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ORIGINAL ARTICLE

Performance and economic analysis of two beef cattle genetic groups fed different nutritional strategies

Desempenho e análise econômica de dois grupos genéticos de bovinos de corte alimentados com diferentes estratégias nutricionais

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ABSTRACT: Genetic resources and well-balanced diets are relevant for improving the performance and profitability of beef cattle finished in feedlots. The objective of the present paper was to determine the performance and economic analysis of 36 non-castrated males (18 Nellore and 18 F1 Angus × Nellore) fed diets containing either fixed or variable nutritional levels. Animals were fed *ad libitum* once a day. Dry matter intake (DMI) was determined daily by the difference between feed offered and feed refused. Body weight (BW) was recorded every two weeks after a twelve-hour solid fasting. Data of economic analysis (diet cost, feeding cost, average productivity, average cost, marginal productivity, marginal cost, total revenue, profit, and marginal revenue) were standardized in 14-day intervals likewise BW recording. The experimental design was completely randomized in a factorial scheme 2 × 2 × 2 (two genetic groups, two diets, and two housing types). F1 Angus × Nellore animals increased (*p <0.05*) DMI, BW, hot carcass weight, total revenue, and profit in comparison with Nellore animals. Conversely, Nellore had a lower (*p <0.05*) feeding cost and average cost compared with F1 Angus × Nellore. No response (*p > 0.05*) of diet (fixed or variable) was detected on performance and economic indicators; therefore the use of a variable diet is not recommended for beef cattle feeding. F1 Angus × Nellore may be indicated in feedlot finishing systems with a high supply of forage and dietary feeds, whereas Nellore may be recommended in feedlot finishing systems with certain limitations for forage and grain production.

RESUMO: *Recursos genéticos e dietas bem balanceadas são relevantes na melhoria do desempenho e lucratividade de bovinos de corte confinados. Objetivou-se no presente trabalho determinar o desempenho e a análise econômica de 36 machos não castrados (18 Nelore e 18 F1 Angus × Nelore) alimentados com dietas contendo níveis nutricionais fixos ou variáveis. Os animais foram alimentados ad libitum uma vez ao dia. O consumo de matéria seca (CMS) foi determinado diariamente pela diferença entre o alimento oferecido do recusado. O peso corporal (PC) foi registrado a cada duas semanas após jejum de sólidos de doze horas. Os dados da análise econômica (custo da dieta, custo com alimentação, produtividade média, custo médio, produtividade marginal, custo marginal, receita total, lucro e receita marginal) foram padronizados em intervalos de 14 dias assim como o PC. O delineamento experimental foi o inteiramente casualizado em esquema fatorial 2 × 2 × 2 (dois grupos genéticos, duas dietas e dois tipos de alojamento). F1 Angus × Nelore aumentou (p <0,05) o CMS, PC, peso da carcaça quente, receita total e lucro comparado ao Nelore. Contrariamente, Nelore teve um menor (p <0,05) custo com alimentação e custo médio comparado ao F1 Angus × Nelore. Não houve resposta (p > 0,05) de dieta (fixa ou variável) sobre o desempenho e indicadores econômicos, portanto não se recomenda o uso da dieta variável na alimentação de bovinos de corte. F1 Angus × Nelore pode ser indicado em sistemas de terminação em confinamento com alta oferta de forragem e concentrados, ao passo que Nelore pode ser recomendado em sistemas de terminação em confinamento com certa limitação para a produção de forragem e grãos.*

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1 Introduction

Brazil has settled as the second beef producer and leading beef exporter in the world. Brazil reached a historical record of 2.04 million tons of carcass exported in 2018 versus 1.79 million tons of carcass exported in 2017, which means a 14% growth (Anualpec, 2019). To meet the demand from both domestic and foreign markets, producers should be aware of the necessities of the beef industry and final consumer to improve beef yield, carcass traits, and meat quality.

Efficient feedlot finishing systems are the ones that optimize genetic, environmental, and economic resources associated with management practices that aim higher profitability during the beef production cycle. The increasing competitiveness with other types of meat and the search for new markets has demanded from Brazilian producers an improved efficiency and a continuous supply of high-quality meat.

Finishing beef animals in feedlot may be a good strategy to increase weight gain and body weight (BW) at slaughter, as well as reduce slaughter age, which in turn may improve carcass finishing and add value to the final product, thereby increasing the return on the invested capital. On the other hand, feedlots may result in financial losses when viewed as a single practice for beef cattle finishing depending on the level of concentrate in the diet (Pacheco et al., 2014) or the efficiency of animals to convert feed in meat (Lopes et al., 2011).

Because of the recent changes that have occurred in the beef industry, the economic analysis in a feedlot is extremely important, since not always the greatest animal performance will result in the best good economic indicator. Additionally, the bioeconomic evaluation estimates the impact of productive technologies and represents an important decision-making tool for the beef industry (Santana et al., 2013). Thus, an adequate diet balancing is critical to the performance and economic feasibility of a feedlot, since feeding is one of the most costly items in this finishing system, ranging from 12 to 48% of the total production cost (Lopes et al., 2011) or 66 to 77% of the total production cost disregarding the price of acquisition of the animals at the beginning of the feedlot (Pacheco et al., 2014).

The adoption of intensive management that aims higher yields in feedlot involves several factors, such as the genetic potential of the animals and feeding strategies that meet their nutritional requirements. As an example, crossbreeding *Bos taurus* with *Bos indicus* has increased animal performance compared with Zebu animals in tropical environments because of heterosis and complementarity between breeds (Vaz & Restle, 2003).

