Performance of crossbred steers post-weaned in an integrated crop-livestock system and finished in a feedlot

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Abstract – The objective of this work was to evaluate the performance of crossbred steers post-weaned in an integrated crop-livestock system (ICL) and finished in a feedlot, fed either a high-level concentrate diet or whole corn with no roughage. Weaned calves of two breed groups – ½ Angus × ½ Nellore, and ½ Charolais × ¼ Angus × ¼ Nellore – were allotted in a completely randomized experimental design (CRD). During the rainy season, the ½ Angus × ½ Nellore animals showed a higher performance than the ½ Charolais × ¼ Angus ×¼ Nellore ones, with 0.748 and 0.490 kg average daily gain, respectively. The productivity in the post-weaning period was 926 kg ha^{-1} body weight in a 11-month period, in the ICL system. Subsequently, the animals were confined and fed high-concentrate diet or whole corn with no roughage, in a CRD with a 2×2 factorial arrangement. In the feedlot, the ½ Charolais × ¼ Angus × ¼ Nellore animals showed lower values for carcass average daily gain, carcass yield, and slaughter weight than the ½ Angus × ½ Nellore animals. The high productivity in the ICL shows that this strategy, associated with the use of crossbreeding during the post-weaning and finishing stages, can be indicated for the new demand for a sustainable livestock activity.

Index terms: beef cattle, crossbreeding, feed intake, integrated systems, intensification.

Desempenho de bovinos cruzados, recriados em sistema de integração lavoura-pecuária e terminados em confinamento

Resumo – O objetivo deste trabalho foi avaliar o desempenho de bovinos cruzados, recriados em sistema de integração lavoura-pecuária (ILP) e terminados em confinamento, alimentados com dietas com alto nível de concentrado ou exclusivamente de concentrado. Bezerros desmamados de dois tipos de cruzamento – ½ Angus × ½ Nelore e ½ Charolês × ¼ Angus × ¼ Nelore – foram distribuídos em delineamento experimental inteiramente casualizado (DIC). No período das águas, os animais ½ Angus × ½ Nelore apresentaram desempenho superior ao dos animais ½ Charolês × ¼ Angus × ¼ Nelore, com ganho médio diário de 0,748 e 0,490 kg, respectivamente. A produtividade na recria foi de 926 kg ha^{-1} de peso corporal no período de 11 meses, no sistema de ILP. Posteriormente, os animais foram confinados e alimentados com dietas com alto nível de concentrado ou exclusivamente de concentrado, em DIC, com arranjo fatorial 2×2. No confinamento, os animais ½ Charolês × ¼ Angus × ¼ Nelore apresentaram valores menores de ganho médio diário de carcaça, rendimento de carcaça e peso ao abate do que os animais ½ Angus × ½ Nelore. A elevada produtividade no sistema ILP mostra que essa estratégia, associada ao uso de cruzamentos durante a recria e a terminação, pode ser indicada para a nova demanda por uma pecuária sustentável.

Termos para indexação: bovinos de corte, cruzamento industrial, consumo alimentar, sistemas integrados, intensificação.

Introduction

Global population growth will increase the demand for animal products (OCDE-FAO…, 2014). Therefore, a great challenge that the world will face is to produce more food in a sustainable way. Increased food productivity is sought by the agricultural systems, without negatively affecting the environment (Fraser et al., 2014).

In Brazil, pastures are the main source of feed for cattle; however, these systems are generally associated with low-productivity indexes, due to incorrect management that leads to the loss of productivity and pasture degradation. The use of the integrated crop-livestock (ICL) system for the recovery of degrading or degraded pastures has been a priority, and it is currently a public policy of the Brazilian federal government (Plano…, 2012). Besides recovering the degraded areas, this strategy is aimed at environmental sustainability and it is important for the country, as environmental restrictions should reduce the expansion of areas for the incorporation of new pastures (Latawiec et al., 2014). Furthermore, the improvement of pastures with the ICL system helps to mitigate greenhouse gases (GHG) (Wang et al., 2014).

The intensification of the production system with the use of more efficient models of beef cattle production – through the ICL system, strategic nutritional supplementation, crossbreeding, and feedlot – makes it possible to increase productivity, by improving the use of areas and decreasing deforestation (Godfray et al., 2010; Silva et al., 2016). Crossbreeding between European and Zebu breeds is performed to improve the efficiency of meat production, as it increases the average daily gain in the post-weaning and shortens the production cycle. Feedlot allows of a better diet control and the monitoring of animal responses, besides leaving pasture areas free for other uses.

