^B	264.08 ^B	276.71 ^A	4.534	< 0.01
Final pH, 24 h	5.82	5.87	5.74	5.88	0.062	0.266
Hot carcass yield, %	53.87	52.75	53.09	52.42	0.495	0.166
Ribeye area, cm ²	64.37	63.05	64.48	63.30	2.880	0.974
Backfat thickness, mm	1.98	1.94	3.39	3.10	0.460	0.058
<i>Primary carcass cut yields</i>						
Forequarter, %	42.04	42.16	41.67	42.80	0.545	0.499
Hindquarter, %	47.50	48.08	47.41	46.10	0.514	0.056
¹ MS/MS: mineral supplementation during both, dry and rainy seasons; MS/CS: mineral supplementation during the dry season and concentrate supplementation during the rainy season; CS/MS: concentrate supplementation during the dry season and mineral supplementation during the rainy season; CS/CS: concentrate supplementation during both, dry and rainy seasons.						
² Differences between letters indicate statistical differences between treatment means (P < 0.05). P values between 0.05 and 0.10 were considered as trending towards significance.						

Data showed that supplementation strategy did not influence ($P = 0.499$) the forequarter yield in bulls (Table 3). Conversely, the hindquarter yield showed a tendency ($P = 0.056$) to be greater for animals that

were supplemented with concentrate in the rainy season (i.e., MS/CS).

Quality and chemical composition of meat

There was no effect ($P > 0.05$) of supplementation strategy on meat quality traits (i.e., shear force, myofibrillar fragment index, sarcomere length, and color parameters) of bulls (Table 4). Chemical composition of meat (i.e., moisture, crude protein, and fat) was not affected ($P > 0.05$) as well (Table 4).

Table 4
Quality and chemical composition of meat from young bulls subjected to different supplementation strategies

Variables	Supplementation strategy ¹				SEM	P-value ²
	MS/MS	MS/CS	CS/MS	CS/CS		
<i>Meat quality traits</i>						
Shear force, kgf	5.15	4.76	5.20	4.68	0.783	0.938
Myofibrillar fragment index	54.85	43.13	39.20	57.61	0.886	0.408
Sarcomere length, μm	1.45	1.45	1.53	1.41	0.043	0.248
Color						
L	35.08	34.83	36.47	35.23	0.857	0.512
a*	13.33	13.54	14.13	12.16	0.897	0.483
b*	2.01	2.12	3.04	2.05	0.546	0.507
<i>Chemical composition of meat, %</i>						
Moisture	77.45	77.22	76.99	77.19	0.168	0.341
Crude protein	20.73	20.95	21.25	20.93	0.160	0.180
Fat	0.75	0.72	0.78	0.83	0.132	0.933
¹ MS/MS: mineral supplementation during both, dry and rainy seasons; MS/CS: mineral supplementation during the dry season and concentrate supplementation during the rainy season; CS/MS: concentrate supplementation during the dry season and mineral supplementation during the rainy season; CS/CS: concentrate supplementation during both, dry and rainy seasons.						
² Differences between letters indicate statistical differences between treatment means (P < 0.05).						

Economic feasibility assessments

Economic indicators associated with expenses revealed that supplementation strategies with concentrate during the dry and/or rainy seasons (i.e., MS/CS, CS/MS, and CS/CS) showed the greatest supplementation expense values (Table 5). The EOC and total cost of animals showed the highest values for the supplementation strategy with concentrate in both, the dry and rainy seasons (i.e., CS/CS),

whereas the MS/MS supplementation strategy showed the lowest values (Table 5). The profitability indicators indicated that supplementation strategy with concentrate in both, the dry and rainy seasons (i.e., CS/CS) produced the highest gross revenue, profit, and profit index, whereas the MS/MS supplementation strategy showed the lowest values (Table 5).

