Italian Journal of Animal Science 2013; volume 12:e42

PAPER

Palm kernel cake for lactating cows in pasture: intake, digestibility, and blood parameters

Raimundo Luiz N.V. Silva,[1]
Ronaldo L. Oliveira,[2] Ossival L. Ribeiro,[2]
André G. Leão,[2] Gleidson G.P. Carvalho,[2]
Ana Carolina Ferreira,[2]
Luís Fernando B. Pinto,[2]
Elzânia S. Pereira[3]

[1]Departamento de Zootecnia, Instituto Federal de Ciência e Tecnologia da Bahia, Brazil
[2]Departamento de Zootecnia, Universidade Federal da Bahia, Brazil
[3]Departamento de Zootecnia, Universidade Federal do Ceará, Brazil

Abstract

Multiparous dairy cows (n=16) of the Holstein x Gir crossbreed, with an average weight of 436.6 kg (±59.7), were tested to determine the best level of Palm kernel cake in a dietary supplement for lactating cows at pasture. The experiment utilized a Latin square design, with the cows distributed in four Latin squares. Intake, digestibility of nutritional fractions, and the metabolic profile, as determined from blood parameters, were analyzed for grazing cattle with a dietary supplement containing 0%, 25%, 50%, and 75% of palm kernel cake. Intake of dry matter, crude protein, ether extract, neutral detergent fibre, nonfibrous carbohydrates, total carbohydrates, and total digestible nutrients within the supplement, as well as the intake of total crude protein, total ether extract, and total nonfibrous carbohydrates, were negatively influenced by level of Palm kernel cake supplementation. The intake of dry matter had the mean values of 11.34 kg/day The intake of crude protein decreased from 1.10 to 0.87 kg/day. The digestibility of dry matter, organic matter, crude protein, nonfibrous carbohydrate, and total carbohydrates was significantly reduced with an increased percentage of Palm kernel cake in the supplement. The concentration of blood glucose was not affected by the amount of Palm kernel cake. However, these averages of urea nitrogen are still considered to be physiological norms. A decrease in intake, digestibility of crude protein and nonfibrous carbohydrates indicates that Palm kernel cake is not an adequate ingredient in nutritional supplements for dairy cows at pasture.

Introduction

The use of vegetation in the production of energy, notably biodiesel, generates a large amount of residual products from processing. These residual products represent a great threat to the environment if alternatives from developing technologies regarding the reutilization of these residuals are not found. Palm kernel is a predominant source for use in the production of bio combustibles in tropical regions, the processing of which produces a by-product, namely, Palm kernel cake. The inclusion of Palm kernel cake in the diet of ruminants, for use within milk-producing systems, provides a cheap and abundant ingredient. This considerable potential for the use of Palm kernel cake as an animal nutrition supplement is chiefly due to the crude protein and digestible nutrient content of Palm kernel cake, with average of 14% and 70%, respectively (Rodrigues Filho *et al*., 2001; Correia *et al*., 2011). In particular, it could constitute a vital ingredient for formulating dietary supplements, especially for use within the production of milk at pasture, a situation which is susceptible to seasonal variations in forage supply. However, the use of Palm kernel cake in the composition of dietary supplements for cows in lactation at pasture has not been sufficiently studied. Aspects including the level of ingestion and digestion of palm kernel cake as well as metabolic parameters are not well understood.

The objective of this experiment was to determine the appropriate amount of Palm kernel cake for inclusion within a dietary supplement for lactating cows at pasture.

Materials and methods

Location

The experiment was conducted from the 27th of July to the 27th of August 2009, on the Federal University of Bahia's experimental farm (12° 23'57.51" S, 38° 52' 44.66" W) in the municipality of São Gonçalo dos Campos, Bahia. This site is located 108 km from Salvador, in the north-central region of Bahia and the micro-region of Feira de Santana. The regional climate fluctuates from humid and sub-humid to dry and is classified as As (A denotes a tropical climate in which monthly average temperature exceeds 18°C, and s denotes a dry season with long periods of sun and longer days) according to the climate classification of Wilhelm K ppen.

Corresponding author: Dr. Ronaldo Lopes Oliveira, Universidade Federal da Bahia, Escola de Medicina Veterinária e Zootecnia, Departamento de Produção Animal, 500 Rua Adhemar de Barros, Salvador/BA, 40170-110, Brazil.
Tel. +55.71.32836716.
E-mail: ronaldooliveira@ufba.br

Key words: By-products, Nutritional value, Metabolism, Ruminant nutrition.

Received for publication: 17 April 2012.
Revision received: 26 February 2013.
Accepted for publication: 12 March 2013.

Italian Journal of Animal Science 2013; 12:e42
doi:10.4081/ijas.2013.e42

Animals and experimental handling

Sixteen multiparous dairy cows, of the Holstein x Gir crossbreed, with an average weight of 436.6 kg (±59.7), were used. All cows had given birth between April and July of 2009 and were between the peak and intermediary stage of lactation at the beginning of the experimental period. Ten days before the period of adaptation, the experimental herd was disinfested (Ivermectin at 1% solution) and supplemented with an injected solution of vitamins A, D and E in conjunction with a salt mineral tonic, vitamin B complex, and amino acids. The experimental period was 60 days, divided into four periods of 15 days, of which 11 days were for adaptation and four days were for collection. The cows were distributed among four simultaneous 4 x 4 Latin squares (four treatments x four periods x four animals in each treatment).

