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Feeding behavior and productive performance of steers fed pearl millet grain-based diets containing proportions of babassu mesocarp bran

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ABSTRACT - The objective of this study was to evaluate the feeding behavior and feedlot productive performance of dairy-origin steers fed for 84 days ground pearl millet grain-based diets with 0, 120, 240, 360, and 480 g kg^{-1} of babassu mesocarp bran (BMB) and a standard diet based on ground corn. Thirty Holstein-Zebu steers with average initial body weight of 371.02±27 kg were used. The experimental design was completely randomized, with five replications. Dry matter intake showed better fit with the quadratic regression equation with the inclusion of BMB, reaching a maximum value in diets with 360 g of this by-product. There was no difference for dry matter intake between pearl millet- and corn-based diets. There was no difference in total digestible nutrients intake between diets. The digestibility coefficient of organic matter decreased linearly with the increase in the dietary level of BMB. The digestibility coefficient of organic matter was not different between corn and millet diets. There was no difference in feeding time between diets. Total requirement of metabolizable energy increased linearly with inclusion of BMB. However, total requirements of metabolizable energy did not differ between the corn- and pearl millet-based diets. Average daily gain decreased linearly with the increase in BMB, with adjustment forced by the sharp decline of this variable in diets with 480 g of BMB. There was no difference in average daily gain between corn- and pearl millet-based diets. The inclusion of levels above 360 g of babassu mesocarp bran in pearl millet-based diets reduces the supply of metabolizable energy and the productive performance of feedlot dairy steers.

Key Words: by-products, dairy-origin, digestibility, dry matter intake, weight gain

Introduction

Finishing dairy-origin males in the feedlot is an alternative for increasing beef production and the income of farmers without reducing pasture areas intended for milk production. The cost of traditional concentrates based on corn and soybean meal can represent up to 45% of the production cost, varying significantly with the level of concentrate in the diet (Missio et al., 2009). Cruz et al. (2014) demonstrated that diets in which the concentrate proportion exceeds the forage, source, amount and commercial value of foods are more important in shaping the cost of production than the manipulation of the amount of forage/concentrate in the diet. This demonstrates the importance of using lower-cost feedstuffs.

The pearl millet grain (*Pennisetum americanum*), in this context, is an alternative for lowering the feedlot cost, since its trade value is less than or equal to 77.78% of the cost of the corn grain (Silva et al., 2014). Cultivation of pearl millet has increased in th center-west and northeast regions of Brazil, with an increase in area of soybean (*Glycine max*) cultivation. Pearl millet is cultivated after the harvest of this legume and used for grazing, production of straw for no-tillage management, and grain and/or silage production (Bergamaschine et al., 2011). The babassu (*Orbynia speciosa*), on the other hand, is a palm tree occurring naturally in Brazil, Central America, and Bolivia. In Brazil, the babassu forest has a potential production of 6.8 million tons of fruits per year (main potential in Maranhão state - 92%) and is of great socioeconomic importance (Teixeira and Carvalho, 2007; Teixeira, 2008). The babassu fruit is used mainly for production of flour and oil for human consumption. The babassu mesocarp bran (BMB) is produced from the mesocarp (23% of the fruit) of babassu and can replace the corn grain without affecting animal performance, but it lowers the feed cost (Silva et al., 2012; Cruz et al., 2014).

Reviewing the literature, no studies were found evaluating the mix of millet grain and babassu mesocarp bran in diets for feedlot cattle, justifying the development of this research. Therefore, the present study aimed to

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evaluate the best level of inclusion of babassu mesocarp bran in substitution of pearl millet in feedlot diets.

Material and Methods

The experiment was conducted from April to July 2012 in the county of Araguaína - TO, Brazil. The procedures performed in this experiment were approved by the Ethics Committee for Animal Experimentation of Universidade Federal do Tocantins, under number 23101003927/2012-19.

Thirty 30-month-old crossbred Holstein-Zebu steers with an initial average body weight of 371.02±27 kg were used. Animals were kept in individual concrete floor stalls (12 m^2) with troughs for food and water. At the beginning of the adaptation phase (14 d), all animals were dewormed and supplemented with vitamins A, D, and E.