The use of diets with increasing levels of energy and decreasing concentration of protein is not a common practice in beef cattle finished in a feedlot, although in poultry and swine this nutritional strategy is well established to provide higher performance and better carcass finishing (Longo et al., 2006; Gonçalves et al., 2015). Thus, the formulation of beef cattle diets based on an accurate prediction for both energy and protein requirements for weight gain may increase the productive efficiency and improve the economic efficiency.

In this context, the objective of the present study was to determine the performance and economic analysis of 36 non-castrated males (18 Nellore and 18 F1 Angus × Nellore) fed diets containing either fixed or variable nutritional levels and housed in individual or collective pens. It was hypothesized that animal performance and economic indicators would be influenced by genetic groups and the type of diet fed.

2 Material and Methods

The present experiment was conducted at the Dairy and Beef Research and Education Center of the Goiano Federal Institute of Education, Science, and Technology (IF Goiano), Iporá, Goiás State, Brazil, from June 4 through September 12, 2016. The study was run for 98 days (14 days for adaptation of the animals for the new facilities and experimental diets and 84 days for data collection). Thirty-six non-castrated males (18 Nellore e 18 F1 Angus × Nellore) with approximately 24 months of age were ranked by BW and randomly assigned to receive diets containing either a fixed or a variable nutritional composition as described in Table 1. The initial mean BW for Nellore and F1 Angus × Nellore animals was 402.5 and 419.6 ± 7.3 kg, respectively.

After the first randomization by initial BW to each diet group, animals were again randomly assigned according to the type of housing with twelve animals housed in individual pens, and 24 animals were housed in eight collective pens (three animals per pen).

The distribution of animals alongside the individual pens was the following: Nellore (fixed diet), F1 (fixed diet), Nellore (variable diet), and F1 (variable diet) with the same sequence repeated two more times to result in twelve animals. Similarly, the same distribution pattern was used for the animals housed in the collective pens: pen 1 = three Nellore (fixed diet), pen 2 = three F1 (fixed diet), pen 3 = three Nellore (variable diet), pen 4 = three F1 (variable diet), pen 5 = three Nellore (fixed diet), pen 6 = three F1 (fixed diet), pen 7 = three Nellore (variable diet), and pen 8 = three F1 (variable diet).

Individual pens measured two meters wide by five meters long (10 m²/animal) whereas collective pens measured five meters wide by ten meters long (16.66 m²/animal). The volumetric capacity of feeders in the individual and collective pens was 0.35 and 1.05 m³, respectively. The feed bunk space in each collective pen was 3.8 meters long (1.26 m/animal).

There were six drinkers alongside the 12 individual pens (one drinker for two animals) with a capacity of 240 L and four drinkers for the eight collective pens (one drinker for two pens) with an individual capacity of 380 L. Drinkers in the individual pens were under a shade and in the collective pens exposed to the sun. All drinkers had automatic floats that allowed a continuous water flow.

Animals were fed once daily between 05:00 to 07:00

am in amounts that ensured *ad libitum* intake (10 to 15% of orts) with rations containing sugar cane silage, soybean hulls, ground corn, soybean meal, urea, mineral/vitamin premix, and sodium bicarbonate (Table 1). Urea was added (1 kg/100 kg on a green matter basis) during sugar cane ensiling to reduce ethanol production during the fermentation process (Castro Neto et al., 2008).

One experimental diet contained a fixed nutritional composition throughout the entire experiment (control), whereas a variable diet contained increasing levels of non-fiber carbohydrates (NFC) through a gradual increase of ground corn and a decreasing concentration of crude protein (CP) through a gradual reduction of soybean meal (Roman et al., 2011). Both experimental diets were formulated and balanced to meet the NRC (2000) guidelines for beef cattle finished in a feedlot with an expected weight gain of 1.8 kg/day. The variable diet was rebalanced every time the animals' BW was registered, which occurred every two weeks. All experimental protocols were approved by the "IF Goiano" Ethical Committee in the Use of Animals (decision nº 2284220216).

Sugar cane silage samples were collected weekly and dried in a forced-air circulation oven for 72 hours at 65ºC for dry matter (DM) determination (AOAC, 2000) to adjust the nutritional composition of the experimental diets throughout the experiment.

Diet samples were collected every two weeks and stored frozen at -4ºC. Shortly after the end of the experiment, samples were thawed at room temperature, merged to form one composite sample of each diet/14 days, and dried in a forced-air circulation oven for 72 hours at 65ºC for DM analysis (AOAC, 2000). Diet samples were then ground using a Willey mill to pass a 1-mm screen and analyzed for CP, ether extract (EE), ash (AOAC, 2000), and neutral detergent fiber (NDF) (Goering & Van Soest, 1970). NDF residues were subsequently analyzed for acid detergent fiber (ADF) and lignin concentrations (Goering & Van Soest, 1970). Cellulose was determined as ADF minus lignin, and hemicellulose was calculated as NDF minus ADF (Goering & Van Soest, 1970). NFC was determined as 100 – CP% – NDF% – EE% – ash% (AOAC, 2000).

Feed refusals were weighed daily and DMI was determined by the difference between feed offered and feed refused. BW was recorded every two weeks on days 1, 14, 28, 42, 56, 70, and 84 days relative to the beginning of the experiment after a twelve-hour solid fasting. Subcutaneous fat thickness (SFT) was obtained on days 28, 70, and 84 by ultrasonography between the 12th and 13th rib (Brethour, 1992).

