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Feeding behavior and responses in grazing lactating cows supplemented with peanut cake

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ABSTRACT - This experiment was conducted to study the substitution of soybean meal with peanut cake in the supplement by assessing the feeding behavior and the interaction between the thermal environment and the physiological responses of eight crossbred cows with an average live weight of 500 kg. Cows were divided into two 4 × 4 Latin squares and managed on pasture. The peanut cake was included at the levels of 0, 330, 660, and 1,000 g kg^{-1} in the supplement as a replacement for soybean meal. The feeding behavior variables were not affected by the levels of peanut cake. No differences were found for the physiological parameters of the animals with the replacement of soybean meal for peanut cake in the supplements. Peanut cake can replace up to 100% soybean meal in the supplement of grazing lactating crossbred cows without altering the feeding behavior or physiological parameters of the animals.

Key Words: biodiesel, idleness, pasture, respiratory rate, ruminants

Introduction

The Brazilian milk production increased by 4.5% from 2010 to 2011, reaching a total of 32.091 billion liters of milk. The effectiveness of milked cows increased by 1.3% and the national average milk yield also rose compared with 2010, with 1,382 liters/cow/year (IBGE, 2011).

The pasture-based milk production system has been linked to aspects regarding the reduction of production costs and when rationally conducted makes the dairy business competitive, since it elevates the availability of forage and provides a more efficient use of the dairy herd.

Tropical pastures are potentially able to provide the production of up to 13.5 kg of milk/cow/day without supplementation (Deresz et al., 1994). According to Deresz and Mozzer (1994), it is possible to maintain the dairy herd on pasture during the year in most regions of Brazil, supplementing only in the period of forage scarcity. However, the forage supply varies during the year due to different pasture growth rates. An efficient bulk feeding should ensure that the nutritional requirements of the herd are met primarily by the pasture during the year, within the conditions of economic profitability.

With the effect caused by climatic seasonality, the use of alternative feeds in these periods is essential, which may include residues and by-products from the agro- or biofuel industries, complementing the feeding of animals during the off-season. During this period the prices of traditional feed concentrates with corn and soybean meal tend to increase. Among the oilseeds used for biofuel production, the peanut has excelled because of its oil content, wherein 50% can be extracted for the production of the fuel. The peanut cake is a by-product of this process resulting from mechanical extraction of the oil, which, according to Abdalla et al. (2008), contains average values of 43% crude protein and 8.5% ether extract.

The number of studies on the ingestive behavior of ruminants has increased considerably due to their relevance in the interpretation of the effects found in many other studies (Santana Jr. et al., 2012). According to Welch (1982), the feeding behavior of an animal varies according to the characteristics of the feed, as a resource to maintain feed intake and its productive potential. This makes it important to assess the feeding and rumination behavior to discover its implications on the daily feed intake, and additionally provide information on the interaction between diet and animal, which are essential to predict the likely effects of supplementation on feed intake of lactating cows on pasture (Dado and Allen, 1994).

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In this sense, this study was conducted to evaluate the effect of replacing soybean meal for peanut cake in diets for lactating dairy cows on pasture and its implications on their feeding behavior.

Material and Methods

The experiment was conducted in the municipality of São Gonçalo dos Campos, BA, Brazil, from July to September 2011. The experimental site is characterized by average annual temperature of 26 ºC, 85% relative humidity, and annual rainfall of approximately 1,200 mm.

Eight Gir × Holstein crossbred lactating multiparous cows with a LW of 500 kg, between the 60th and 90th days of lactation and with a milk yield of 15 kg/day, were used for the experiments. The experimental period was 60 days divided into four periods of 15 days, in which 11 days were used for adaptation and four days for collection. The cows were divided into two simultaneous 4 × 4 Latin squares. The animals were housed in ten paddocks with Tanzania grass (*Panicum maximum* cv. Tanzânia), with an area of 0.8 ha each, delimited by a electric fence with a rotational stocking system with three days of occupation and 27 days of rest. All paddocks had shaded areas with water and mineral supplementation *ad libitum*. The pasture was managed in a variable stocking system, and whenever necessary regulator animals were used to adjust the supply forage to provide 8% of the live weight on a dry matter (DM) basis.

