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Feed efficiency and meat quality of crossbred beef heifers classified according to residual feed intake

Eficiência alimentar e qualidade da carne de novilhas de corte cruzadas classificadas através do consumo alimentar residual

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SUMMARY

This study aimed to evaluate feed efficiency and meat quality of 31 three-crossbred beef heifers during 84 days in a feedlot system. A 60:40 concentrate and sorghum silage ration on DM basis (ME = 2.73Mcal/kg of DM, CP = 11.90% DM) was fed *ad libitum*. Based on residual feed intake (RFI) calculations, the heifers were ranked in three groups of feed efficiency: High RFI (average mean = 0.776; n = 9), medium RFI (average mean = -0.010; n = 11), and low RFI (average mean = - 0.624; n = 11). High RFI heifers consumed 4.56% more DM per day than low RFI heifers (P <0.05). The ADG did not differ (P> 0.05) among RFI groups (1.40kg/day). No differences (P>0.05) were detected for digestibility of the nutrients: DM (64.00%), CP (60.01%), crude fat (72.90%), NDF (54.80%) and non-fibrous carbohydrate (NFC) (78.91%). There were no differences between low and high RFI groups for slaughter weight (475.00 vs. 479.55kg), hot carcass weight (259.09 vs. 261.44kg), *Longissimus dorsi* (LD) area (69.02 vs. 68.11 cm^2), back-fat thickness (5.74 vs. 6.26 cm), shear force (5.45 vs. 5.19kg), sensorial traits of LD muscle, LD color (intensities L=40.47 a*=24.74 and b*=16.13) or commercial cuts yield. Low RFI heifers presented similar meat quality and carcass traits as high RFI heifers, however low RFI heifers consumed less DM (kg/d).

Keywords: beef cattle, carcass evaluation, net feed intake, shear force

RESUMO

O objetivo com este estudo foi avaliar a eficiência alimentar, qualidade da carne e digestibilidade dos nutrientes em 31 novilhas de corte mestiças durante 84 dias de confinamento. A relação volumoso:concentrado da dieta oferecida *ad libitum* foi de 60:40 (EM= 2,73 Mcal/kg MS, PB= 11,90% MS). Baseado no consumo alimentar residual (CAR), os animais foram classificados em três grupos de eficiência alimentar: Alto CAR (média= 0,776; n = 9), médio CAR (média= -0,010; n = 11) e baixo CAR (média = - 0,624; n = 11). Novilhas alto CAR consumiram 4,56% a mais de MS diária comparadas à novilhas baixo CAR (P<0,05). O ganho médio diário não diferiu (P>0,05) entre animais de diferentes grupos de eficiência (1,40kg/dia). Não houveram diferenças para a digestibilidade dos nutrientes entre os grupos avaliados: MS (64,00%), PB (60,01%), EE (72,90%), FDN (54,80%) e CNF (78,91%). Não houveram diferenças entre alto e baixo CAR para peso ao abate (475,00 vs. 479,55kg), peso de carcaça quente (259,09 vs. 261,44kg), área do músculo *Longissimus dorsi* (LD) (69,02 vs. 68,11 cm^2), espessura de gordura subcutânea (5,74 vs. 6,26cm), maciez (5,45 vs. 5,19kg), características sensoriais do músculo LD, coloração do músculo LD (intensidades L=40,47 a*=24,74 e b*=16,13) ou rendimento de cortes comerciais. Novilhas baixo CAR apresentaram similar qualidade de carcaça e carne à novilhas classificadas como alto

CAR, entretanto novilhas baixo CAR apresentaram um menor consumo de MS (kg/d).

Palavras-chave: avaliação de carcaça, bovinos de corte, consumo residual líquido, maciez da carne

INTRODUCTION

Residual feed intake is a well-established tool to compare beef cattle for feed efficiency (GRION et al., 2014). However, there is a lack of information about the impact of residual feed intake (RFI) ranking on meat quality of tropical beef cattle. Efficient cattle for feed conversion, ranked as low RFI, are metabolically more efficient than their counterparts at the same level of production. A lower protein turnover is associated with greater nutrient utilization efficiency in low RFI cattle, but it may be associated to reduced protein degradation, possibly resulting in a tougher meat and inferior carcass quality (CASTRO BULLE et al., 2007).