Corn is a traditional food commonly used to supply the energy demands of animals. The use of whole corn with no roughage (in a concentrate-only diet), in the feedlot, is an alternative for eliminating forage from the diet. Other advantages of this diet include the use of only one type of food and concentrate for beef cattle in feedlots, and the reduction of expenses with roughage production, labor, and infrastructure; besides reducing cost per unit due to reduced consumption of the diet, leading to a greater biological efficiency. Due to the lack of processing, the passage rate of whole corn and starch fermentation are slower than that for ground corn or wet grain (Schwartzkopf-Genswein et al., 2003). Therefore, whole grain corn may prevent ruminal disorders that occur due to the excessive production of organic acids in the rumen; moreover, the use of additives to maintain ruminal pH is also recommended (Gorocica-Buenfil & Loerch, 2005).

There is little information regarding ICL systems and their effects on the productivity of crossbred cattle finished in feedlot with the use of ICL products, including finishing with grain-only diet. Studies related to integrated systems such as ICL, in which animals were finished in feedlots with the use of cultivated products, are essential for the establishment of productive and sustainable cattle breeding activity in Brazil. Knowledge on the factor interactions is a key for the development, optimization, and establishment of these technologies.

The objective of this work was to evaluate the performance of crossbred steers post-weaned in an integrated crop-livestock system (ICL) and finished in a feedlot, fed either a high-level concentrate diet or whole corn with no roughage.

Materials and Methods

The study was carried out in the experimental field of Embrapa Milho e Sorgo, in the municipality of Sete Lagoas, in the state of Minas Gerais, Brazil (19°28'S, 44°15'W, at 732 m altitude). The climate of the region is Aw, typical of savannah according to the classification of Köppen-Geiger. The annual average temperature of the area is 21.2°C, and the average annual rainfall is 1378.2 mm. The technological reference unit for integrated crop-livestock system (TRU-ICLS) was implemented in a 22 ha area, which included the rotation and mixed cropping of corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], sorghum [*Sorghum bicolor* (L.) Moench], and pasture.

The area was divided into four plots of approximately 5.5 ha each; and crop rotation under no-tillage system has been adopted since 2005. Each plot was used as follows: soybean production, corn intercropped with *Urochloa brizantha* 'Marandu' (Syn. *Brachiaria brizantha* 'Marandu'), forage sorghum intercropped with *Megathyrsus maximus* 'Tanzania', and a pasture of *Megathyrsus maximus* 'Tanzania' in annual rotation.

Climate data for the experimental period (Figure 1) were obtained at the meteorological station located at Embrapa Milho e Sorgo.

All experimental procedures were approved by the Ethics Committee for Animal Use of Universidade Federal de Minas Gerais (CEUA 326/2014). Seven-month-old weaned calves from two crossbreeds were studied, from which 20 animals were ½ Angus × ½ Nellore (AN), and 10 animals were ½ Charolais × ¼ Angus × ¼ Nellore (CAN), with initial mean body weight of 157.20 (±17.57) and 151.93 (±13.30) kg, respectively. Because there was an unequal number of animals in each group, a completely randomized unbalanced design was considered. The genetic groups were evaluated in the rearing period, in the ICL system.

The animal performance in the pastures was evaluated from July 2013 to May 2014. During the dry season, between July and September 2013, animals grazed on the remaining lands under pasture. During the rainy season, from October 2013 to May 2014, after the sorghum removal, the animals grazed on the pasture of *Megathyrsus maximus* 'Tanzania' grass, which was subdivided into five pickets in a rotation system of seven days of occupation and 28 days of rest.

The animals received a supplement with mineral and protein ad libitum during the rainy and dry seasons, respectively (Table 1). Consumption of daily supplement was calculated by dividing the total supplement consumed by the number of animals per day in each period.

The pasture was sampled every 28 days by cutting forage samples close to the soil, as described by McMeniman (1997). The samples were weighed and homogenized, and a subsample was taken for subsequent analysis of the potentially digestible dry matter (pdDM) (Paulino et al., 2008). The pdDM was calculated by the equation pdDM = [0.98 × (100 - NDF) + (NDF - iNDF)], in which NDF is the neutral detergent fiber, and iNDF is the indigestible neutral detergent fiber. The iNDF was obtained after in situ incubation of a whole plant sample for 288 hours in the rumen of a fistulated bovine (Valadares Filho et al., 2010). The NDF was calculated using the 2002.04 method described by Latimer Jr. (2012).

The grazing simulation of each picket was carried out together with the forage harvest, to determine the nutritional value of the forage consumed by the animals (Table 1).

The forage allowance (kg of dry matter 100 kg^{-1} of animal body weight per day) was calculated by the ratio of forage yield (kg per day of DM) to total body weight of animals. The average daily gain (ADG) was calculated as the difference between the final body weight (FBW) and the initial body weight (IBW) of each period, divided by the total number of days. The productivity of the area (kg ha^{-1}) was calculated based on the ADG and the number of animals per hectare in the evaluated period.