Table 1. Ingredient and nutrient composition of the experimental diets[1].
Tabela 1. Ingredientes e composição nutricional das dietas experimentais[1].

Ingredients, % of DM	Fixed diet	Variable diet					
		Day 1-14	Day 15-28	Day 29-42	Day 43-56	Day 57-70	Day 71-84
Sugar cane silage	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Soybean hulls	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Ground corn	**66.0**	**59.5**	**61.5**	**63.5**	**65.4**	**67.1**	**68.6**
Soybean meal	**6.0**	**12.5**	**10.5**	**8.5**	**6.6**	**4.9**	**3.4**
Urea	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mineral/vitamin Premix[2]	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Sodium bicarbonate	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Nutrient composition							
DM[3], %	72.51	71.95	72.49	73.91	71.50	73.15	74.41
CP[4], % of DM	**13.71**	**16.06**	**15.93**	**14.69**	**14.34**	**13.29**	**12.00**
NDF[5], % of DM	38.43	42.64	40.11	38,69	37.36	36.77	38.02
ADF[6], % of DM	21.71	20.40	16.20	23.17	19.95	19.96	18.27
Cellulose, % of DM	17.14	14.27	13.41	18.38	16.49	16.63	14.45
Hemicellulose, % of DM	16.72	21.71	20.49	19.47	17.41	16.81	19.75
Lignin, % of DM	4.57	6.13	2.79	4.79	3.46	3.33	3.82
Ash, % of DM	5.98	5.73	6.32	5.32	5.69	5.62	4.93
EE[7], % of DM	4.38	4.66	4.85	4.96	4.44	4.83	4.23
NFC[8], % of DM	**37.50**	**30.91**	**32.79**	**36.34**	**38.17**	**39.49**	**40.82**

[1]Mean analysis of composite samples (n = 6), [2]Contained 18% Ca, 20 g/kg P, 17g/kg Mg, 26.7g/kg S, 66.7 g/kg Na, 25.2 mg/kg Co, 416 mg/kg Cu, 490 mg/kg Fe, 25.2 mg/kg I, 832 mg/kg Mn, 7 mg/kg Se, 2,000 mg/kg Zn, 833.5 mg/kg Monenzin, 83,200 IU/kg vitamin A, 10,400 IU/kg vitamin D, 240 IU/kg vitamin E, [3]Dry matter, [4]Crude protein, [5]Neutral detergent fiber, [6]Acid detergent fiber, [7]Ether extract, [8]Non-fiber carbohydrates = 100 – CP% – NDF% – EE% – ash%.

Animals were slaughtered on September 12, 2016, in a slaughterhouse located at Iporá, Goiás State, Brazil. Prior to transportation to the slaughterhouse, animals were weighed after a twelve-hour solid fasting and slaughtered following the procedures and normal flow of the abattoir. After hide removal and evisceration, carcasses were weighed to determine the hot carcass weight (HCW). Dressing percentage (DP) was calculated as the proportion between HCW and BW before slaughter.

Data of economic analysis were standardized in 14-day intervals likewise BW recording. The DMI was obtained in 14-day intervals by the sum of the daily DMI in the following intervals (1-14 days, 15-28 days, 29-42 days, 43-56 days, 57-70 days, and 71-84 days).

The cost of experimental diets in R$/kg on a dry matter basis (DMB) was obtained by multiplying the diet cost on a fresh matter basis (FMB) × diet DM% at feed delivery. Feeding cost was calculated as DMI in a 14-day interval × diet cost (R$/kg on a DMB). Both equations are demonstrated below:

Diet cost (R$/kg) on a DMB = diet cost on a FMB × 100 ÷ diet DM%

Feeding cost (R$/14 days) = DMI (14 days) × diet cost (R$/kg) on a DMB

The DP data for each animal was used to determine the proportional increase of carcass weight at each 14-day interval, therefore it was estimated that at the beginning of the study animals had an estimated DP of 50% (Kuss et al., 2009). The result of the subtraction between DP after slaughter from the estimated DP at the beginning of the experiment was divided by six BW recordings, which was cumulatively added in the carcass weight in each 14-day interval.

Average productivity (AP) and average cost (AC) were determined following Vasconcellos & Garcia (2014):

AP (@ of carcass/kg of DM ingested) = carcass weight (@) ÷ DMI (14 days)

AC (R$/@ of carcass) = feeding cost (R$/14 days) ÷ carcass weight (@)

Marginal productivity (MP) was obtained by subtracting carcass weight (@) from DMI in 14-day intervals, which indicates an increase in carcass weight with the addition of one kg of DM ingested. Similarly, marginal cost (MC) was determined by subtracting feeding cost from carcass weight (@) in 14-day intervals, which indicates an increase in feeding cost with the addition of one @ of carcass (Vasconcellos & Garcia, 2014).

MP (@ of carcass/kg of DM ingested) = Δ @ of carcass ÷ Δ DMI

Table 2. Demonstration of the calculations of the economic analysis in 14-day intervals using the animal with ear tag # 3121 (Nellore/variable diet/individual housing).

Tabela 2. Demonstração dos cálculos da análise econômica em intervalos de 14 dias usando o animal com brinco # 3121 (Nelore/dieta variável/alojamento individual).