There are few number of studies conducted on cattle raised under tropical conditions looking at the relationship between feed efficiency and beef quality attributes. The utilization of *Bos indicus* cattle in tropical environments may yield substantially different results from those obtained for *Bos taurus* breeds in temperate regions (ELZO et al., 2009). Additionally, is important the establishment of RFI as a feed efficiency measure and its relation with production and quality traits valuable to beef industry. In this context, the objectives of this study were to investigate feed efficiency and meat quality of crossbred beef heifers ranked by residual feed intake (low, medium and high RFI). To better understand the links between feed efficiency and nutrient metabolism, digestibility data were included on this study.

MATERIAL AND METHODS

The experiment was conducted at Embrapa Gado de Corte, Brazil, located in Campo Grande-MS. Embrapa Animal Care and Use Committee approved animal care and all handling techniques. Thirty-seven crossbred beef heifers 22 months of age, originated from different bulls, were used: CRANN: ½ Caracu ¼ Angus ¼ Nelore (n = 11); CRVN: ½ Caracu ¼ Valdostana ¼ Nelore (n = 15); and RCN: ½ Red Angus ¼ Caracu ¼ Nelore (n = 11). The average ± SD initial shrunk body weights (SBW) were 342 ± 14kg for CRANN, 311 ± 16kg for CRVN and 352 ± 14kg for RCN. The heifers were housed in individual pens and adapted during 15 days to the experimental diet and handling. The experiment arrangement was a completely randomized design with a total of 84 days, divided in 3 periods of 28 days. Heifers were weighed at the end of each period (day 28, day 56 and day 84). A 60:40 concentrate and roughage ratio was fed over the experiment (Table 1).

A digestion trial was conducted to determine DM and nutrient total tract apparent digestibility. Indigestible acid detergent fiber (iADF) was used as internal marker to estimate fecal output (CASALI et al., 2008). Fecal grab samples were taken from all heifers during the third week of each experimental period, three times as follows: day 1, 08:00h, day 2 12:00h, and day 3 16:00h. Individual samples

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consisted of approximately 200g (wet basis) of fecal material. Samples from each heifer and within each collection period were composited for analysis. Feed (silage and concentrate), and orts samples of the week of the digestion trial were taken, dried at 55°C, ground through a Willey mill (1mm screen), and proportionally sub-sampled to create a composite sample. Feed was offered for *ad libitum* consumption (10% feed orts). The diet was fed twice daily at 08:00h and 14:00h. Feeds and orts were weighed daily, sampled and frozen for later chemical analyses.

Table 1. Ingredients and chemical composition of concentrate and diet, % of DM

Item	Concentrate	Diet
Ingredient		
Sorghum silage	-	40.00
Soybean meal	3.34	2.00
Corn	54.00	32.00
Soybean hulls	40.33	24.38
Mineral premix[1]	1.00	0.70
Urea	1.33	0.92
Chemical Composition		
DM, %	88.43	64.89
OM	94.85	94.39
CP	15.18	11.90
Ether Extract	2.77	2.76
NDF (corrected for protein)	31.74	43.78
Indigestible ADF	1.29	5.64
Non-fiber Carbohydrates	48.89	39.30
TDN	-	71.65
DE, Mcal/kg DM	-	3.33
ME, Mcal/kg DM	-	2.73

[1]Mineral premix contained per kilogram of DM: 151.4g of Na; 105.6g of Ca; 89.2g of P; 1.075mg of Mg; 6,691.10mg of Zn; 2,829.80mg of Fe; 1,153mg of Cu; 797.05mg of Mn; 90.20mg of I.
DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; TDN = total digestible nutrients; DE = digestible energy; ME = metabolizable energy;

Samples (fecal material, feeds, orts) were subjected to all of the following analysis: DM (oven drying at 105°C until no further weight loss; method 930.15, AOAC, 1986); ash (method 942.05, AOAC, 1986); Kjeldahl N (method 984.13, AOAC, 1986); ether extract (EE) (Soxhlet extraction method) and NDF (VAN SOEST et al., 1980). Nonfiber carbohydrates (NFC) were calculated as follows: 100 − [(%CP − %CP from urea + % of urea) + %NDF + %crude fat + %Ash] (HALL, 2000). The apparent total digestible nutrient (TDN) was calculated as (CP intake − fecal CP) + (NDF intake − fecal NDF) + (NFC intake − fecal NFC) + [2.25 × (EE intake − fecal EE)] (SNIFFEN et al., 1992). Digestible energy of the diet