Individual dry matter intake was determined for 10 animals from each group using the Lipe external marker (Produtos de Pesquisa Simões Saliba, Florestal, MG, Brazil). The marker dose was 0.5 g per animal per day, for seven days, including two days of adaptation

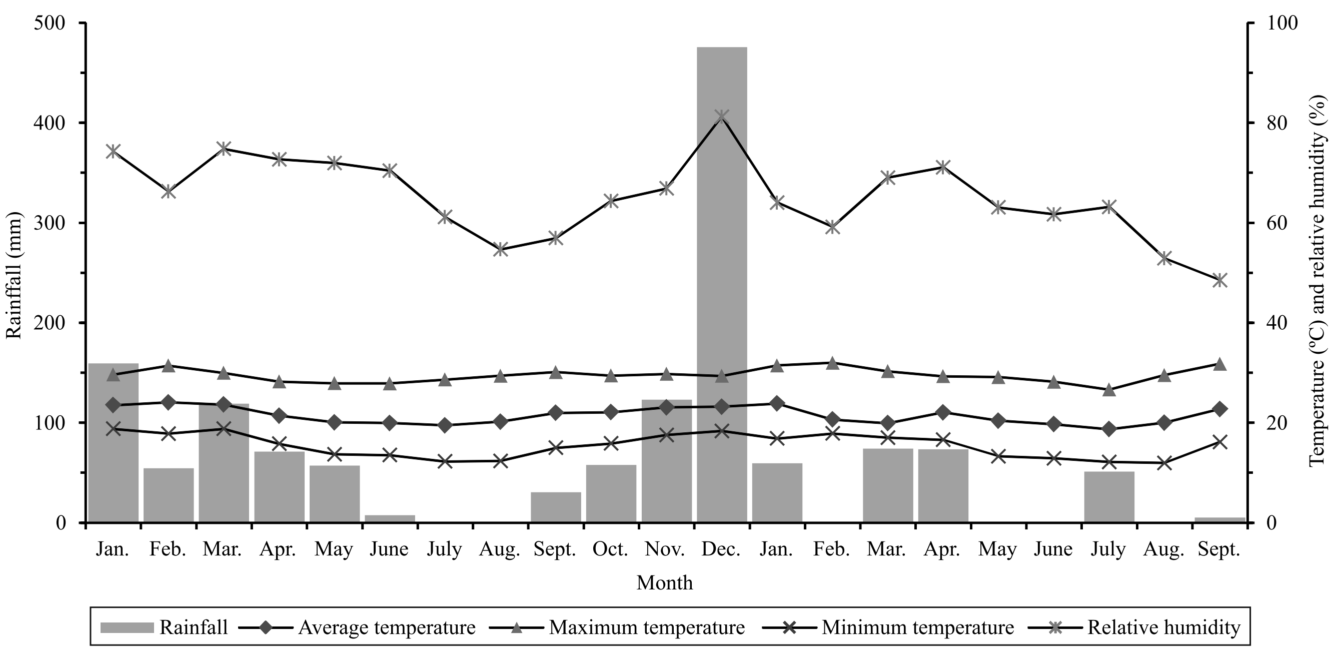

Figure 1. Climate data for the experimental period from January 2013 to September 2014, measured at the Embrapa Milho e Sorgo meteorological station, in the municipality of Sete Lagoas, in the state of Minas Gerais, Brazil.

and five days of fecal collection in the first week of January 2014, during the rainy period. The Lipe content in feces was calculated by near-infrared spectroscopy using a NIR 900 PLS spectrometer (Femto, São Paulo, SP, Brazil). Fecal production was calculated by the logarithmic ratio of the absorption intensities of the spectral bands, at 1,050 and 1,650 cm^{-1} wavelengths, as described by Saliba et al. (2015). Fecal production (FP) and dry matter intake per day (DMI) were calculated by the following formulas: FP = {[Lipe administered (g per day)] / [Lipe content in feces (g kg^{-1} DM)] } and DMI (g per day) = [(FP/1) - (digestibility/100)].

Table 1. Proportion of ingredients and nutritional composition, based on the percentage of dry matter (DM) in the supplements supplied; composition (%), based on the percentage of dry matter in the fodder, during grazing in the dry (DS) and rainy seasons (RS); and nutritional composition (%), based on the percentage of dry matter in the diets offered to the different genetic groups during confinement.