Item	Days relative to the beginning of the experiment					
	14	28	42	56	70	84
Feed offered on a FMB[1] (kg)	258.10	277.60	279.10	257.20	261.70	249.90
DM% of feed offered	72.03	77.18	73.98	72.25	70.82	65.41
Feed offered on a DMB[2] (kg)	185.90	214.26	206.47	185.84	185.34	163.45
Feed refused on a FMB (kg)	35.90	36.40	42.10	32.10	29.90	33.90
DM% of feed refused	71.00	81.67	83.46	85.88	86.06	69.97
Feed refused on a DMB (kg)	25.49	29.73	35.14	27.57	25.73	23.72
DMI[3] (kg)	160.41	184.53	171.34	158.27	159.61	139.73
Diet cost on a DMB (R$/kg)	1.06	0.97	1.00	1.00	1.00	1.06
Feeding cost (R$)	169.55	178.54	171.11	158.03	160.09	148.47
Carcass weight (@)	16.27	17.60	17.99	19.30	20.01	20.83
AP[4] (@ of carcass/kg of DM ingested)	0.10	0.10	0.10	0.12	0.13	0.15
AC[5] (R$/@ of carcass)	10.42	10.15	9.51	8.19	8.00	7.13
MP[6] (@ of carcass/kg of DM ingested)	-	0.05	-0.03	-0.10	0.53	-0.04
MC[7] (R$/@ of carcass)	-	6.79	-19.18	-9.94	2.90	-14.14
Carcass price (R$)	156.16	156.29	153.54	151.00	149.51	148.40
TR[8] (R$)	2,541.39	2,750.37	2,761.48	2,914.38	2,991.87	3,091.67
Profit (R$)	2,371.83	2,571.83	2,590,37	2,756.34	2,831.78	2,943.20
MR[9] (R$/@ of carcass)	-	157.89	28.68	116.26	109.04	121.38

[1]Fresh matter basis, [2]Dry matter basis, [3]Feed offered – feed refused, [4]Average productivity, [5]Average cost, [6]Marginal productivity, [7]Marginal cost, [8]Total revenue, [9]Marginal revenue. Data of MP, MC, and MR at 14 days relative to the beginning of the experiment are missing because there was not a previous interval for these calculations.

MC (R$/@ of carcass) = Δ feeding cost ÷ Δ @ of carcass

Carcass prices (R$/@) were obtained from Cepea (2019) during the experimental period for the calculations of total revenue (TR). Profit was determined as TR minus feeding cost in 14-day intervals.

TR (R$) = carcass weight (@) × carcass price (R$/@)
Profit (R$) = TR - feeding cost

Marginal revenue (MR) was calculated by the difference of TR from carcass weight (@) in 14-day intervals, which indicates an increase in revenue with the addition of one @ of carcass (Vasconcellos & Garcia, 2014).

MR (R$/@ of carcass) = Δ TR ÷ Δ @ of carcass

A better understanding of the calculations of the economic analysis is demonstrated in Table 2 in which the animal with ear tag # 3121 (Nellore fed a variable diet and housed in an individual pen) was taken as an example.

The experimental design utilized was completely randomized in a factorial scheme 2 × 2 × 2 (two genetic groups, two diets, and two types of housing). The data were analyzed using the "R" open system (R Core Team, 2014) in a mixed model of double repeated measurements in time (days), considering genetic group (Nellore or F1 Angus × Nellore), diet (fixed or variable), and housing (individual or collective) as fixed effects, and animal as random.

The structure of covariance that best fitted to the model was chosen according to the lowest Bayesian Information Criterion. Analysis for DMI was run separately between individual and collective housing, and considered only genetic group and diet as fixed effects. Analyses for BW, SFT, DP, and economic analysis were run considering all three fixed effects (genetic group, diet, and housing).

The model accounted for the effects of genetic group (gg), diet (d), housing (h), days of the experiment (days), gg × d, gg × h, gg × days, d × h, d × days, h × days, gg × d × h, gg × d × days, gg × h × days, d × h × days, and gg × d × h × days, according to the following equation: $y_{ijklm} = \mu + gg_i + d_j + h_k + days_l + ggd_{ij} + ggh_{ik} + ggdays_{il} + dh_{jk} + ddays_{jl} + hdays_{kl} + ggdh_{ijk} + ggddays_{ijl} + gghdays_{ikl} + dhdays_{jkl} + ggdhdays_{ijkl} + e_{ijklm}$; where y = independent variable, μ = mean, and e = experimental error. When a fixed effect was significant ($p \leq 0.05$), means were compared using the Tukey test. Values are reported as least square means and associated standard errors of means (SEM).

3 Results and Discussion

The DMI and feed conversion ratio (FCR) of animals housed in individual and collective pens are reported in Table 3. F1 Angus × Nellore animals increased ($p < 0.05$) DMI expressed as kg/day both in individual (10.5 vs. 11.8 ± 0.36 kg/day for the Nellore vs. F1 Angus × Nellore, respectively) and collective pens (28.22 vs. 35.24 ± 1.13 kg/day for the Nellore vs. F1 Angus × Nellore, respectively). Also, F1 Angus × Nellore animals housed in collective pens increased ($p < 0.05$) DMI expressed as a BW% (2.05 vs. 2.36 ± 0.05% for the Nellore vs. F1 Angus × Nellore, respectively) and metabolic weight (124.73 vs. 146.31 ± 3.37 g/kg $BW^{0.75}$ for the Nellore vs. F1 Angus × Nellore, respectively).