Table 5
Economic analysis of supplementation and profit of young Nellore bulls subjected to different supplementation strategies

Variables	Supplementation strategy ³			
	MS/MS	MS/CS	CS/MS	CS/CS
<i>Expenses</i>				
Supplementation cost - dry season ¹	0.07	0.07	0.41	0.41
Supplementation cost - rainy season ²	0.07	0.58	0.07	0.61
EOC, \$/animal	43.97	128.45	87.62	170.37
EOC, \$/ kg of body weight	0.46	0.80	0.60	0.84
Total cost, \$/animal	581.34	651.16	614.16	702.94
<i>Profitability</i>				
Gross revenue, \$/ animal	612.30	715.54	684.05	787.95
Profit, \$/ animal	30.96	64.38	69.89	85.01
Profit index, % of gross revenue	4.61	8.79	9.77	10.78
^{1,2} \$/animal/day; EOC = effective operational cost; Total cost = EOC + purchase of animals.				
³ MS/MS: mineral supplementation during both, dry and rainy seasons; MS/CS: mineral supplementation during the dry season and concentrate supplementation during the rainy season; CS/MS: concentrate supplementation during the dry season and mineral supplementation during the rainy season; CS/CS: concentrate supplementation during both, dry and rainy seasons. Comparison between variables was performed from their descriptive statistics due to lack of replications within treatments.				

Discussion

This study explored the effects of different supplementation strategies adopted during the dry and rainy seasons in the tropics, on the carcass traits, meat quality, and economic viability of Nellore steers production. As expected, a quantitative restriction produced by the supply of different energy density diets across the seasons (i.e., different supplementation strategies), resulted in different hot carcass weights. This agrees with Silva et al. (2020) findings, who showed that quantitative feed restrictions in Nellore

cattle associated to different nutritional plans, influence the growth rate, body composition, and performance of the animals.

A reduction in the forage quality associated with the MS of the animals in the dry season (i.e., MS/MS and MS/CS groups), resulted in the lowest hot carcass weights (i.e., animals with the lightest carcasses); however, animals supplemented with concentrate in both periods (i.e., CS/CS) showed the highest values. This indicates that the selection of the season period when animals are supplemented with concentrate under tropical conditions may have a significant influence in their performance. Animals under MS/CS and CS/MS supplementation strategies produced higher hot carcass weights than those of animals supplemented with mineral salt in both seasons (i.e., MS/MS). Hence, animal supplementation with concentrate in at least one season presented a compensatory gain, which conforms to Hornick et al. (1998) and Sampaio et al. (2017) findings, who observed a compensatory gain in Nellore cattle after feed restriction.

Concomitantly, the concentrate supplementation in both dry and rainy seasons (i.e., CS/CS) produced animals with the highest hot carcass weight among the other supplementation strategies evaluated. This may be due to the highest energy density of the diet supplied in this supplementation strategy compared to others explored. It is known that the adequate supply of protein and energy requirements contributes to the growth of ruminal microorganisms, increasing fiber digestibility and, consequently, improving the response to weight gain in cattle (Detmann et al., 2014); in addition, the greater availability of concentrate leads to an increase in the propionate concentration in the rumen, thereby enhancing glucose production, and this fact is positively associated with muscle growth (Ladeira et al., 2016; Wicks et al., 2019). The latest effect was also in accordance with the highest hot carcass weights observed in animals under MS/CS, CS/MS, and CS/CS nutritional strategies, suggesting that an improvement in nutritional inputs in at least one of the climatic seasons (i.e., dry, or rainy), may be advantageous over the traditional finishing system in tropical pastures, without concentrate supplementation (i.e., MS/MS).

Data revealed that backfat thickness tended to be lower for animals supplemented with mineral salt in the dry season (i.e., MS/MS and MS/CS) compared to other supplementation strategies. This fact demonstrates that animals under feed restriction in the dry season prioritize the growth of visceral organs instead of depositing subcutaneous fat (Silva et al., 2020). Regarding ribeye area, no differences were observed across supplementation strategies; nevertheless, animals under MS/MS and MS/CS supplementation strategies tended to produce the highest hindquarter yields, demonstrating the priority in muscle deposition over the adipose tissue deposition, which is in line with other studies (Hornick et al., 1998; Silva et al., 2017).