Twenty changes of paddocks were made throughout the experiment, determined by the previously established support and grazing pressure. To ensure the intended forage provision, forage availability in the pasture was monitored according to the methodology described by McMeniman (1997). This material was weighted and the values were recorded to calculate its availability for animal consumption.

The feeds used as ingredients in the supplement were peanut cake (*Arachis hypogaea*), soybean meal, and ground corn (Table 1). The peanut cake was included at the levels of 0, 330, 660, and 1,000 g kg^{-1} in substitution of soybean meal, formulated according to the NRC (2001) to be isonitrogenous (18% CP). The supplement was supplied in the amount of 3.0 kg per day during the 15 days of each experimental period, twice daily, at 06.00 h and at 15.00 h, during milking.

Concentrations of dry matter (DM), ash, organic matter (OM), crude protein (CP), ether extract (EE) and lignin (Table 2) were obtained according to the methodology described by the AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to the methodology described by Mertens (2002).

The corrections of NDF and ADF for ash and protein were performed according to Detmann et al. (2012). The percentage of total carbohydrates (TC) was obtained by the equation of Sniffen et al. (1992), and non-fiber carbohydrates according to Detmann and Valadares Filho (2010).

Indigestible neutral detergent fiber (iNDF) was used as an internal marker to evaluate the dry matter intake, obtained after ruminal incubation for 240 h (Casali et al., 2008).

Intake estimates were obtained according to Detmann et al. (2001). The animals were weighed before each experimental period to adjust the stocking rate and forage supply and to estimate DM intake based on body weight.

The feeding behavior assessments were performed on the 10th day of each experimental period before the morning milking, when the animals were marked with paint for easy identification from a distance. The assessments were performed in all experimental periods, during 24 h, at

Table 1 - Chemical composition of the ingredients

Nutrient	Forage	Feedstuff		
		Maize	Soybean meal	Peanut cake
Dry matter	266.4	881.2	885.3	909.4
Ash[1]	88.1	13.8	65.3	52.0
Organic matter[1]	911.9	986.2	934.7	948
Crude protein[1]	116.3	50.1	483.6	446.5
Ether extract[1]	17.8	46.9	20.9	185.3
NDFap[1]	590.1	106.5	112.2	118.3
Acid detergent fiber[1]	383.8	53.8	101.2	109.4
Lignin[1]	68.2	13.4	12.7	29.5
Cellulose[1]	315.6	40.4	88.5	79.9
Hemicellulose[1]	265.5	77.9	52.1	52.2
Total carbohydrates[1]	777.8	889.2	430.2	316.2
Non-fiber carbohydrates[1]	128.5	757.5	276.9	154.6
Fiber carbohydrates[1]	649.3	131.7	153.3	161.6

NDFap - neutral detergent fiber corrected for ash and protein.
[1] g kg^{-1} of the dry matter.

five-minute intervals, by visual observation. After milking, the animals remained in the waiting corral until completing all the process, then returning to the paddock with the other animals that were not part of the experiment. At each interval the activities of grazing, rumination, idleness and permanence at the trough were recorded, and the behavioral variables occurring during the 24 h of evaluation were calculated based on these data. The time spent to consume the supplement during milking sessions corresponded to the time spent at the trough.

On the subsequent day, the number of chews was counted and the rumination time of each ruminal bolus was assessed per animal, using a digital timer. The total chewing time was determined according to methodology described by Polli et al. (1996).The feed (FE) and rumination efficiencies (RUE) of DM and NDF and the total chewing time (TCT, in/day) were calculated according to the methodology described by Burger et al. (2000).

The variables grams of DM and NDF per meal were obtained by dividing the average individual intake of each fraction by the number of grazing and trough periods per day during 24 h. Feed and rumination efficiencies expressed in g/h of DM and NDF were obtained as the average daily intake of DM and NDF divided by the total time spent feeding and the total time spent ruminating, respectively, during 24 h. The variables grams of DM and NDF per bolus were obtained by dividing the average individual intake of each fraction by the number of boli ruminated during 24 h. Discretization of the time series was performed directly on data collection spreadsheets, as described by Silva et al. (2006). The average duration of each of the discrete periods was obtained by dividing the daily times for each of the activities by the number of discrete periods. In all behavioral variables, an animal represented one experimental unit.