As shown in Table 4, F1 Angus × Nellore animals had the greatest ($p < 0.05$) BW (478.5 vs. 515.9 ± 6.7 kg for the Nellore vs. F1 Angus × Nellore, respectively) and HCW (289.8 vs. 328.9 ± 5.8 kg for the Nellore vs. F1 Angus × Nellore, respectively). The results reported in Tables 3 and 4 corroborate the original hypothesis that animal performance would be influenced by the genetic group, in this case in favor of the F1 Angus × Nellore animals.

The superior BW of F1 Angus × Nellore compared with Nellore has been well documented in previous studies (Goulart et al., 2008; Souza et al., 2012), which demonstrates the benefits of heterosis in F1 animals (Vaz & Restle, 2003). *Bos taurus* versus *Bos indicus* F1 animals inherit desirable productive characteristics, such as earlier slaughter age, greater growth potential, and better carcass finishing that come from *Bos taurus* breeds, whereas better adaptability to tropical climates, good maternal ability, and resistance to external parasites come from *Bos indicus* breeds. Altogether these characteristics are not present in pure breeds of both species, but only in crossbred animals (Prado et al., 2008).

Additionally, F1 Angus × Nellore animals have higher net energy requirements for weight gain compared with Nellore animals (Goulart et al., 2008), consequently, an increase in DMI can be expected in the F1 group. DMI can be also influenced by differences in the size of internal organs, which are larger in *Bos taurus* and F1 crosses than in *Bos indicus* (Souza et al., 2012; Peripolli et al., 2013), therefore a reduction in DMI of Nellore animals is expected due to a lower net energy requirement for maintenance (Paulino et al., 2004).

No effect ($p > 0.05$) of diet (fixed or variable) was detected on DMI (Table 3) and BW (Table 4), refuting the hypothesis that type of diet would alter animal performance. Such results corroborate previous information reported by Roman et al. (2011), who also evaluated diets with constant or variable nutritional levels (decreased CP and increased NFC and starch concentrations) and did not find differences in performance. A possible reason for the lack of diet effect ($p > 0.05$) in the present study could be the short period of time in feedlot compared with the total life cycle, although there is clear evidence that beef cattle finished in feedlot reduce protein and increase energy requirements with an increasing BW (Owens et al., 1995; Freitas et al., 2006).

Animals housed in individual pens had an increased ($p < 0.05$) BW (511.7 vs. 482.6 ± 7.6 kg for the individual vs. collective housing, respectively) and SFT (4.58 vs. 3.69 ± 0.29 mm for the individual vs. collective housing, respectively) compared with collective housing (Table 4).

Although the area per animal and feed bunk space of the collective pens in this experiment exceeded animal welfare guidelines for beef cattle finished in feedlot (Grandin, 2016), social hierarchy among animals within the same pen (as in the case of commercial feedlots) may have contributed to disruptions, limited access to the feed bunk and less time spent eating (Custodio et al., 2017), which in turn may have been the reason for a decreased ($p < 0.05$) BW and SFT in animals housed in the collective pens. However, BW, HCW, and SFT were not altered ($p > 0.05$) by the type of housing × genetic group interaction (Table 4), indicating that both Nellore and F1 Angus × Nellore had a similar performance housed either in individual or collective pens.

The F1 Angus × Nellore genetic group obtained greater ($p < 0.05$) TR (R$ 2,562.50 vs. R$ 2,858.46 ± R$ 55.42 for the Nellore vs. F1 Angus × Nellore, respectively) and a greater ($p < 0.05$) profit (R$ 2,423.79 vs. R$ 2,693.71 ± R$ 52.62 for the Nellore vs. F1 Angus × Nellore, respectively) compared with Nellore animals (Table 5). These results are closely related to a greater ($p < 0.05$) HCW by the F1 Angus × Nellore animals (Table 4), which in turn had a direct impact on TR and profit (Table 5).

Based on the results of animal performance (Tables 3 and 4) and economic analysis (Table 5), the F1 Angus × Nellore genetic group should be indicated in feedlot finishing systems with more potential to produce forage and concentrate feeds in big quantities, considering that F1 Angus × Nellore animals had an increased ($p < 0.05$) DMI (Table 3) to achieve a greater ($p < 0.05$) BW (Table 4).

Conversely, feeding cost (R$ 138.70 vs. R$ 164.75 ±

Table 3. Effect of the genetic group (Nellore or F1 Angus × Nellore) and diet (fixed or variable) on dry matter intake (DMI) and feed conversion ratio (FCR) of 36 non-castrated males finished in a feedlot and housed in individual or collective pens.

Tabela 3. Efeito de grupo genético (Nelore ou F1 Angus × Nelore) e dieta (fixa ou variável) sobre o consumo de matéria seca (CMS) e conversão alimentar (CA) de 36 machos não castrados terminados em confinamento e alojados em baias individuais ou coletivas.