Six diets were formulated to meet the requirements for growth and finishing with an estimated dry matter (DM) intake of 24 g kg^{-1} of body weight (BW), according to NRC (1996). These diets included elephant-grass silage as forage and concentrates composed mainly of ground corn grain or pearl millet grain, BMB, and soybean meal (Table 1). Elephant grass forage was harvested and ensiled at 70 d of regrowth and shredded to a particle size of 8-10 mm. The BMB was obtained commercially by grinding the mesocarp of babassu fruit until 96% of particles were smaller than 1.18 mm in diameter (Penn State Particle Size Separator) and high dustiness was achieved. The treatments were diets containing BMB at increasing levels (0, 120, 240, 360, and 480 g kg^{-1}) in replacement of pearl millet grain and a standard corn grain-based diet, maintaining the ratio of 20% forage (Table 2).

Animal performance was measured for 98 days, which consisted of 14 days of adaptation to diet and stalls and 84 days of data collection. The animals were fed at 12.00 h *ad libitum* and the diet was adjusted to allow for 10% as orts (dry matter basis). Animals were weighed at the beginning and end of the evaluation period after fasting for 14-16 h. To obtain the average feed intake, feed and orts were weighed daily. Throughout the performance test, samples of ingredients and orts from each animal and ingredients of feed concentrates from mixture preparations were collected weekly to provide representative samples. The samples were placed in plastic bags, labeled, and stored in a freezer at −10 °C until laboratory analysis. At the end of the feedlot period, animals were slaughtered at a commercial slaughterhouse under supervision of the

Table 1 - Chemical composition of ingredients (g kg^{-1} of dry matter)

Nutrient	Ingredient				
	Elephant grass silage	Corn	Millet	BMB	Soybean meal
Dry matter (g kg^{-1} as fed)	242.10	844.40	865.70	838.30	908.80
Ash	13.50	12.80	17.60	50.40	65.00
Crude protein	39.60	77.30	129.80	30.50	480.90
Ether extract	21.50	37.80	34.90	12.50	15.00
Neutral detergent fiber	700.00	116.60	109.10	360.30	191.50
Total carbohydrates	804.20	872.20	817.70	906.70	439.10
Non-fiber carbohydrates	104.20	755.60	708.60	546.40	247.60

BMB - babassu mesocarp bran.

Table 2 - Proportion of ingredients in the diets (g kg^{-1} of DM)

Item	g kg^{-1} of BMB in the diets					Corn diet
	0	120	240	360	480	
Elephant grass silage	200.00	200.00	200.00	200.00	200.00	200.00
Ground corn	-	-	-	-	-	708.40
Ground millet grain	777.90	650.10	523.70	364.50	206.20	-
Babassu mesocarp bran	-	123.90	246.80	368.30	488.60	-
Soybean meal	-	-	-	37.60	75.70	69.50
Limestone	5.80	9.70	13.30	13.30	13.30	5.80
Urea	7.90	8.00	7.90	8.00	7.90	7.90
Mineral mixture[1]	5.40	5.30	5.30	5.30	5.30	5.40
Sodium chloride	2.60	2.60	2.60	2.60	2.60	2.60
Rumensin®	0.30	0.30	0.30	0.30	0.30	0.30
Ammonium sulfate	0.10	0.10	0.10	0.10	0.10	0.10

DM - dry matter; BMB - babassu mesocarp bran.

[1] Composition: P - 40 g; Ca - 146 g; Na - 56 g; S - 40 g; Mg - 20 g; Cu - 350 mg; Zn - 1,300 mg; Mn - 900 mg; Fe - 1,050 mg; Co - 10 mg; I - 24 mg; Se - 10 mg; F (max.) - 400 mg; excipient q.s. - 1,000 mg.

Federal Inspection Service. Prior to the slaughter, animals were fasted for 14-16 h. After slaughter, carcasses were identified, divided in half, and weighed.

Feeding behavior data were collected during the period of confinement of animals, in three days, when, in each trial, 48 consecutive hours of visual evaluation were undertaken by the method of scan sampling (Martin and Bateson, 1986), with five-minute intervals. Visual assessments were made by a trained observer for every four experimental animals. The behavioral variables observed and recorded were the times spent consuming feed and water, ruminating, and on other activities (water intake and idle and social behaviors).