Ingredients and nutritional composition (%)	Supplement during DS	Supplement during RS
Ground corn	52	-
Urea	10	-
White salt	25	55
Mineral	10(1)	45(2)
Total	100	100
Dry matter	88.57	91.96
Crude protein	32.89	-
Neutral detergent fiber	8.40	-
Acid detergent fiber	2.33	-
Ashes	29.43	21.80
	Fodder – DS	Fodder – RS
Dry matter	49.90	32.19
Crude protein	8.69	16.02
In vitro DM digestibility	55.48	62.67
Total digestible nutrients	56.63	58.20
Neutral detergent fiber	68.10	65.79
Acid detergent fiber	33.11	31.03
Lignin	4.05	2.8
Ethereal extract	3.04	2.03
Ashes	8.93	8.11
Phosphorous	0.19	0.22
Calcium	0.84	0.64
	High – concentrate diet(3)	Concentrate – whole corn with(4)
Dry matter	61.44	89.51
Neutral detergent fiber	32.63	8.69
Acid detergent fiber	16.20	2.82
Dry matter	2.32	0.12
Ash	5.69	5.57
Crude protein	15.67	14.05
In vitro DM digestibility	70.58	87.03
Total digestible nutrients	61.72	82.61
Ethereal extract	4.06	2.14

(1)Mineral supplement: P, 152 g kg^{-1}; Ca, 202 g kg^{-1}; S, 26 g kg^{-1}; Mg, 30 g kg^{-1}; Na, 26 g kg^{-1}; Zn, 5,140 mg kg^{-1}; Cu, 1,300 mg kg^{-1}; Mn, 2,050 mg kg^{-1}; Co, 50 mg kg^{-1}; I, 50 mg kg^{-1}; Se, 20 mg kg^{-1}. (2)Mineral Supplement: P, 85 g kg^{-1}; Ca, 110 g kg^{-1}; S, 10 g kg^{-1}; Mg, 10 g kg^{-1}; Na, 97.5 g kg^{-1}; Zn, 3,200 mg kg^{-1}; Cu, 1,200 mg kg^{-1}; Fe, 1,500 mg kg^{-1}; Mn, 1,200 mg kg^{-1}; Co, 50 mg kg^{-1}; I, 65 mg kg^{-1}; and Se, 12 mg kg^{-1}. (3)High concentrate: diet with 66% concentrate and 34% roughage. (4)Whole corn with no roughage: diet with 85% corn and 15% pellets.

In vitro dry matter digestibility analyses (IVDMD) were performed as described by Tilley & Terry (1963).

In the feedlot, animals were allocated to a corral composed of four collective pens measuring 20×12 m each, equipped with troughs for drinking and eating. The pens had enough space to ensure an adequate animal well-being, with 24 m^2 area per animal, in pens with ten animals, and 48 m^2 per animal in pens with five animals. Trough of each pen was 12 m long, with an average space of 1.2 m per animal in pens with ten animals, and 2.4 m per animal in pens with five animals. All animals had free access to food; the diet was distributed in the troughs and did not limit their performance.

In the feedlot, the animals were divided into four groups, according to the type of crossbreeding and diet (Table 1), and distributed as follows: ten animals ½ Angus × ½ Nellore, who received a whole corn with no roughage, composed of 85% whole grain corn and 15% pelleted commercial supplement; 10 animals ½ Angus × ½ Nellore, which received a high-concentrate diet, composed of 34% corn silage and 66% concentrate; 5 animals ½ Charolais × ¼ Angus × ¼ Nellore, which received a whole corn with no roughage; and 5 animals ½ Charolais x ¼ Angus x ¼ Nellore, who received a high-concentrate diet.

The composition of the pelleted commercial supplement was as follows: P, 9 g kg^{-1}; Ca, 40 g kg^{-1}; S, 48 g kg^{-1}; Mg, 5,4 g kg^{-1}; Na, 12 g kg^{-1}; Zn, 400 mg kg^{-1}; Cu, 80 mg kg^{-1}; Fe, 300 mg kg^{-1}; Mn, 200 mg kg^{-1}; Co, 3 mg kg^{-1}; I, 4 mg kg^{-1}; Se, 2 mg kg^{-1}; crude protein (CP), 38%; total digestible nutrients (TDN), 50%; virginiamycin, 2,000 mg kg^{-1}; monensin, 1,500 mg kg^{-1}; vitamin A, 2,000 IU kg^{-1}; vitamin D3, 100 IU kg^{-1}; and vitamin E, 100 IU kg^{-1}.

The animals were adapted to the experimental diets for 29 days, with a dry matter intake of 1.8% of body weight. Adaptation to the high-concentrate diet consisted of 50% corn silage and 50% concentrate, initially, with a gradual increase of concentrate content until a ratio roughage: concentrate 34:66 (DM base). Adaptation to the diet of concentrate-only consisted of 50% corn silage and 50% mixed grain corn and pelleted supplement, with a gradual replacement of roughage until it was completely removed on the first day of the experiment.