Item	Genetic group		SEM[4]	P-values				
	Nellore	F1 Angus × Nellore		GG[5]	Days[6]	GG × days	GG × diet	GG × diet × days
Individual pens								
DMI (kg/day)	10.50	11.80	0.36	<0.05	<0.05	0.52	0.28	0.73
DMI (BW%)[1]	2.23	2.26	0.07	0.75	<0.05	0.69	0.58	0.71
DMI (g/kg $BW^{0,75}$)[2]	103.84	108.04	2.86	0.33	<0.05	0.65	0.43	0.73
FCR (kg DM/kg gain)[3]	7.64	7.48	0.77	0.89	<0.05	1.00	0.22	0.21
Collective pens								
DMI (kg/day)	28.22	35.24	1.13	<0.05	<0.05	<0.05	0.54	<0.05
DMI (BW%)	2.05	2.36	0.05	<0.05	<0.05	<0.05	0.53	<0.05
DMI (g/kg $BW^{0,75}$)	124.73	146.31	3.37	<0.05	<0.05	<0.05	0.53	<0.05
FCR (kg DM/kg gain)	6.43	5.83	0.44	0.38	<0.05	<0.05	0.86	0.70
Item	**Diet**		**SEM**	**P-values**				
	Fixed	Variable		Diet	Days	Diet × days	Diet × GG	Diet × GG × days
Individual pens								
DMI (kg/day)	10.96	11.35	0.36	0.48	<0.05	0.72	0.28	0.73
DMI (BW%)	2.21	2.28	0.07	0.46	<0.05	0.68	0.58	0.71
DMI (g/kg $BW^{0,75}$)	104.19	107.69	2.86	0.41	<0.05	0.73	0.43	0.73
FCR (kg DM/kg gain)	7.56	7.56	0.77	0.99	<0.05	0.34	0.22	0.21
Collective pens								
DMI (kg/day)	31.44	32.02	1.13	0.74	<0.05	0.31	0.54	<0.05
DMI (BW%)	2.17	2.23	0.05	0.40	<0.05	0.53	0.53	<0.05
DMI (g/kg $BW^{0,75}$)	133.71	137.33	3.37	0.49	<0.05	0.45	0.53	<0.05
FCR (kg DM/kg gain)	5.95	6.30	0.44	0.60	<0.05	0.93	0.86	0.70

[1]Dry matter intake expressed as a BW%, [2]Dry matter intake in relation to metabolic weight, [3]Feed conversion ratio, [4]Standard error of means, [5]Genetic group, [6]Days when DMI was determined (1-84).

Table 4. Effect of the genetic group (Nellore or F1 Angus × Nellore) and diet (fixed or variable) on BW, hot carcass weight (HCW), dressing percentage (DP%), and subcutaneous fat thickness (SFT) of 36 non-castrated males finished in a feedlot and housed in individual or collective pens.

Tabela 4. Efeito de grupo genético (Nelore ou F1 Angus × Nelore) e dieta (fixa ou variável) sobre o peso corporal, peso da carcaça quente (PCQ), rendimento de carcaça (RC%) e espessura de gordura subcutânea (EGS) de 36 machos não castrados terminados em confinamento e alojados em baias individuais ou coletivas.

Item	Genetic group		SEM[2]	P-values			
	Nellore	F1 Angus × Nellore		GG[3]	Days[4]	GG × diet	GG × days
BW[1], kg	478.5	515.9	6.7	<0.05	<0.05	<0.05	<0.05
HCW, kg	289.8	328.9	5.8	<0.05	-	0.42	-
DP%	54.1	54.9	0.4	0.16	-	0.81	-
SFT, mm	3.99	4.28	0.25	0.42	<0.05	0.53	0.06

Item	Diet		SEM	P-values			
	Fixed	Variable		Diet	Days	Diet × GG	Diet × days
BW, kg	492.4	501.9	6.7	0.31	<0.05	<0.05	0.37
HCW, kg	309.0	309.7	5.8	0.93	-	0.42	-
DP%	54.3	54.8	0.4	0.33	-	0.81	-
SFT, mm	3.97	4.30	0.25	0.38	<0.05	0.53	0.28

Item	Housing		SEM	P-values			
	Individual	Collective		Housing	Days	Housing × GG	Housing × days
BW, kg	511.7	482.6	7.6	<0.05	<0.05	0.58	<0.05
HCW, kg	312.9	305.8	6.7	0.40	-	0.30	-
DP%	54.3	54.7	0.4	0.39	-	<0.05	-
SFT, mm	4.58	3.69	0.29	<0.05	<0.05	0.46	<0.05

[1]Body weight, [2]Standard error of means, [3]Genetic group, [4]1, 14, 28, 42, 56, 70, and 84 days for BW recording and 28, 70, and 84 days for SFT determination.

R$ 3.64/14-day interval for the Nellore vs. F1 Angus × Nellore, respectively) and AC (R$ 8.32 vs. R$ 8.90 ± R$ 0.16/@ of the carcass for the Nellore vs. F1 Angus × Nellore, respectively) were both decreased ($p < 0.05$) in Nellore animals compared to F1 Angus × Nellore. Therefore Nellore may be indicated in feedlot systems with limitations in the production or acquisition of forage and dietary energy and protein ingredients, or even at times when dietary feeds may become very expensive. The economic indicators were also influenced by genetic groups, which confirm the original hypothesis.

Average productivity (expressed as the amount of @ of carcass/kg of DM ingested) did not differ ($p > 0.05$) between genetic groups and type of diet due to a similar ($p > 0.05$) FCR (Table 3).

Regardless of genetic group and type of diet, MP had negative values (-0.9373 and -1.0141 ± 0.99 @ of carcass/kg of DM ingested for the F1 Angus × Nellore and fixed diet, respectively). Likewise, MC also had negative values (-1.94 and -4.22 ± 1.71 R$/@ of the carcass for the Nellore and variable diet, respectively), as shown in Table 5.