Feces were collected for the digestibility trial during the last three days of the experimental period. Feces collection (300 g) was performed manually, after spontaneous defecation and before the fecal bolus reached the floor of the pen, with animals monitored from 06.00 h until the collection of the sample from the last animal. For the digestibility trial and analysis of nutrients, samples were pre-dried in a forced-air oven at 55 ºC for 72 h and ground through a 1-mm sieve. From the three ground samples, a composite sample was made and stored in plastic containers for subsequent laboratory analyses. The fecal dry matter excretion was estimated using indigestible neutral detergent fiber (iNDF) according to the methodology of Cochran et al. (1986). The iNDF contents of the samples of feces, feed (roughage and ingredients of the concentrate), and orts were obtained after *in situ* rumen incubation for 240 h (Casali et al., 2008). The fecal output (kg of DM day^{-1}) was calculated as iNDF intake/iNDF in feces. Digestibility was calculated by the following expression: apparent digestibility of nutrient = [(nutrient intake – nutrients excreted)/nutrient intake].

Standard procedures of AOAC (1990) were adopted to obtain the following components from the feed, orts, and fecal samples: dry matter (DM), mineral matter, crude (CP) protein, and ether extract (EE). Neutral detergent fiber (NDF) was determined according to Van Soest et al. (1991). Total carbohydrates (TC), non-fiber carbohydrates (NFC), and total digestible nutrients (TDN) were estimated according to Sniffen et al. (1992), as follows: TC = 1,000 – (CP + EE + mineral matter [MM]); NFC = 1,000 – (TC + NDF); TDN = digestible CP + (digestible EE × 2.25) + digestible NDF + digestible TC. The metabolizable energy of diets was estimated considering 1 kg TDN = 4.4 Mcal digestible energy and 1 Mcal of digestible energy = 0.82 Mcal of metabolizable energy (Table 3).

The energy required for maintenance (NE_m, Mcal/day), corrected for the sexual condition, was estimated as NE_m = 0.077 Mcal/$BW^{0.75}$. The net energy required for 1,000 g of gain (NE_g, Mcal/day) was estimated as $NE_g = (0.0635 \times EBW^{0.75}) \times EBG^{1.097}$; EBW is empty body weight (EQSBW × 0.891), and EBG is empty body weight gain (body weight gain × 0.956). The equivalent body weight (EQSBW) was calculated by the equation: EQSBW = SBW × (SRW/FSBW); EQSBW is equivalent body weight, SBW is shrunk initial body weight being evaluated (14-16 h); SRW is standard reference body weight of 478 kg; and FSBW is final shrunk body weight. The conversions of NE_m and NE_g (Mcal/kg DM) to metabolizable energy values (ME, Mcal/kg DM) were represented by the following equations: $NE_m = 1.37\ ME - 0.138\ ME^2 + 0.0105\ ME^3 - 1.12$ and $NE_g = 1.42\ ME - 0.174\ ME^2 + 0.0122\ ME^3 - 1.65$, respectively. Net protein requirement for gain was calculated by the equation: retained protein = SWG × (268 – (29.4 × (NE_g/SWG)). This value was then divided by the efficiency of use of absorbed protein to obtain the metabolizable protein required for gain, which has added to the metabolizable protein required for maintenance (3.8 × $SBW^{0.75}$) to obtain the total metabolizable protein required (NRC, 1996).

The experimental design was completely randomized, with six treatments (diets) and five replicates. The Shapiro Wilk test was performed to evaluate the normality and Cochran and Bartlett's test was used to evaluate the homogeneity of variances, and whenever necessary the data were transformed by log^2. The data were subjected to analysis of variance and contrast by the mixed model

Table 3 - Chemical composition of the diets (g kg^{-1} of DM)

Item	g kg^{-1} of BMB in the diets					Corn diet
	0	120	240	360	480	
Dry matter, g kg^{-1} as fed	729.10	730.10	730.80	734.30	732.90	733.30
Mineral matter	54.30	59.60	62.80	66.30	77.60	54.90
Crude protein	131.90	125.00	129.70	133.80	132.70	119.90
Ether extract	36.20	30.20	23.70	22.50	12.90	33.90
Neutral detergent fiber	234.10	267.90	311.30	340.80	414.50	237.70
Total carbohydrates	777.60	785.20	783.80	777.30	776.70	791.40
Non-fiber carbohydrates	543.50	517.30	472.50	436.60	362.20	553.70
Total digestible nutrients	849.50	812.40	769.50	753.30	727.70	854.40
ME (Mcal kg^{-1} of DM)	3.07	2.94	2.78	2.72	2.63	3.09

DM - dry matter; BMB - babassu mesocarp bran; ME - metabolizable energy.

methodology (Littell et al., 2006), in which the model included the fixed effect of treatment and random effects of animal. The sum of squares of treatments in contrasts analysis was decomposed into three contrasts: pearl millet grain vs. corn grain-based diets (1 0 0 0 0 –1), diets with babassu mesocarp bran vs. corn grain-based diet (0 1 1 1 1 –4), and pearl millet grain-based diet vs. diets with babassu mesocarp bran (4 –1 –1 –1 –1 0). Inclusion of babassu mesocarp bran in the diets was analyzed separately by regression analysis. For probability of type-I error, $\alpha = 0.05$. Statistical procedures were carried out using SAS software (Statistical Analysis System, version 9.1).