Diets were given ad libitum, divided into two daily treatments, at 8:00 a.m. and 3:00 p.m., for the diet exclusively made up of concentrate, and three daily treatments – at 8:00 a.m., 11:00 a.m. and 3:00 p.m. for the diet containing a high level of concentrate. The amount of food supplied was adjusted daily to allow of 5 to 10% refussalls of foods. Diets and leftovers were sampled daily to prepare a monthly composite sample, which was analyzed later.

The diet was formulated to allow of 1.3 kg average daily weight gain, as described by Valadares Filho et al. (2010). The following parameters were determined: DMI, in kg per day, and as a percentage of body weight; average daily gain (ADG); initial body weight (IBW); and final body weight (FBW). The DMI per bay was determined as the difference between the amount of diet provided and leftovers (kg of DM), divided by the number of animals in each bay. ADG was calculated as the difference between FBW and IBW, divided by the total number of days. Feed conversion (FC) was measured by the ratio between DMI and ADG.

Animals were slaughtered when they reached a minimum body weight of 480 kg, and after the required 84 days of feedlot, except for CAN animals fed the whole corn with no roughage, for which 103 days were required to reach the slaughter weight. The day of slaughter was determined when the animals reached a minimum carcass weight of 240 kg, and approximately 90 kg of carcass gain per animal, considering 50% of carcass yield.

On the day of slaughter, animals were weighed in the morning, before being sent to the slaughterhouse, where they were fasted for 24 hours with ad libitum water intake. All the animals were slaughtered in a commercial slaughterhouse, according to the humanitarian procedures required by Brazilian legislation.

The weight of hot carcass (WHC) was recorded immediately after the carcass was cleaned. Carcass yield (CY) was calculated by the ratio of WHC to FBW. The mean daily weight gain of carcass (ADGc) was calculated by the following equation: ADGc = WHC - (IBW × 50%)/ number of days in feedlot.

Forage samples of the simulated grazing, supplements, diets, and refussals of foods were pre-dried in a forced-ventilation oven at 55 °C, for at least 72 hours, and ground in a Willey mill (Alpax, Diadema, SP, Brazil) through a 1 mm mesh sieve. The contents were determined as described by Latimer Jr. (2012), according to the following methods: dry matter (DM), 934.01; crude protein (CP), 984.13; neutral detergent fiber (NDF), 2002.04; acid detergent fiber (ADF), 973.18; neutral detergent-insoluble nitrogen (NDIN), 984.13; ethereal extract, 920.85; and ashes, 938.08. Total digestible nutrients (TDN) were estimated using equations suggested by the National Research Council (NRC, 2001).

To evaluate the animal performances in pasture, a completely randomized design was used. For the evaluations of animal performance in the feedlot, and the carcass characteristics, a completely randomized design was used, in a 2×2 factorial arrangement (type of crossing × diet). Statistical analyses were performed using the PROC GLM from SAS (SAS Institute Inc., Cary, NC, USA), and means were compared using the Fisher's test, at 5% probability.

The mathematical model used to determine the performance variables in the period post-weaning was $Y_{ij} = \mu + R_i + \varepsilon_{ij}$, in which: Y_{ij} is the observation of the animal j, from the treatment i; μ is the mean effect; R_i is the fixed effect of the crossbreed type i, (i = 1, 2); and ε_{ij} is the random error associated with each animal.

The mathematical model used to determine the performance variables at finishing was $Y_{ijk} = \mu + R_i + D_j + I_{ij} + \varepsilon_{ijk}$, in which: Y_{ijk} is the performance of the animal k, from the crossbreed type i and the diet j; μ is the mean effect; R_i is the fixed effect of crossbreed type i, (i = 1, 2); D_j is the fixed effect of the diet j, (i = 1, 2); I_{ij} is the effect of the interaction between the type of crossing i and the diet j; and ε_{ijk} is the random error associated with each animal.

Results and Discussion

The potentially digestible dry matter (pdDM), for the experimental periods, was 1,418.25 and 3,276.50 kg ha^{-1}, which correspond to 55.34 and 60.02% of total dry matter in the dry season an in the rainy season, respectively. According to Paulino et al. (2008), the values recommended for the allowance of forage in pdDM are 4 to 5% of body weight (BW), in order to associate the production of animals per area with the use efficiency of the area. Forage allowance in pdDM was 13.69% of the BW, in the dry season, and 8.32% of the BW in the rainy season, which indicates the high-nutrient availability that can be used by ruminal bacteria.