Looking solely at the economic perspective, MC negative values mean that for every additional @ of carcass produced there will be revenue of R$ 1.94 and R$ 4.22 for the Nellore and variable diet, respectively (Kimmura & Santos, 2016). However, caution should be exercised when interpreting MC negative values in the case of beef cattle finished in feedlot due to a growth pattern that is typical of these animals.

Cattle reach their mature weight when there is a maximum of protein mass despite an increased fat deposition that can occur beyond this point. After reaching the mature weight DMI is decreased as fat mass increases (Owens et al., 1993).

Such growth pattern was clear in both genetic groups fed either a fixed or a variable diet when feed intake was reduced towards the end of the experiment (between 56 to 70 days relative to the beginning of the study), although animals continued to gain @ of carcass, but in a slower rate (Figure 1, panels A through D). Furthermore, feeding cost is a dependent variable of DMI (DMI in 14-day intervals × diet cost on a DMB), consequently, if DMI decreases the same will happen with feeding cost, thereby when the MP and MC data were averaged across days of the experiment, some values were negative in Table 5 depending on the slope that DMI and feeding cost were reduced as a result of the mathematical equation used to determine MP and MC (Figure 1, panels E through G).

In a world with globalized economies, it is important

Table 5. Effect of the genetic group (Nellore or F1 Angus × Nellore) and diet (fixed or variable) on economic indicators of 36 non-castrated males finished in a feedlot and housed in individual or collective pens.

Tabela 5. Efeito de grupo genético (Nelore ou F1 Angus × Nelore) e dieta (fixa ou variável) sobre os indicadores econômicos de 36 machos não castrados terminados em confinamento e alojados em baias individuais ou coletivas.

Item	Genetic group		SEM[8]	P-values				
	Nellore	F1 Angus × Nellore		GG[9]	Days[10]	GG × days	GG × diet	GG × diet × days
Diet cost on a DMB[1] (R$/kg)	1.0000	1.0079	0.004	0.20	<0.05	<0.05	0.33	<0.05
Feeding cost (R$)	138.70	164.75	3.64	<0.05	<0.05	<0.05	0.27	0.25
AP[2] (@ of carcass/kg of DM ingested)	0.1229	0.1168	0.002	0.10	<0.05	<0.05	0.22	<0.05
AC[3] (R$/@ of carcass)	8.32	8.90	0.16	<0.05	<0.05	<0.05	0.50	0.17
MP[4] (@ of carcass/kg of DM ingested)	0.0139	-0.9373	0.99	0.51	<0.05	0.20	0.39	0.38
MC[5] (R$/@ of carcass)	-1.94	0.01	1.71	0.43	<0.05	0.13	0.36	0.20
TR[6] (R$)	2,562.50	2,858.46	55.42	<0.05	<0.05	<0.05	0.46	0.81
Profit (R$)	2,423.79	2,693.71	52.62	<0.05	<0.05	<0.05	0.49	0.73
MR[7] (R$/@ of carcass)	120.89	126.99	2.30	0.09	<0.05	0.12	0.32	0.78
Item	**Diet**		**SEM**	**P-values**				
	Fixed	Variable		Diet	Days	Diet × days	Diet × GG	Diet × GG × days
Diet cost on a DMB (R$/kg)	1.0004	1.0075	0.004	0.25	<0.05	<0.05	0.33	<0.05
Feeding cost (R$)	148.96	154.50	3.64	0.30	<0.05	<0.05	0.27	0.25
AP (@ of carcass/kg of DM ingested)	0.1217	0.1181	0.002	0.31	<0.05	0.46	0.22	<0.05
AC (R$/@ of carcass)	8.44	8.78	0.16	0.19	<0.05	<0.05	0.50	0.17
MP (@ of carcass/kg of DM ingested)	-1.0141	0.0907	0.99	0.45	<0.05	0.21	0.39	0.38
MC (R$/@ of carcass)	2.28	-4.22	1.71	<0.05	<0.05	<0.05	0.36	0.20
TR (R$)	2,705.10	2,715.85	55.42	0.89	<0.05	0.42	0.46	0.81
Profit (R$)	2,556.15	2,561.35	52.62	0.94	<0.05	0.58	0.49	0.73
MR (R$/@ of carcass)	124.41	123.47	2.30	0.78	<0.05	0.83	0.32	0.78

[1]Dry matter basis, [2]Average productivity, [3]Average cost, [4]Marginal productivity, [5]Marginal cost, [6]Total revenue, [7]Marginal revenue. [8]Standard error of means, [9]Genetic group, [10]14-day intervals (1-14 days, 15-28 days, 29-42 days, 43-56 days, 57-70 days, and 71-84 days).

to be aware of changes that may interfere with the production cost and consequently on profitability. The Brazilian economic scenario in 2016 was characterized by an increase in corn prices that reached R$ 49.12/bag of 60 kg (Cepea, 2019) at the beginning of the present study due to a severe drought that occurred during the second crop season (February through July), when most of the corn crops are cultivated in the Central and Western part of Brazil.

Recent market analyses indicated unfavorable prospects for beef cattle feedlots that rely on corn for animal finishing due to losses in the last US crop and reduction of the American corn supply, which has resulted in increased corn prices in Brazil (Cepea, 2019). However, the swine fever outbreak in China has boosted Brazilian beef exports and carcass reached a record price of R$ 200/@ that was never seen before (Cepea, 2019). Moreover, other uses for corn such as bioethanol power plants also demand an increasing part of its production. Hence the animal performance and economic information reported in this study combined with a careful analysis of the domestic and world economic scenarios may be useful for the planning and management of beef cattle finished in feedlot.