The general mathematical model is represented by $Y_{ij} = \mu + T_i + e_{ij}$, in which μ = overall mean; T_i = effect of the diets; and e_{ij} = residual random error.

For the regression study, the following model was used: $\gamma_{ij} = \beta_0 + \beta_1 X_i + \beta_2 X_i^2 + \beta_3 X_i^3 + \alpha_j + \varepsilon_{ij}$, in which γ_{ij} = dependent variables; β = regression coefficients, X_i = independent variables; α_j = deviations of regression; and ε_{ij} = residual random error.

Results

Dry matter intake (kg day^{-1} and g kg^{-1} of body weight) had a quadratic response ($P<0.05$) to the BMB levels, with maximum values for diets containing 360 g of BMB (Table 4). On the other hand, the intakes of CP (kg day^{-1}) and NDF (kg day^{-1} and g kg^{-1} of body weight) showed to fit the linear equation regression ($P<0.05$), increasing with the increasing dietary levels of BMB. A linear decrease ($P<0.05$) in EE intake with the increasing dietary levels of BMB was also observed. There were no differences ($P>0.05$) in the intakes of DM, CP, EE, and NDF between steers fed pearl millet- or corn-based diets. The intakes of DM, CP, and EE were similar between BMB- or pearl millet-based diets. The NDF intake was greater ($P<0.05$) for steers that received diets with BMB inclusion than in steers fed pearl millet- or corn-based diets. The EE intake was lower ($P<0.05$) in steers on diets with BMB inclusion than in those on pearl millet or corn-based diets. There was no difference ($P>0.05$) in TDN intake between experimental diets.

A linear decrease ($P<0.05$) was observed in the digestibility coefficients of DM, organic matter (OM), and NDF with the increasing dietary level of BMB (Table 5). No differences ($P>0.05$) in digestibility coefficients of DM, OM, and NDF between pearl millet- and corn-based diets were observed. The digestibility coefficients of DM, OM, and NDF were lower ($P<0.05$) for diets with BMB inclusion than for the corn grain-based diet. There were no differences ($P>0.05$) in the digestibility coefficients of DM and NDF between BMB and pearl millet grain diets. The digestibility coefficients of OM was lower ($P<0.05$) for diets with BMB inclusion than for the pearl millet grain diet.

Table 4 - Intake of nutrients according to the diets

Item	g kg^{-1} of BMB in the diets					Corn diet	CV	Contrast		
	0	120	240	360	480			A	B	C
				Intake (kg day^{-1})						
DM	9.40	10.66	11.93	14.85	11.40	9.59	14.51	0.287	0.021	0.286
CP	1.22	1.31	1.53	1.97	1.48	1.18	16.70	0.552	0.035	0.157
EE	0.34	0.33	0.29	0.35	0.16	0.33	13.76	0.623	0.045	0.185
NDF	2.36	3.14	3.88	5.23	4.95	2.32	19.27	0.157	<0.001	0.009
TDN	6.96	6.99	6.66	7.80	6.04	6.30	10.32	0.967	0.619	0.582
				Intake (g kg^{-1} of body weight)						
DM	21.97	25.05	28.02	34.68	27.42	22.67	13.38	0.187	0.004	0.185
NDF	5.51	7.38	9.11	12.21	11.90	5.48	15.20	0.079	<0.001	0.001

DM - dry matter (kg day^{-1}) = 9.058 + 0.2179BMB – 0.0033BMB^2 ($R^2 = 0.35$; $P = 0.049$); CP - crude protein (kg day^{-1}) = 1.2807 + 0.0089BMB ($R^2 = 0.27$; $P = 0.019$); EE - ether extract (kg day^{-1}) = 0.3662 – 0.00031BMB ($R^2 = 0.45$; $P = 0.034$); NDF - neutral detergent fiber (kg day^{-1}) = 5.5697 + 0.1497BMB ($R^2 = 0.84$; $P<0.001$); TDN - total digestible nutrients; DM, g kg^{-1} of body weight = 21.31 + 0.483BMB – 0.007BMB^2 ($R^2 = 0.64$; $P<0.001$); NDF, g kg^{-1} of body weight = 5.3651 + 0.1582BMB ($R^2 = 0.93$; $P<0.001$).
BMB - babassu mesocarp bran; CV - coefficient of variation (%); Contrasts - A: millet vs. corn diet, B: corn vs. BMB diets, C: millet vs. BMB diets.