During all data collection periods, the environment was monitored daily by the weather station at the experimental farm and by an alcohol thermometer inserted in a small plastic globe, painted black (black globe), and placed at the mean height of the animal body (Table 3). The black globes with thermometers were maintained on the pasture exposed

Table 2 - Centesimal composition of the ingredients and chemical composition of the experimental diets

Item (g kg^{-1} DM)	Forage	Peanut cake level (g kg^{-1} DM)			
		0	330	660	1000
Centesimal composition					
Maize	-	656.8	651.6	646.4	641.0
Soybean meal	-	320.5	214.7	108.9	-
Peanut cake	-	-	111.1	222.2	336.5
Vitamin-mineral mix (Top Milk Núcleo)	-	22.6	22.6	22.5	22.5
Chemical composition					
Dry matter	266.4	862.6	865.3	868.1	870.9
Organic matter[1]	911.9	810.0	813.9	818.0	822.1
Ash[1]	88.1	52.6	51.4	50.1	48.8
Crude protein[1]	116.3	187.9	186.1	184.3	182.4
Ether extract[1]	17.8	37.5	55.6	73.8	92.4
Indigestible neutral detergent fiber[1]	24.14	4.98	5.01	5.03	5.06
NDFap[1]	590.1	105.9	106.6	107.3	108.1
Neutral detergent insoluble protein[2]	359.1	160.7	158.8	156.9	154.9
Acid detergent fiber[1]	383.8	67.8	68.9	70.1	71.3
Acid detergent insoluble protein[2]	75.6	36.5	35.9	35.4	34.8
Lignin[1]	68.2	12.9	14.7	16.6	18.5
Cellulose[1]	315.6	54.9	54.2	53.5	52.8
Hemicellulose[1]	265.5	67.8	67.8	67.6	67.5
Fibrous carbohydrates[1]	649.3	135.6	136.7	137.7	138.8
Non-fiber carbohydrates[1]	128.5	586.4	570.2	554.1	537.6
Total carbohydrates[1]	777.8	722.0	706.9	691.8	676.4

DM - dry matter; NDFap - neutral detergent fiber corrected for ash and protein.
[1] g kg^{-1} dry matter.
[2] g kg^{-1} crude protein.

Table 3 - Mean values of black globe temperature, air temperature, relative humidity and black globe temperature index

Climate variables	BGTm	BGTp	BGTs	AT	RH, %	BGTIm	BGTIp	BGTI
Mean	23.60	29.09	25.91	26.33	68.59	72.33	70.59	67.41

BGTm - black globe temperature in the milking parlor; BGTp - black globe temperature in the paddock; BGTs - black globe temperature in natural shade; AT - air temperature; RH - relative humidity; BGTIm - black globe temperature in the milking parlor; BGTIp - black globe temperature in the paddock; BGTIs - black globe temperature in natural shade.

to direct sunlight, protected from direct sunlight (shade tree) and in the milking parlor. Air temperature, relative humidity, and black globe temperatures were recorded during the last four days of each experimental period, every hour, for 12 h/day, beginning at 06.00 h and ending at 18.00 h. From the obtained data, the thermal comfort index was calculated based on the black globe temperature and humidity index (BGTHI), according to the formula developed by Buffington et al. (1981).

Rectal temperature, respiratory rate, and heart rate were evaluated after milking in the last four days of each experimental period. Rectal temperature was measured using a digital thermometer inserted into the rectum of the animal until the buzzer sounded indicating temperature stability. The respiratory rate was measured on each animal by counting the movements of the flank for 15 s and multiplying the number of movements by four to obtain the corresponding value per minute. Heart rate was obtained with a stethoscope and the number of heartbeats per 15 s was recorded, and the result was multiplied by four to obtain the number of beats per minute.