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was obtained as described by NRC (2001), DE (Mcal/kg DM) = 5.6 × PBD+ 9.4 × crude fat D+ 4.2 × FDND+ 4.2 × CNFD, while metabolizable energy (ME) was considered as 82% of the DE (NRC, 2000).
A baseline group (two heifers from each genetic group, totaling 6 heifers) was slaughtered at day 0 of the experimental period in order to obtain initial carcass dressing percentage and initial empty body weight (EBW). After 84 d on feed, all heifers were slaughtered at Embrapa's experimental slaughterhouse by captive bolt stunning followed by exsanguination. After slaughter the carcasses were split into 2 identical longitudinal sides and chilled during 18 hours at 2°C. After chilling, carcass length was measured in the right side carcass, while subcutaneous fat thickness (SFT), rib eye area (REA) and objective color (MiniScan XE Plus from Hunter Lab A/10 illuminant, CIELAB System) measurements were taken on the exposed surface of the *Longissimus dorsi* (LD) at the 12th-13th rib interface of the left side-carcass within 1 h after ribbing. To estimate carcass physical composition (fat, bone and muscle), the 9-11th rib cut methodology of Hankins & Howe (1946) was used. Right carcass sides were divided into the forequarter and hindquarter by cutting along the curvature between the 4th and 5th ribs and then reduced into fabricated cuts as follows: beef plate; tenderloin, strip loin, short ribs boneless, top round, top round cap, bottom round, eye of round, beef knuckle, top sirloin, top sirloin cap, and tri tip. Carcass commercial cut yield was expressed as percentage of right-carcass side weight. At 18h post-mortem, 3 steaks (2.54cm thick) were removed from LD (top loin) of each carcass, packaged and stored at -20°C for subsequent analyses. Frozen steaks were thawed at 5°C for 24 h and then cooked on a conventional electric oven to a final internal temperature of 71°C as described by Wheeler et al. (1997). For assessment of shear force steaks were cooled for 24 h at 5°C before removal six cylindrical samples (1.27cm in diameter) from each steak, parallel to the longitudinal orientation of the muscle fibbers (AMSA, 1995; WHEELER et al., 1997). The shear strength was realized using TA XT PLUS (G-R Manufacturing Company, Manhattan, KS). Each cylindrical sample was sheared completely in its geometric center by an accessory "Warner-Bratzler" V "blade slot" (thickness of 3.0mm and triangular opening 60°). A cell with a load of 30kg and a compression speed of 20 cm / min (WHEELER et al., 1997) was used, and the value obtained in Kgf texturometer. A sensorial panel, composed of regular beef consumers (up to 3 times/week) was used for sensorial evaluation, LD samples were cooked as stated above and then cut into 1 × 1 × 1 cm and served to panelists for evaluation. Panelists scored the samples using a 9-point scale in which 1 extremely tough, dry, and bland; 9 extremely tender, juicy, and intense beef flavor. After each sample panelists cleansed their palates using distilled water.
For calculation of RFI, DMI was regressed against the average MBW and ADG as follows: DMI, kg/d = $\beta_0 + (\beta_1 \times \text{MBW}) + (\beta_2 \times \text{ADG}) + e$, where *e* represents RFI (actual DMI minus the expected DMI) as suggested by Koch et al. (1963). Because there was no significant difference between equations for the different genetic groups (*data not shown*), a single regression equation was fitted to all data. Equations were compared according to Regazzi (1999). The overall average for the variables used

to estimate RFI for the different genetic groups were: MBW (CRAN: 97.7kg; CRVN: 86.42kg; RCN: 93.15kg), GMD (CRAN: 1.43kg; CRVN: 1.32kg; RCN: 1.39kg). The distribution of the genetic groups in the RFI groups was: CRAN (High RFI: 22.22%, Medium RFI: 22.22%, Low RFI: 55.55%), CRVN (High RFI: 30.7%, medium RFI: 30.7%, low RFI: 38.5%), RCN (High RFI: 33.33%, medium RFI: 55.55%, low RFI: 11.11%).

Heifers were ranked in high (> 0.5 SD from the mean; n = 9), medium (± 0.5 SD from the mean; n = 11), and low (< 0.5 SD below the mean; n = 11) RFI groups. Statistical analyses were conducted using MIXED procedure of SAS (2012) version 9.3. A mixed linear model was applied to test the effect of RFI groups on feed efficiency, digestibility, meat and carcass quality, the RFI groups were considered as fixed effect and sire as random. When a significant RFI group effect was identified (P<0.05), means generated by the LSMEANS statement were partitioned using the PDIFF option of SAS (2012). Tukey test was then applied as appropriate to evaluate pairwise comparisons between RFI group means.