The high-pdDM availability during the experimental period may have resulted from nitrogen fertilization (150 kg ha^{-1} N) at the beginning of the experiment and, mainly, from the use of the ICL system (Table 2). These systems can improve the physical and biological characteristics of the soil, due to the large amount of straw and roots left by fodder, which contribute to the increase of organic matter (Loss et al., 2011). In the present study, the high production of forage provided 2.8 AU ha^{-1} average stocking during the experimental period.

The forage allowance varied during the experimental period due to climatic variations in the region, with a mean of 11.03 kg DM 100 kg^{-1} BW per day. Hodgson (1990) suggested that values between 10 and 12 kg DM 100 kg^{-1} BW per day of forage allowance as the maximum intake of pasture dry matter. In the dry season, the supply of fodder was lower because this is a critical period for fodder production. The supply of 9.37% is close to the limit, in order to prevent consumption restriction (Sulc & Tracy, 2007). This fact can be verified by the performance of cattle with an average ADG of more than 0.651 kg per day in this period (Table 3).

The high content of CP in pasture during the dry season (Table 1), together with the adequate allowance of forage, is attributed to the recent forage planting and subsequent use with a high content of green dry matter. This is a characteristic of well-managed ICL systems, with crop rotation in the same area, which can increase soil nutrients and provide higher forage quality (Macedo, 2009).

In the ICL system, an average animal weight gain of 0.651 kg per day was observed in the dry season (Table 3). The diet of the animals consisted of pasture and of 0.08% BW of a protein supplement with 33% of CP (Table 1). The pasture already provided adequate

Table 2. Total availability of dry matter (TADM), availability of potentially digestible dry matter (pdDM), stocking rate, and forage allowance during dry and rainy seasons.

Season	TADM (kg ha^{-1} MS) [1]	pdDM (kg ha^{-1} MS) [2]	Stocking rate (AU ha^{-1})	Forage allowance (%)
Dry	2,562.81	1,418.26	2.43	9.37
Rainy	5,412.67	3,276.48	3.18	12.70

Table 3. Average daily gain (ADG) (kg per animal per day) in the dry and rainy seasons, and initial and final body weight of weaned animals of the two genetic groups[1].

Item	Type of crossing		p-value	Coefficient of variation (%)
	AN[2]	CAN[3]		
Initial weight (kg)	157.20a	151.93a	0.4776	10.68
Final weight (kg)	397.65a	323.21b	<0.0001	7.00
Average daily gain – dry season[4]	0.679a	0.622a	0.0865	19.38
Average daily gain – rainy season[5]	0.748a	0.490b	<0.0001	11.35
Average daily gain mean[6]	0.714a	0.556b	<0.0001	9.98
DM intake, in percentage of body weight [7]	2.00b	2.16a	0.0308	11.81
DM intake [(g kg^{-1})$^{0.75}$][8]	89.06a	81.63b	<0.0001	1.96
Food efficiency (kg gain per kg of ingested DM)	0.10a	0.08b	<0.0001	5.07

[1]Mean values followed by equal letters, in the rows, do not differ by the Fisher's test, at 5% probability. [2]AN: crossbred cattle, ½ Angus × ½ Nellore. [3]CAN: crossbred cattle, ½ Charolais x ¼ Nellore × ¼ Angus. [4]Average daily gain between July 2013 and September 2013. [5]Average daily gain between October 2013 and May 2014. [6]Average daily gain, in both dry and rainy seasons. [7]Dry matter intake, as a percentage of body weight. [8]Dry matter intake, by metabolic weight.

CP levels, as described by Moore et al. (1991), who considered 7% of CP as the minimum required to meet the needs of ruminal bacteria. Below that level, a decreased consumption of dry matter digestibility of the diet is observed. The quantity of forage, along with protein supplementation, promoted an adequate supply of nutrients to the animals, and allowed them to show a high-weight gain for the period.

In the rainy season, the forage allowance (Table 2) and CP levels (Table 1) were high and did not limit the animal performance; however, an imbalance in the relationship between CP content and the amount of TDN in the feed was observed. This imbalanced relationship allows of conditions for limiting the microbial protein synthesis and for the inefficient use of this protein, thus compromising animal performance (Detmann et al., 2008). Therefore, the dietary energy contents may have limited the performance of these animals.

The DM consumption was higher for CAN; however, AN animals showed a 65.5% higher ADG than CAN animals during the rainy season (Table 3). The lower performance of CAN animals may be related to the genetic composition of these animals, which have an amino acid composition that is ¾ taurine and are less adapted to tropical conditions (Tucker et al., 2008); thus, although they showed a higher consumption, these animals had lower ADG, probably due to thermal stress, as a result of the high temperatures registered in the period (Figure 1).