The results regarding the effect of the peanut cake levels on feeding behavior and physiological variables were interpreted by analysis of variance and regression analysis, using the System for Statistical and Genetic Analyses (SAEG), at 5% probability.

Results and Discussion

There was no difference (P>0.05) for the feeding behavior variables as a function of the peanut cake levels (Table 4). The results for grazing time (494 min, on average), were lower than those found by Silva et al. (2004), who evaluated the feeding behavior of ¾ Holstein × Zebu heifers on *Brachiaria decumbens* pasture with levels of supplementation in the trough and found grazing times varying between 10.35 and 11.03 h. The lower values found in the present study are due to the fact that animals remained in the waiting corral after milking, awaiting completion of the milking time for all animals.

The idle time was not influenced (P>0.05) by the levels of peanut cake, averaging 351.56 min. This finding differs from that found by Patiño Pardo et al. (2003), who, in observations of the diurnal feeding behavior of steers on pasture subjected to supplementation levels, noted a linear increase in relation to the supplementation level.

The lack of significant effect on the idle activity can be explained by the similarity of physical and chemical properties of diets with similar NDF. The time results are in agreement with the cattle feeding behavior pattern, confirming the responses obtained by several authors (Pinto et al., 2010; Pinheiro et al., 2012).

The animals consumed on average 11.798 kg of DM and 6.449 kg of NDF. This statement is also supported by Carvalho (2002), who worked with levels of NDF in the diet of lactating goats and observed a linear increase in the time spent feeding as the level of fiber in the diets also increased.

The NDF contents of up to 10% in the diet contributed to the lack of effect of the inclusion of the peanut cake on DM and NDF intakes, confirming the results of Mertens (1997), who reported that the fiber content is inversely related to the net energy content, and when the NDF content of the diet is elevated there is increased energy expenditure for feeding, so that the animal may meet its energy requirements.

In this work, the feeding time was shorter than that described by Correia et al. (2012), who studied Zebu steers

Table 4 - Feeding behavior and efficiency of dairy cows supplemented with peanut cake

Item	Peanut cake level (g kg^{-1} DM in the supplement)				SEM	Significance	
	0	330	660	1000		L	Q
			Behavior (min)				
GRAZING	493.13	495.00	497.50	491.88	1.22	0.992	0.849
RUM	575.00	542.50	560.63	528.12	10.26	0.210	0.992
IDLE	326.25	359.38	340.00	380.63	11.83	0.096	0.841
TROUGH	45.63	43.12	41.87	39.37	1.30	0.216	0.992
			Intake (g)				
DM/day	12700.43	11578.29	11736.42	11177.07	323.00	0.156	0.677
NDF/day	7056.90	6296.68	6407.02	6036.35	216.94	0.143	0.657
FE g DM/h	1460.40	1295.43	1359.70	1271.71	42.17	0.160	0.624
FE g NDF/h	811.14	703.56	744.75	686.56	27.716	0.136	0.613
			Intake (min)				
kg DM	43.05	48.01	47.37	48.52	1.25	0.174	0.455
kg NDF	78.13	89.26	87.62	90.81	2.85	0.145	0.467

SEM - standard error of the mean; L - linear effect; Q - quadratic effect; RUM - rumination; TROUGH - remaining at the trough; FE - feed efficiency; ns - not significant.

fed diets with peanut cake replacing soybean meal in the concentrate and observed a feeding time of 330 min/day. The result was attributed to the concentrate fraction, which corresponded to 35% of the diet, whereas in the present study it corresponded to 60% of the total diet.

There was no difference (P>0.05) between the feed and rumination efficiencies in g DM/h and g NDF/h in response to the levels of peanut cake in the supplement (Table 5). It was also observed that rumination in min/kg DM and min/kg NDF and chewing in min/kg DM and min/kg NDF were not influenced by the levels of peanut cake in the supplement, which contradicts the findings of Carvalho et al. (2011), in which the intake of nutrients had implications in the time spent on feeding activities and idle time. The feed and rumination efficiencies are affected primarily by the animal intake, which could affect the time spent on activities of feeding, rumination, and idleness. In the present study, the similarity in the feed and rumination efficiencies is possibly due to the absence of a significant effect of the grazing and rumination activities on the levels of peanut cake (Carvalho et al., 2008).