Table 5 - Apparent digestibility of nutrients according to the diets

Item	g kg^{-1} of BMB in the diets					Corn diet	CV	Contrast		
	0	120	240	360	480			A	B	C
DM	0.72	0.61	0.57	0.55	0.53	0.64	9.30	0.118	<0.001	0.437
OM	0.85	0.76	0.69	0.67	0.65	0.80	8.51	0.077	<0.036	<0.085
NDF	0.38	0.27	0.27	0.24	0.24	0.32	22.60	0.098	<0.001	0.915

DM - dry matter (g kg^{-1}) = 0.66811 – 0.24226BMB ($R^2 = 0.43$; $P = 0.015$); OM - organic matter (g kg^{-1}) = 0.82903 – 0.004296BMB ($R^2 = 0.68$; $P<0.001$); NDF - neutral detergent fiber (g kg^{-1}) = 0.3564 – 0.2902BMB ($R^2 = 0.43$; $P = 0.012$).
BMB - babassu mesocarp bran; CV - coefficient of variation (%); Contrasts - A: millet vs. corn diet, B: corn vs. BMB diets, C: millet vs. BMB diets.

The feeding time was not influenced ($P>0.05$) by the diets (Table 6). The rumination time increased linearly ($P<0.05$) with the increasing proportion of BMB in the diet. A linear decrease ($P<0.05$) was observed in the time on other activities with the increase in the proportion of dietary BMB. There were no differences ($P>0.05$) in the times spent feeding, ruminating, and on others activities between corn- and pearl millet-based diets or diets with BMB, or between pearl millet-based diets and diets with BMB.

A linear decrease ($P<0.05$) was observed in average daily gain, final body weight, and hot carcass weight with the increasing dietary level of BMB (Table 7). Corn- or pearl millet-based diets provided similar ($P>0.05$) average daily gains. The average daily gain did not differ between corn diet and diets with inclusion of BMB. The pearl millet diet provided similar ($P>0.05$) average daily gains to diets with inclusion of BMB. There were no differences ($P>0.05$) in final body weight and hot carcass weight between corn and pearl millet diets or between the corn diet and diets with BMB. Feed conversion ratio increased linearly ($P<0.05$) with the increasing dietary level of BMB. There was no difference ($P>0.05$) in the feed conversion ratio between corn and pearl millet diets. Diets with inclusion of BMB provided worse ($P<0.05$) feed conversion ratios than the pearl millet- and corn-based diets.

There were no differences ($P>0.05$) in the requirements of metabolizable protein and energy for maintenance between diets (Table 8). Inclusion of BMB depressed linearly ($P<0.05$) the requirements of metabolizable protein for gain and increased linearly the requirements of metabolizable energy for gain. There were no differences ($P>0.05$) in the requirements of metabolizable protein and energy for gain between corn and pearl millet diets. Diets with inclusion of BMB provided, respectively, lower and higher ($P<0.05$) requirements of metabolizable protein and energy for gain than pearl millet- or corn-based diets. The total requirements (maintenance + growth and finishing) of metabolizable protein were not altered by diets. However, total requirements of metabolizable energy increased linearly ($P<0.05$) with inclusion of BMB. The total requirements of metabolizable energy did not differ ($P>0.05$) between the corn and pearl millet-based diets. The requirement of total metabolizable energy was greater ($P<0.05$) in diets with inclusion of BMB than corn and pearl millet-based diets. The supply of total metabolizable protein requirements increased ($P<0.05$) with inclusion of BMB in the diet. The supply of total metabolizable protein requirements did not differ ($P>0.05$) between the corn- and pearl millet-based diets, or between diets with inclusion of BMB and pearl millet. The supply of total metabolizable protein requirement was greater ($P<0.05$) in diets with inclusion of BMB than in corn-based diets. The supply of total metabolizable energy requirements decreased linearly ($P<0.05$) with inclusion of BMB in the diet. There were no differences ($P>0.05$) in the supply of metabolizable energy requirements between diets with corn and pearl millet or diets with inclusion of BMB, or between the pearl millet diet and diets with BMB.