According to the National Research Council (NRC, 1996), all homeothermic animals consume food levels which are inversely proportional to the environment temperature (reduced consumption of about 50% at elevated temperatures). The altered food consumption due to the ambient temperature allows the animal to regulate its body temperature within a thermal limit compatible with its metabolic activity. Therefore, the animal reduces food intake when temperature is high; this food behavior is associated with heat loss mechanisms. CAN animals consumed more food and showed a higher-maintenance energy than that of the AN animals. However, CAN animals showed an inferior performance, possibly as a consequence of high temperatures, and the thermoregulation occurred in an unsatisfactory manner. This could have caused the action of mechanisms responsible for heat dissipation, such as an increase of the respiratory rate, and an increase of energy expenditure that could have been used by the animal to produce meat (Façanha et al., 2013).

During the feedlot, DM consumption by AN animals was 10.20 kg per day (2.21% of BW) and 8.03 kg per day

Table 4. Average daily gain of crossbred cattle ½ Angus × ½ Nellore (AN) and ½ Charolais × ¼ Nellore × ¼ Angus animals (CAN) in feedlot, according to diet and genetic group[1].

Diet[2]	Average daily gain (kg per day)		p-value			Coefficient of variation (%)
	AN	CAN	Diet	Genetic group	D × R	
Concentrate only	1.588aA	1.336aB	0.0053	0.8213	0.020	15.38
High-concentrate	1.654bA	1.957aA				

[1]Means followed by the equal letters, lowercase in the rows and uppercase in the columns, do not differ by the Fisher's test, at 5% probability. [2]Exclusively concentrate-only, diet with 85% corn and 15% pellets; and high-concentrate, diet with 66% concentrate and 34% roughage.

Table 5. Performance and carcass characteristics of confined cattle as a consequence of diet and genetic group [1].

Variable[2]	Type of crossing		p-value	Diet		p-value	Coefficient of variation (%)
	AN[3]	CAN[4]		Concentrate-only[5]	High-concentrate[6]		
IBW (kg)	397.65a	323.21b	<0.0001	376.04a	380.50a	0.3046	7.27
FBW (kg)	532.25a	475.07b	0.0003	509.23a	525.04a	0.0614	6.20
ADGc (kg)	1.124a	0.966b	0.015	1.063a	1.097a	0.4532	13.46
WHC (kg)	292.18a	248.33b	<0.0001	280.25a	281.32a	0.5476	7.58
Carcass yield (%)	54.88a	52.33b	0.005	55.00a	53.49b	0.0069	3.45

[1]Mean values represented by equal letters, in the rows, do not differ by the Fisher's test, at 5% probability [2]IBW, initial weight; FBW, final weight; ADGc, average daily gain of carcass; WHC, weight of hot carcass; [3]AN: cattle crosses: ½ Angus × ½ Nellore [4] CAN, crossbred cattle: ½ Charolais × ¼ Nellore × ¼ Angus [5]Concentrate-exclusive: diet with 85% corn and 15% pellets. [6] High concentrate: diet with 66% concentrate and 34% roughage.

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(1.77% of BW) for the high-concentrate diet and whole corn with no roughage, respectively. Consumption by CAN animals was 9.85 kg per day (2.64% of BW) and 6.46 kg per day (1.83% of BW) for high-concentrate diet and whole corn with no roughage, respectively.

There was interaction between the diets and the crossbreed types only for the ADG (Table 4). CAN animals showed a higher ADG when they fed the high-concentrate diet; however, regardless of the evaluated diet, the CAN animals had lower ADGc than AN animals (Table 5). CAN animals in the feedlot, which fed the high-concentrate diet, may have shown a compensatory gain when they fed a diet of higher nutritional value. Compensatory growth occurs in animals that have suffered sufficient food restriction to depress their continuous growth. When they subsequently receive adequate feed, during the feedback period, they tend to have higher rates of weight gain than animals of the same age and size that did not suffer diet restriction (Barbosa et al., 2016).

There were no differences for IBW, FBW, ADGc, FC, and WHC among the evaluated diets. The carcass yield was superior in the whole corn with no roughage, and this fact can be explained by the higher-energetic density of this diet, which results in a smaller size of the gastrointestinal tract (Silva et al., 2002). Therefore, there is a greater efficiency of energy use associated with a greater transfer of body weight gain, in which dietary energy is used for tissue production, and this results in carcass gain (Paulino et al., 2013). Turgeon et al. (2010) evaluated diets with high levels of concentrate and whole grain corn, and observed a lower final BW, lower ADG, and lower intake of dry matter in the diet with whole grain corn. However, the efficiency of this diet was better, since the weight gain in relation to food consumption was higher.