RESULTS AND DISCUSSION

The daily DMI was 4.56% lower for heifers ranked as low RFI (Table 2). The difference in DMI between the most efficient (RFI = -0.96kg) and least efficient (RFI = 1.78kg) heifer of the experiment was 2.73kg/day, showing a high feed efficiency heterogeneity among the contemporaries heifers. In general, the literature reported values are variable (3.60kg/d, KOLATH, et al., 2006, 1.26kg /d, PAULINO et al., 2008). No difference (P>0.05) in feed efficiency (kg/d) was detected among RFI groups (Table 2), with an average of 119 grams of weight converted per kg of DMI. Similarly, carcass deposition efficiency did not differ for high, medium or low RFI heifers, averaging 0.10g of carcass gain weight per kg of DMI. The major process associated with feed efficiency is individual variations in energy requirements of maintenance. Richardson et al. (2004a) hypothesized that lower energy requirement for maintenance of low RFI animals would occur due to a more efficient conversion of protein deposition into lean tissue (i.e. muscle). Some studies have reported decrease in fat and consequent increase in lean tissue in low RFI animals (CARSTENS et al., 2002; BASARAB et al., 2003). There was no difference (P>0.05) on apparent digestibility of DM, CP, EE, NDF and NFC for RFI groups (Table 3).

Digestibility of nutrients in the gut is a possible mechanism associated to low RFI. Phenotypic and genetic associations between cattle with low RFI and characteristics of indicative greater utilization of starch in the gut have also been reported in the literature. Channon et al. (2004) suggested that low RFI animals might develop some distinct process that improves the efficiency of starch digestion. However, in the current study we did not find differences among RFI groups. Likewise, Paulino et al. (2008) and Richardson et al. (2004a) did not report differences in apparent digestibility of nutrients in different classes of RFI. Richardson et al. (2006) attributed greater DM and CP digestibilities for low RFI steers, suggesting that this could be a mechanism explaining the variation among RFI classes. Possible differences on diet digestibility among RFI groups would be due to the rumen retention time and individual feeding behavior (RUSSEL & GAHR, 2000). Richardson et al. (2004b) observed strong negative correlation between RFI and DM digestibility (r = -0.44). The RFI groups did not differ (P>0.05) for final body weight, average daily gain and carcass traits (Table 2). Differences among RFI classes were not detected for HCW, CCW, fat thickness and rib eye area (Table 2). These data are consistent with other studies (WELCH et al., 2012; NKRUMAH et al., 2004; BAKER et al., 2006) reporting similar findings.

Table 2. Least squares means for performance traits and intake of beef heifers finished in feedlot according to their residual feed intake

Items	Residual feed intake			SEM	P =
	High n = 9	Medium n = 11	Low n = 11		
Initial body weight, kg	339.13	334.01	339.60	7.30	0.871
Final body weight, kg	484.44	480.91	477.40	8.90	0.970
DMI, kg/day	12.61[a]	11.72[a]	11.00[b]	0.20	0.028
ADG, kg/day	1.41	1.41	1.38	0.02	0.944
DMI[2], kg/ % BW	3.06[a]	2.87[b]	2.69[c]	0.01	0.001
Feed efficiency[3]	0.114	0.122	0.121	<0.001	0.072
Carcass deposition efficiency[4]	0.09	0.10	0.11	0.05	0.940
Initial body weight, kg	338.00	331.90	328.54	7.30	0.874
Slaughter body weight, kg	479.55	479.54	475.00	8.85	0.970
Hot carcass weight, kg	261.44	260.58	259.09	4.70	0.979
Cold carcass weight, kg	259.34	257.55	256.59	4.70	0.972
Fat thickness, mm	6.26	6.45	5.74	0.15	0.778
Rib eye area, cm²	68.11	65.26	69.02	1.60	0.702
Carcass length, cm	128.59	127.36	129.71	1.15	0.548
Carcass yield, %	54.50	54.48	54.53	0.20	0.998

[1]Within a row means without a common superscript differ (P< 0.05); [2]DMI = dry matter intake; [3]kg gain/kg DMI; [4]kg daily carcass gain/ kg DMI.