Table 6 - Variables associated with the feeding behavior according to the diets

Item	g kg^{-1} of BMB in the diets					Corn diet	CV	Contrast		
	0	120	240	360	480			A	B	C
FT	15.97	13.02	13.44	16.32	15.35	13.34	25.48	0.248	0.512	0.403
RT	24.25	23.99	25.83	27.99	29.72	27.54	14.88	0.931	0.167	0.072
OA	58.38	61.76	60.73	55.69	57.55	59.98	6.45	0.221	0.957	0.130

FT - feeding time (% of day); RT - rumination time (% of day) = 23.1895 + 0.1291BMB ($R^2 = 0.29$; P = 0.019); OA - time on other activities (% of day) = 61.35625 – 0.10469BMB ($R^2 = 0.22$, P = 0.047).
BMB - babassu mesocarp bran; CV - coefficient of variation (%); Contrasts - A: millet vs. corn diet, B: corn vs. BMB diets, C: millet vs. BMB diets.

Table 7 - Mean values for performance variables according to the diets

Item	g kg^{-1} of BMB in the diets					Corn diet	CV	Contrast, P-value		
	0	120	240	360	480			A	B	C
IBW	367.70	368.00	369.90	374.00	377.60	367.60	7.43	-	-	-
FBW	488.40	483.10	481.60	482.40	454.00	478.50	7.27	0.839	0.421	0.580
HWC	241.70	253.60	239.60	238.80	224.30	242.83	7.20	0.536	0.422	0.121
ADG	1.44	1.37	1.33	1.29	0.91	1.32	14.39	0.564	0.022	0.099
FC	6.55	7.79	8.98	10.70	12.57	7.36	11.50	0.069	<0.001	<0.001

IBW - initial body weight (kg); FBW - final body weight (kg) = 493.37 – 0.69BMB ($R^2 = 0.20$, P = 0.049); HWC - hot carcass weight (kg) = 247.775 – 0.0395BMB ($R^2 = 0.27$, P = 0.027); ADG - average daily gain (kg d^{-1}) = 1.495 – 0.0009BMB ($R^2 = 0.45$, P<0.001); FC - feed conversion (kg of DM kg^{-1} body weight gain) = 6.33 + 0.0125BMB ($R^2 = 0.85$, P<0.001).
BMB - babassu mesocarp bran; CV - coefficient of variation (%); contrasts - A: pearl millet vs. corn diet, B: corn vs. BMB diets, C: pearl millet vs. BMB diets.

Table 8 - Nutrient requirements estimated according to the diets

Item	g kg^{-1} of BMB in the diets					Corn diet	CV	Contrast, P-value		
	0	120	240	360	480			A	B	C
Maintenance										
MP	357.61	356.07	356.13	357.70	349.90	354.50	5.05	0.932	0.900	0.985
ME	11.88	11.94	12.11	12.24	12.09	11.76	5.06	0.829	0.437	0.611
Growth and finishing (DWG = 1.0 kg^{-1} d)										
MP[1]	263.97	262.33	261.17	259.85	249.62	261.14	1.85	0.543	0.013	0.071
ME[2]	8.11	8.37	8.72	8.92	9.65	8.20	2.53	0.059	<0.001	<0.001
Maintenance + growth and finish (DWG = 1.0 kg^{-1} d)										
MP	621.57	618.40	617.31	617.55	599.52	615.64	2.93	0.805	0.412	0.607
ME[3]	19.98	20.31	20.83	21.16	21.74	19.96	3.24	0.406	0.005	0.058
Supply (% of total requirements for DWG of 1.0 kg^{-1} d)										
MP[4]	131.90	142.35	166.56	214.37	165.89	128.80	12.33	0.491	<0.002	0.054
ME[5]	125.93	124.44	115.58	133.28	100.43	114.11	12.66	0.851	0.182	0.267

Calculated according to NRC (1996).
ME - metabolizable energy (Mcal^{-1} d); MP - metabolizable protein (g^{-1} d).
BMB - babassu mesocarp bran; CV - coefficient of variation (%); Contrasts - A: pearl millet vs. corn diet, B: corn vs. BMB diet, C: pearl millet vs. BMB diets.
[1] $\hat{Y} = 264.7546 - 0.22131BMB$ ($R^2 = 0.41$, $P = 0.003$).
[2] $\hat{Y} = 8.06778 + 0.02847BMB$ ($R^2 = 0.86$, $P<0.001$).
[3] $\hat{Y} = 19.95143 + 0.03917BMB$ ($R^2 = 0.58$, $P<0.001$).
[4] $\hat{Y} = 133.4251 + 1.33279BMB$ ($R^2 = 0.58$, $P<0.001$).
[5] $\hat{Y} = 127.018 - 0.33877BMB$ ($R^2 = 0.31$, $P = 0.046$).