The CAN animals showed lower ADGc and carcass yield, and had a lower slaughter weight than AN animals (Table 5), although they remained in the feedlot for a longer time. This effect may be related to the lower performance of the CAN animals in the post-weaning period, and to a lower initial weight in the feedlot, which resulted in a lower final body weight. Compensatory gains were observed in animals subjected to some food restriction, whose continuous growth was depressed and, after this period, the animals showed a greater growth than which is normal (Ben Salem & Smith, 2008). This effect of the compensatory gain was observed by Barbosa et al. (2016), in animals that received supplementation with 0.1 and 0.2% of body weight, and started to receive a protein-energy-mineral supplement with an intake of 0.5% of body weight, which resulted in higer- average daily gain and higher final weight.

The carcass yield of the CAN genetic group was lower than that of the AN group, since those animals showed a lower final weight. Carcass yield may be affected by several factors, such as weight of the gastrointestinal content, type of diet, age and weight at slaughter, degree of finishing, breeds, and crossings (Patterson et al., 1995). The weight at slaughter also interferes directly in the carcass yield because heavier animals show greater fat deposition, and, consequently, they have a higher yield (Pazdiora et al., 2013). British breeds and their crosses have a higher fat deposition and higher carcass yield than continental breeds, mainly due to the higher amount of fat in the carcass (Patterson et al., 1995). In the current study, the weight at slaughter and the type of crossing could have interfered in the carcass yield. Thus, the lower final weight and the lower carcass weight of the CAN animals, which were of continental origin, resulted in a lower carcass yield.

It would be possible for CAN animals to show carcass weight similar to that of AN animals, if feedlot time was longer, which would lead to a higher slaughter weight. A shorter time in feedlot is associated with animals with a higher BW at the beginning of confinement, as observed for AN animals. According to Kippert et al. (2008), the greater performance of crossbreed cattle occurs due to the effects of individual and maternal heterosis. In addition, the different performances may be related to the selection for weight gain to which different genetic groups or herds have been subjected over previous generations.

Table 6. Animal productivity during pasture grazing in the ICL system, and feedlot finishing with high-concentrate or whole corn with no roughage.

System	Productivity	
	(kg ha^{-1})	(@[3]ha^{-1})
Pasture	1001.6	33.39
Feedlot	731.0	24.40
Total in period[1]	1732.6	57.79
Total per year[2]	2022.6	67.42

[1]Total productivity in the 14-month period. [2]Total corrected productivity for the year. [3]@ = 30 kg live weight.

The observed animal production performance is attributed to the association of integrated systems with the maintenance fertilization of pastures and with the concentrated supplementation technique, which allows of a greater production of BW per unit area. These values are well above the Brazilian productivity of 98.7 kg ha^{-1} per year, for the complete cycle system (Barbosa et al., 2015). These differences were observed by Macedo (2009), who found 141 kg ha^{-1} per year in extensive systems, and 518.1 kg ha^{-1} per year in integrated systems. These results, as well as those of the present study, show the increase of beef production in integrated systems, which is consistent with the new global demand for "sustainable intensification" (Godfray et al., 2010; Niedertscheider et al., 2014).

The productivity in the post-weaning period, in the ICL system, was 926 kg ha^{-1} of BW , in the 11-month period, with the average stocking rate of 2.8 AU ha^{-1}. With the free pasture area in 2014, and the entry of a new post-weaning category into the ICL system during the 2013/2014 production cycle, 75.6 kg ha^{-1} BW was incorporated. These gains, observed in August and September 2014, resulted in a total productivity of 1,001.6 kg ha^{-1} BW, in 13 months (Table 6). Productivity in the feedlot was 731 kg ha^{-1}, in 3.5 months, which, when added to the post-weaning period and corrected for the year results in 2,022.65 kg ha^{-1} per year in the integrated system. These results show that the ICL system use with crosses, during bovine post-weaning and finishing, can result in a high productivity in small areas without the need for new areas to be occupied and associated with the system, thus reducing the negative impacts on the environment as for land use.

Conclusions

1. Crossbred animals ½ Angus × ½ Nellore show a better performance than the ½ Charolais × ¼ Angus × ¼ Nellore animals, both in feedlot and pasture, in the integrated crop-livestock system.

2. There is an interaction between diet and crossing type, for the average daily gain, which is higher for the animals ½ Charolais × ¼ Angus × ¼ Nellore, using the diet containing a high level of concentrate.

3. The ½ Charolais × ¼ Angus × ¼ Nellore animals show a lower average daily gain of carcass, carcass yield, and slaughter weight than the ½ Angus × ½ Nellore animals.

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