Although the levels of EE in the concentrates with peanut cake varied from 3.75 to 9.24, respectively, for diets with 0 and 100% cake in the total diet, when considering forage intake, the values were close to 3% of EE, therefore not interfering with the rumination activity. It is known that diets with high levels of EE may affect feed intake by reducing the fiber digestion and the passage rate of the digesta through the gastrointestinal tract (NRC, 2001), which was not observed in the present study.

The chewing activity is one of the most commonly used measures for evaluating the effectiveness of the fiber, due to the effects on salivary secretion, the feed crushing process, rumen functioning, and dry matter intake (Colenbrander et al., 1991). For the number of chews per bolus and chewing time per bolus, as well as the number of boli ruminated per day, and the total chewing time, no differences were observed (P>0.05) with the replacement of soybean meal for peanut cake in the supplement. As shown in Table 4, there was no difference in dry matter intake (DMI) and therefore the chewing time was not affected, corroborating Cardoso et al. (2006), who stated that chewing time is directly related to DMI and the concentration of neutral detergent fiber (NDF) in the diet.

The number of ruminated boli and the chewing time per bolus are associated with the proportion of concentrate, the NDF, and the physical form of diet (Mendes et al., 2015). Thus, diets with higher levels of concentrate usually cause a reduction in the number and average time for each bolus to be ruminated, due to the lower NDF content.

For the discretization of the time series, the periods of grazing, remaining at the trough, rumination, and idle (n/day) as well as the time spent per period in grazing, remaining at the trough, ruminating, and idle (min/period) did not change with the levels of peanut cake in the diet (Table 6). The average number of periods spent at the trough was 3.40, with no difference between the levels of peanut cake in the supplement.

The values found in the present study for the discretization of the time series were similar to those found

Table 5 - Mean values of time spent in activities related to rumination by cows supplemented with peanut cake

Item	Peanut cake level (g kg^{-1} DM in the supplement)				SEM	Significance	
	0	330	660	1000		L	Q
			Rumination efficiency (g/h)				
gDM/h	1376.69	1300.03	1265.26	1271.72	25.56	0.441	0.676
gNDF/h	766.96	705.77	688.27	685.18	19.02	0.355	0.640
			Chewing activity				
NC/bol	51.479	52.73	53.84	53.66	0.54	0.347	0.685
CT/bol	53.99	56.73	54.54	54.87	0.60	0.965	0.565
NRB/day	642.01	577.68	621.99	586.82	15.05	0.404	0.657
CRB/day	33071.49	30254.63	33042.83	31247.56	695.90	0.586	0.657
TCT h/day	18.562	18.01	18.34	17.65	0.20	0.096	0.841
			Rumination (min/kg)				
kg DM	46.91	48.62	47.69	47.83	0.35	0.874	0.518
kg NDF	85.24	90.25	87.63	89.38	1.11	0.345	0.611
			Chewing (min/kg)				
kg DM	89.968	96.63	95.06	96.35	1.55	0.531	0.651
kg NDF	163.37	179.52	175.25	180.20	3.90	0.762	0.774

SEM - standard error of the mean; L - linear effect; Q - quadratic effect; NC - average number of chews; CT - average chewing time; NRB - number of ruminated boli; CRB - number of chews per ruminated bolus; TCT - total chewing time; ns - not significant.

by Silva et al. (2005), who worked with grazing crossbred heifers and obtained an average of 3.8. The values were obtained by observing the feeding behavior during milking twice a day, wherein this was the time the animals remained at the trough.

Although no difference was detected for the time per period at the trough, it is believed that the chemical composition of the diets and their acceptability by the animals may have resulted in a relatively shorter time (12.96 min) when compared with grazing cows in other studies (Silva et al., 2005; Abreu Filho et al., 2009), showing values greater than 15 min. This fact was explained by the permanence of the animals at the trough during milking, because they received the supplement during this time. This is in agreement with Silva et al. (2005), who stated the preference of the animals to seek food in the trough at the time it is supplied, and that when receiving the concentrate these animals tend to consume it quickly in short periods at the trough, which was observed in the present study.