Discussion

Increases in DM intake with inclusion of BMB are associated with the need for animals to offset the lower energy content of this by-product (Silva et al., 2012). The similar ($P>0.05$) TDN intakes among the experimental diets can confirm this hypothesis (Table 4). The particle size of the BMB may have contributed to the increase in DM intake (ascending part of the regression curve) to the extent that it increases the amount of small particles and the rate of digesta passage through the reticulorumen (Miotto et al., 2013). However, this increase in small fibrous particles, on the other hand, may have impaired feed intake, particularly at the highest levels of inclusion of BMB. It is possible that the inclusion of greater amounts of the by-product combined with the pearl millet, a high-concentrate diet (80%), reduced rumen motility, increasing the digesta retention time and benefiting rumen fill. According to Allen et al. (2006), the ruminal motility is affected by the diet and is likely increased by physically effective fiber and decreased by long-chain fatty acids and butyrate. Contributing to this hypothesis, it appears that the NDF intake (12.21 and 11.90 g kg^{-1} body weight, respectively) at the inclusion levels of 360 and 480 g of BMB exceeds the value (11 g kg^{-1} body weight) considered the threshold for the occurrence of the intake restriction by the physical limitation of reticulorumen proposed by Mertens (1994). Silva et al. (2012) evaluated 0, 20, 40, and 60% of BMB in the concentrate of diets with 44% of mombasa grass silage for Nellore males and Cruz et al. (2014) evaluated 0 and 35% of BMB in concentrate fraction of diets with different proportions of concentrate (65 and 71%) for Nellore young bulls and observed a linear increase in DM intake. In these studies, however, the NDF intake was not limiting (<11 g kg^{-1} body weight) in any of the inclusion levels of the by-product. Miotto et al. (2012) evaluated 0, 21, 38, 62, and 78% of BMB in sheep diets and did not find alterations in DM intake, which was attributed to the large variability in the acceptance of this by-product by the animal species used.

The similar intakes of CP and extract ether between diets with BMB and pearl millet confirmed in the contrasts analysis could be attributed to similar DM intake among these diets. The greater NDF intake in the diets with BMB in relation to the pearl millet-based diets could be attributed to the NDF content of BMB in relation the pearl millet (Table 1). These results were partially similar to those found by Silva et al. (2012) and Cruz et al. (214), who also found increased consumption of NDF. On the other hand, the similar intakes of DM, EE, CP, NDF, and TDN (Table 4) between diets based on corn and pearl millet was consistent with the literature (Gonçalves et al., 2010; Silva et al., 2014), demonstrating similar nutritional potential between these grains.

The reduction of the digestibility coefficients with BMB inclusion was associated, in part, with the shorter retention time of digesta in the reticulorumen and the increased DM intake, as found by Miotto et al. (2013).

According to these researchers, the increased indigestible fiber content is another aspect responsible for the lower digestibility coefficients of diets with increasing levels of BMB. Moreover, the similar variation in the digestibility coefficients between diets based on corn or pearl millet was consistent with the results obtained by Gonçalves et al. (2010). However, the similarity in the digestibility coefficients of diets in which corn grain was replaced by pearl millet grain is not unanimous in the literature, as some authors (Gelaye et al., 1997) reported a reduced digestibility following the inclusion of pearl millet grain in the diet attributed to the higher lignin content of this grain than corn grain.