Diets with low protein and energy contents, such as provided to grazing animals during the dry period in the tropics (Rufino et al., 2016) may reduce muscle glycogen content, thereby affecting the pH of meat (Vestergaard et al., 2000); however, contrary to the expectations, this response was not observed in this study for the animals supplemented with mineral salt in the dry season (i.e., MS/MS and MS/CS). Furthermore, no differences were observed for any meat quality traits (i.e., shear force, myofibrillar

fragment index, sarcomer length, and color) and chemical composition of meat (i.e., moisture, crude protein, and fat), both group characteristics related to postmortem muscle proteolysis and highly associated with in vivo muscle turnover (Therkildsen et al., 2008).

A possible explanation to these contradictory results may be due to the long refeeding time adopted in this study because this one considered 161 days of the rainy season. According to Therkildsen (2005), the effects of compensatory growth on muscle protein turnover depends on time. Additionally, protein turnover between continuous and compensatory animal growth becomes equivalent for re-feeding periods greater than 77 days. Additionally, forage with a high level of crude protein (112.8 g/ kg DM) and lower neutral fiber (678.1 g/kg DM) contents associated with CS in at least one seasons (i.e., MS/CS, CS/MS, and CS/CS) may also have contributed to this lack of effect.

An economic analysis of the different nutritional strategies revealed that CS/CS strategy had the highest profitability (i.e., gross revenue, profit, and profit index), despite it showed the greatest EOC and total cost, among the supplementation strategies evaluated (Figure 1). These results are in accordance with those of Silva et al. (2020) findings, who observed that although supplementation costs were higher when animals are supplemented with concentrate in both seasons, unrestricted animals are more profitable when considering the cost per kg of carcass produced in relation to animals that were subjected to restriction. Furthermore, the use of concentrate supplementation in at least one season is more economically advantageous than the use of mineral supplementation in both seasons, as this practice provides greater hot carcass weight and shorter finishing time for animals in a grazing system (Sampaio et al., 2017).

Conclusions

The hypothesis of this study was partially accepted due to concentrate supplementation during at least one season (dry or rainy) produces animals with similar meat quality traits and chemical composition of meat, but different hot carcass weight, backfat thickness and hindquarter proportion to those observed when animals were supplemented with concentrate in both seasons. The data also showed that mineral supplementation in both seasons produces animals with the lowest hot carcass weight, backfat thickness and high hindquarter proportion, suggesting a simultaneous qualitative and quantitative restriction under this supplementation strategy. Finally, the economic evaluation of the supplementation strategies revealed that animals kept under concentrate supplementation in both seasons, despite having a high total cost, have great profitability when raised in tropical pasture.

Declarations

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Conflict of interest

None.

Ethics approval

The procedures involving the use of animals were approved by the Ethics Committee on the Use of Animals – CEUA of the Federal Rural University of the Amazon (protocol number: CEUA 020/2016).

Consent to participate

Not applicable.

Consent for publication

All authors approve the publication of the manuscript.

Availability of data and material

The data of this study are available from the corresponding author upon request.

Code availability

Not applicable.

Authors' contributions

JMLR: Data collection, Writing- Original draft preparation. JACV: Writing- Original draft preparation, Writing-Reviewing and Editing. EALD: Data collection, Writing- Original draft preparation. NGL: Data collection, Writing- Original draft preparation. RM: Visualization, Writing- Original draft preparation, Writing- Reviewing and Editing. KSA: Data collection, Investigation. LRSO: Data collection, Investigation. JPBL: Data collection, Writing- Original draft preparation. PRS: Writing- Original draft preparation, Writing- Reviewing and Editing. DIG: Conceptualization of the manuscript, Project administration, Funding acquisition, Supervision, Writing- Original draft preparation.

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Figures

Figure 1

Analysis of total cost, gross revenue, and profit of young Nellore bulls subjected to different supplementation strategies. The values are presented in American dollars.

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