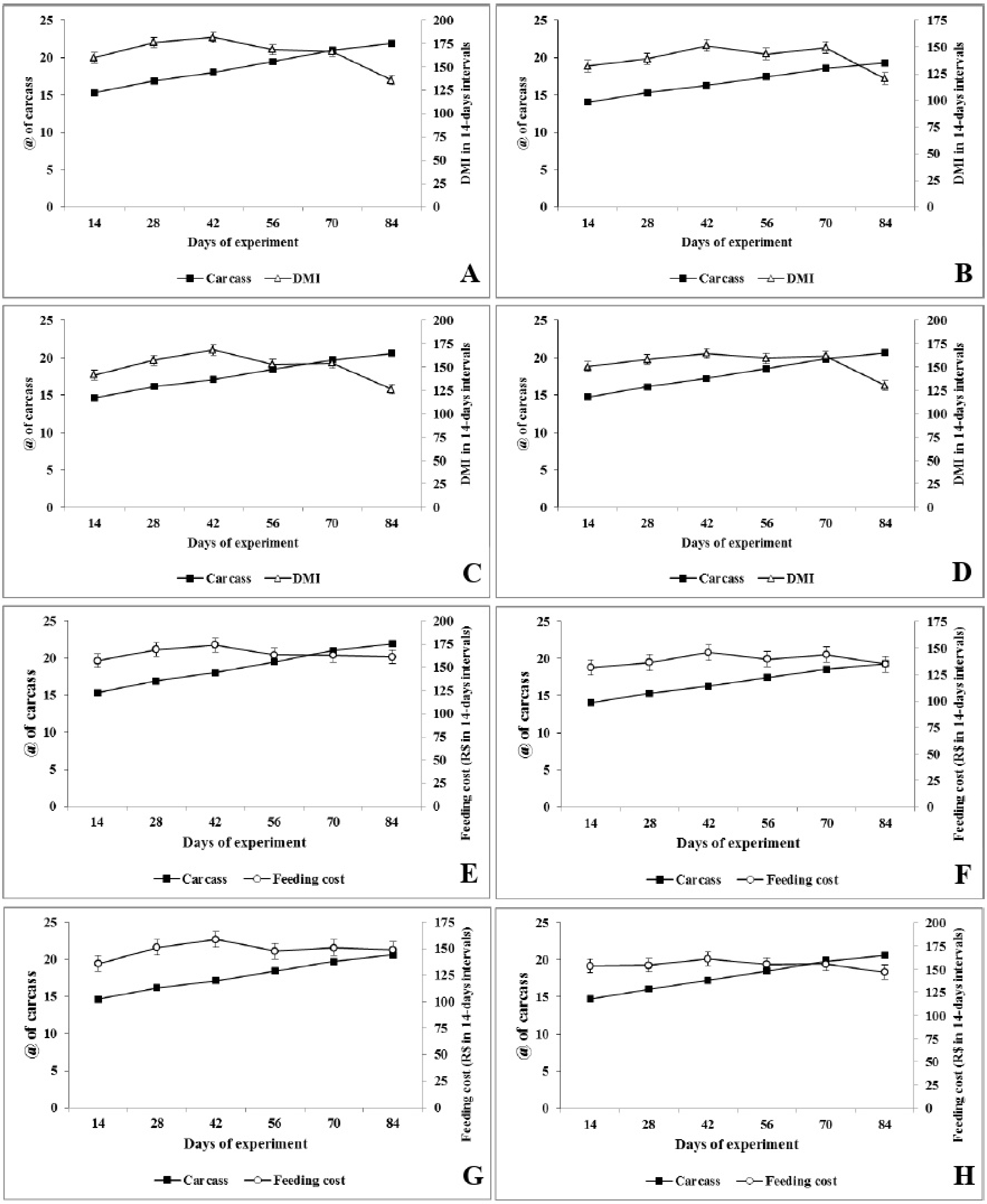

Figure 1. Carcass gain (@) × DMI (14-days intervals) of F1 Angus × Nellore (panel A), Nellore (panel B), fixed diet (panel C), and variable diet (panel D). Carcass gain (@) × feeding cost (14-days intervals) of F1 Angus × Nellore (panel E), Nellore (panel F), fixed diet (panel G), and variable diet (panel H).

Figura 1. Ganho de carcaça (@) × CMS (intervalos de 14 dias) de F1 Angus × Nellore (painel A), Nellore (painel B), dieta fixa (painel C) e dieta variável (painel D). Ganho de carcaça (@) × custo com alimentação de F1 Angus × Nellore (painel E), Nellore (painel F), dieta fixa (painel G) e dieta variável (painel H).

4 Conclusion

F1 Angus × Nellore animals may be indicated in feedlot finishing systems with a high supply of forage and concentrate feeds due to an increased DMI, BW, total revenue, and profit.

On the other hand, Nellore animals may be recommended in feedlot finishing systems where there is a certain limitation for the production or acquisition of forage and concentrate ingredients due to a decreased DMI, feeding cost, and average cost.

The use of a variable diet with increasing levels of NFC and decreasing levels of CP is not recommended for beef cattle feeding in a feedlot.

Even though individual housing is not feasible in commercial feedlots, the data presented here suggest that management practices to mitigate social hierarchy should be implemented in beef animals housed collectively to maximize weight gain.

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