The inclusion of BMB in diets for feedlot cattle may result in increased feeding time due to the reduction of the energy content of diets, as reported by Cruz et al. (2012) and Castro et al. (2009). In the present study this did not occur, possibly due to the moderate levels of inclusion of BMB and because the DM intake and consequently the feeding time were limited by the physical limitation of the reticulorumen at the higher levels of inclusion of this by-product. The increase rumination time with increasing amounts of dietary BMB was the result of variation of DM intake and NDF. According to Van Soest et al. (1991), the rumination time is influenced by the nature of the diet and is proportional to the cell wall content of fibrous feeds. The decrease in the time on other activities with the increase in the inclusion level of BMB, on the other hand, was associated with increase in the rumination time. According to Hodgson (1990), the daily activities of animals are mutually exclusive, in which the increase in rumination and idleness implies a decrease in feeding time. In this study, however, it was evident that the animals abdicated of their resting time in order to compensate for the longer time required for reducing the particle size by rumination, without compromising feeding time and consequently energy intake. Ruminants, like other species, seek to adjust the consumption of their nutritional needs, especially energy (Arnold, 1985).

The results obtained in this study were partially similar to the results obtained by Cruz et al. (2012), who observed that the inclusion of 359 g of BMB impacted rumination time only in the diets with higher proportion of concentrate (71%), but reduced the time on other activities, regardless of the levels of concentrate. Otherwise, the lack of variation in the times spent feeding, ruminating, and on other activities between the corn- and pearl millet-based diets can be justified by the similar intake and digestibility of nutrients in these diets. Corroborating the above, Gelaye et al. (1997) evaluated pearl millet in substitution of corn (50 or 100%) and found no changes in the time and the number of daily meals of growing goats.

The decreased average daily gain and thus final body weight and hot carcass weight of steers fed diets containing BMB (Table 7) can be explained by the increase in the requirements of metabolizable energy (Table 8). According to the NRC (1996), this occurs as a result of the reduction in efficient utilization of metabolizable energy due to the decreased energy content of the diets (Table 3). Furthermore, the decreased DM intake at the highest level of BMB may have compromised the supply of metabolizable energy requirements (Table 8), and certainly determined the linear descending fit of the regression equation.

It can be observed that the average daily gain, final body weight, hot carcass weight, and the energy requirements of diets with up to 360 g of inclusion of BMB were very close to those observed for the corn-based diet. This leads us to believe that low levels (<480 g) of BMB in pearl millet-based diets do not affect the productive performance of feedlot dairy steers. It should be noted that the results obtained in this study were discordant with those reported in the literature (Silva et al., 2012; Cruz et al., 2014; 2015a,b). However, it should be clarified that the aforementioned studies were conducted using BMB in corn-based diets instead of pearl millet, used in this study.

The lack of variation for average daily gain, final body weight, and hot carcass weight between steers fed pearl millet- and corn-based diets (Table 7) was consistent with those observed in other studies (Gonçalves et al., 2010; Silva et al., 2014; Silva et al., 2015); in fact, most studies have demonstrated similar productive performance of animals fed diets containing corn grain and diets containing pearl millet grain. Moreover, the variation in feed conversion reflects the variation in the DM intake with increasing concentration of dietary BMB, which was also reported by Miotto et al. (2013). Another aspect that may have contributed to the worsening of the feed conversion with increasing dietary concentration of BMB was the reduction of the available energy (Table 8) for the use of non-protein nitrogen by the rumen microorganisms, as proposed by Caldas Neto et al. (2007). Moreover, the increased CP intake (Table 4) and reduction of the requirements of metabolizable protein for gain (Table 8) may indicate an increase in the N excretion and energy expenditure for conversion of urea by the liver.

The reduction of metabolizable protein requirements with the increasing dietary BMB levels may be explained by the reduction of body weight (NRC, 1996). This reduction of body weight with the increase in BMB was possibly responsible for the lower requirements of metabolizable protein for gain in diets with inclusion of this by-product compared with the diets based on corn and pearl millet. The lack of variation in feed conversion between corn- and pearl millet-based diets, on the other hand, was in agreement with the result obtained by Hill et al. (1996), which is justified by similar DM intake and average daily gain. Other studies (Gelaye et al., 1997; Silva et al., 2014), however, found a reduction of feed conversion due to the substitution of corn for pearl millet, which was attributed to the reduction of digestibility in diets with pearl millet.

Conclusions

Dairy steers fed pearl millet based-diets containing moderate levels of inclusion of babassu mesocarp bran in the feedlot fit the rumination time and other activities without compromising the feeding time. Nevertheless, the inclusion of levels above 360 g of babassu mesocarp bran in pearl millet-based diets reduces the supply of metabolizable energy and the productive performance of feedlot dairy steers. Dairy steers fed pearl millet grain-based diets manifest similar feeding behavior and productive performance to those fed corn grain-based diets.

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