It was also observed that the amount (kg) of DM and NDF per feeding period were not influenced by the inclusion of peanut cake in the diet, which may be due to the absence of significant effects on the DM and NDF intakes (Table 4) and the number of feeding periods (Table 6).

The levels of peanut cake had no effects (P>0.05) on heart rate, respiratory rate, rectal temperature and body surface temperature (Table 7).

The heart rate of the animals remained similar among the evaluated diets, with an average of 76.63 (beats/min), not exceeding the reference values for cattle, which, according to Detweiler (1988), varies between 48-80 bpm (beats per minute). Silva and Starling (2003) emphasized the importance of respiratory stabilization; high respiratory rates over a long period of time can cause a reduction in blood pressure of CO_2, in addition to increasing the heat accumulated in the tissues due to rapid work of respiratory muscles. The reduction in blood pressure is responsible for the increased heart rate in an attempt to maintain blood pressure at the physiological level considered normal.

The respiratory rate showed a mean value of 36.38 mov/min, which is within the range recommended by Hahn and Mades (1997), who stated that the normal respiratory frequency rate for adult dairy cattle of the Holstein breed is between 10 to 60 flank movements per minute. This indicates either absence of animals with heat stress or that heat stress was minimal.

Rectal temperature and body surface temperature indicate that the animals remained within the normal range for cattle (Detweiler, 1988; Hahn & Mades, 1997).

Table 6 - Mean values of discrete periods relative to feeding behavior

Item	Peanut cake level (g kg^{-1} DM in the supplement)				SEM	Significance	
	0	330	660	1000		L	Q
			Number of periods (n/day)				
GRAZING	8.87	8.75	9.00	8.50	0.11	0.739	0.750
RUM	15.12	14.87	15.25	14.00	0.28	0.363	0.498
IDLE	18.75	18.87	18.62	18.75	0.05	0.957	0.992
TROUGH	3.75	3.25	3.25	3.37	0.12	0.485	0.382
			Time per period (min)				
GRAZING	62.88	67.70	69.38	68.69	1.47	0.272	0.470
RUM	39.16	39.29	37.80	40.10	0.48		
IDLE	18.45	19.53	18.77	22.95	1.27	0.068	0.312
TROUGH	12.48	13.23	13.75	12.39	0.32	0.957	0.293
			Intake per meal				
kg DM	1.57	1.64	1.65	1.58	0.03	0.267	0.651
kg NDF	0.86	0.89	0.90	0.81	0.02	0.711	0.988

SEM - standard error of the mean; L - linear effect; Q - quadratic effect; RUM - rumination, TROUGH - remaining at the trough; ns - not significant.

Table 7 - Mean values of heart rate, respiratory rate, rectal temperature and body surface temperature in cows supplemented with peanut cake

Item	Peanut cake level (g kg^{-1} DM in the supplement)				SEM	Significance	
	0	330	660	1000		L	Q
Heart rate (beats/min)	76.69	75.85	76.71	77.29	0.7552	0.694	0.646
Respiratory rate (mov/min)	34.82	36.43	37.07	37.19	0.4432	0.063	0.401
Rectal temperature (°C)	37.99	38.02	38.05	38.07	0.0628	0.634	0.975
Body surface temperature (°C)	30.77	31.98	30.97	30.52	0.1703	0.584	0.275

SEM - standard error of the mean; L - linear effect, Q - quadratic effect; beats/min - heartbeats in a minute; mov/min - flanking movements in a minute; ns - not significant.

The high temperatures associated with high relative humidity affect the rectal temperature and respiratory rate, and may cause stress (Baêta and Souza, 1997). Because of the high temperatures of tropical regions, animals tend to reduce activities that generate heat to maintain the body temperature, preferring thus to remain idle (Miotto, 2008). However, as shown in Table 7, we can observe that the animals remained within their thermal comfort zone.

Conclusions

Peanut cake originating from biodiesel production can replace up to 100% of soybean meal in supplements for grazing lactating crossbred cows without altering their feeding behavior or negatively influencing their physiological parameters.

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