Table 3. Least square means for digestibility coefficients for dry matter (DM), crude protein (CP), crude fat (CF), neutral detergent fiber (NDF), non-fiber carbohydrates (NFC) and total digestible nutrients (TDN) obtained on experiment

Variables	Residual feed intake			SEM	P =
	High	Medium	Low		
DM	63.64	63.48	64.88	1.25	0.875
CP	59.26	59.58	61.21	0.90	0.626
CF	72.37	74.16	72.14	1.40	0.809
NDF	53.79	55.37	55.25	0.80	0.687
NFC	78.57	78.20	79.96	0.90	0.692
TDN (%)	71.61	71.59	71.63	1.10	0.676

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In this study, beef from heifers with low RFI were as tender as those produced by the other classes of efficiency (Table 4). Residual feed intake groups were similar (P>0.05) for tenderness and sensorial traits of LD muscle (Table 4). For palatability of the meat, the scores were similar among classes of RFI (P>0.05). There was no difference (P>0.05) among RFI groups on LD color measurements (Table 4). The average values of L*, a *, and b * were 40.47, 24.74 and 16.13, respectively. In the current study, the average value for shear force (kg) obtained was 5.30kg. The observed values of shear force and tenderness score are consistent with literature for crossbred animals of similar age in Brazil (BIANCHINI et al., 2007). Bianchini et al. (2007) considered that for the same muscle, shear force values up to 5.5kg would still be acceptable for Zebu cattle. Studies in meat quality have shown that the tenderness is related to activity of proteolytic mechanisms (KOOHMARAIE, 1994; TAYLOR et al., 1995). This system could discriminate animals among RFI classes, since there is a hypothesis that low RFI animals may have lower protein turnover (CASTRO-BULLE et al., 2007). Recent studies done with pigs and cattle have suggested that after 4-5 generations of divergent selection for RFI, the meat can become less tender, as a result of higher calpastatin in the muscle of more efficient animals (LEFAUCHEUR et al., 2011; SMITH et al., 2011; McDONAGH et al. 2001). However, if the quantification of calpain-calpastatin enzyme complex would allow distinguishing classes of RFI in Zebu animals still needs to be addressed.

Table 4. Least Square means for tenderness, juiciness, palatability, color of LD muscle and carcass tissues of beef heifers ranked by residual feed intake

Variables	Residual feed intake			SEM	P =
	High	Medium	Low		
Juiciness	5.63	5.58	5.07	0.15	0.270
Palatability	5.59	5.74	5.65	0.25	0.860
Tenderness (panel)	6.52	6.18	5.76	0.15	0.220
Shear force, kgf	5.19	5.27	5.45	0.60	0.850
LD muscle color					
L*	40.11	39.89	41.35	0.60	0.525
a*	24.88	24.51	24.85	0.30	0.829
b*	15.85	16.14	16.36	0.40	0.861
Carcass tissues					
Muscle, %	59.86	60.93	61.61	0.95	0.761
Fat, %	25.54	24.75	24.19	0.70	0.894
Bone, %	14.60	14.31	14.20	0.35	0.897

The beef consumers were unable to identify differences in traits among the three classes of efficiency (P>0.05). It is worth mentioning that the animals used in this study did not come from a herd divergently selected for feed efficiency. In that case, after some generations of selection, this difference may become much more evident. Mean values obtained for juiciness and palatability were 5.41 and 5.61 (Table 4). Juiciness is directly related to the deposition of intramuscular fat, which in this study were similar (P>0.05) among RFI groups, with mean value of 4.29% of LD ether extract (EE%). Carcass physical composition and yield of commercial cuts were similar (P>0.05) among RFI groups (Table 5).

Table 5. Commercial carcass cuts yield (% of right-side carcass) of beef heifers ranked by residual feed intake

Commercial cuts yield	Residual feed intake			SEM	P =
	High	Medium	Low		
Right carcass side, kg	131.51	131.24	130.33	2.40	0.977
Hindquarter, %	63.79	63.87	63.43	0.20	0.580
Beef plate, %	17.47	17.18	16.49	0.20	0.155
Tenderloin, %	1.35	1.27	1.34	0.03	0.574
Strip loin, %	6.44	5.91	6.12	0.10	0.271
Short rib boneless, %	1.40	1.33	1.27	0.03	0.407
Top round, %	6.45	6.47	6.61	0.08	0.652
Top round cap, %	1.54	1.50	1.56	0.02	0.635
Bottom round, %	3.26	3.42	3.33	0.05	0.430
Eye of round, %	1.52	1.59	1.55	0.02	0.652
Beef knuckle, %	3.38	3.75	3.76	0.08	0.181
Top sirloin, %	2.82	2.67	2.81	0.04	0.309
Top sirloin cap, %	1.76	1.58	1.50	0.05	0.175
Tri rip, %	1.06	1.00	0.98	0.03	0.624

We conclude that low RFI crossbred beef heifers have lower dry matter intake compared to their counterparts high RFI, however, no compromising of their performance and carcass traits is observed. Total tract digestibility of nutrients does not play a significant role on feed efficiency.

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