The animals were managed in seven paddocks [an area of 1.93 hectares (ha) each and enclosed by electric fences] of Massai grass (*Panicum maximum* cv. Massai) and were managed in a rotational system of five days of grazing followed by 35 days of rest. All of the paddocks had areas of shade with water and mineral supplementation *ad libitum*. The grazing was managed by a variable stocking system, and when necessary, regulatory animals were used to adjust the forage with the intention of providing 8% of live bodyweight in dry mass.

During the experiment, 12 changes between the paddocks were tested, determined by the support and grazing pressure of the pasture, as previously established (Paladines *et al*., 1982). Forage offer was monitored in order to guarantee availability. To calculate the forage availability for consumption, one day prior to entrance and on the day of the exit of the animals from the paddocks, ten squares of 0.25 m^2 were randomly chosen per paddock, the forage was cut at soil level and weighed, and the values were obtained. The difference between the amount of forage at the introduction and exit of the animals was used to determine the rate of the development of the pasture, which was necessary in calculating the adjustment in forage as demonstrated by Paladines *et al.* (1982).

Food and treatments

Ingredients within the dietary supplement were Palm kernel cake, soybean meal, and corn meal while the available forage was *Panicum maximum cv. Massai* (Table 1). The treatments consisted of a dietary supplement with 0, 25, 50, and 75% Palm kernel cake. These inclusion levels were determined by the balancing of the diet, to ensure the adequate levels of protein and energy requirements for lactating cows.

Chemical and percentage composition of ingredients and dietary supplement

The chemical and percentage composition of the dietary supplement data was analysed (Tables 1 and 2).

To determine the fatty acid profile of the supplement, ingredients and forage, the method of Rodrigues-Ruiz *et al*. (1998) was used. The values obtained are expressed in percentage of total fatty acids (FA) (Table 3).

Experimental protocol, data collection, and processing of samples

The dietary supplement was provided at 06:00 and 15:00 hours during milking in quantities of 3.0 kg per day, within the 15 days of each experimental period. Total faecal production was estimated beginning on the fifth day until the morning of the fifteenth day, by supplying 10 g of chromium oxide orally in two daily doses of 5 g (in wraps). During the four days of the collection period, approximately 200 g of feces were collected directly from the rectal ampulla, two times per day, at 6:00 and 12:00 hours on the first day of collection, and in increments of two hours each subsequent day of collection. Eight samples per animal per period were obtained and placed into individually identifiable plastic bags and stored at -20°C. Prior to the analysis, the faecal samples were thawed and dried in a chamber at 55°C. After drying, the samples were ground (1 mm), analyzed as a level of chrome in a spectrophotometer by atomic absorption, according to the method of Williams *et al*. (1962).

Indigestible neutral detergent fibre (iNDF) was used as an internal indicator of the measure of intake as demonstrated by Cochran *et al*. (1986). For this method, two castrated bulls of the Taurus x Zebu crossbreed, with a live average weight of 500 kg (±22), fistulated in the rumen and fed with Tifton 85 hay and a dietary supplement containing Palm kernel cake. Samples (ingredients of the dietary supplement, forage, and feces) were incubated *in situ* for 144 h. The samples were milled through a 2 mm diameter sieve and were introduced into the rumen, in bags of TNT of 100 g capacity. Between 4 and 5 g of dry matter of sample was placed into the bags, which had a dimension of 11×6 cm.

Determination of the intake and coefficients of digestibility

Intake estimates were obtained by the following equation:

DMI (kg/day) = { [(FP * CIF) - IS]/CIFO } + DMIS

where

DMI, dry matter intake (kg/day);

FP, faecal production (kg/day);

CIF, concentration of faecal iNDF (kg/kgDM);

IS, indicator (iNDF) in the supplement (kg/day);

CIFO, iNDF of the forage (kg/kgDM);

DMIS, dry matter intake of supplement (kg/day).

The coefficients of digestibility (CD) of DM and nutrients were calculated according to Silva and Le o (1979):

CD = [(kg of nutrient intake - kg nutrient excreted)] / (kg of nutrient intake) x 100

On the days on which paddocks were changed, forage samples were collected by simulated grazing, in order to evaluate the forage consumed by animals, assuming that collected material was similar to eaten material. The resulting sample was stored and then assembled into a composite sample for the analysis of the chemical composition and use in studies of degradation.

Blood parameters

On the sixteenth day, blood samples were obtained by puncturing the coccygeal artery or vein in each of the 16 cows in fasting, two, four and six hours after feeding. The samples were collected in 10 mL vacuolated tubes (Vacutainer) containing a gel phase separator for glucose, urea, and urea nitrogen in serum. Immediately after collection, the tubes were chilled until centrifugation at 3500× g for 20 min. The serum obtained was transferred to plastic microtubes, labeled, and stored at -20°C until ready for analysis. Analyses were performed at the Laboratory of Animal Nutrition and Bromatology of the Federal Institute of Science and Technology of Bahia, Catu Campus, Bahia. Testing was conducted using the commercially available Labtest kits by enzymatic colourimetric endpoint in the automated device for blood biochemistry (System of Automatic Biochemistry SBA-200-CELM). The levels of blood urea nitrogen (UN) and glucose (GLY) were determined in a spectrophotometer, under the assumption that urea within blood plasma contains 46% nitrogen.

Chemical-bromatological analysis

Measurements of dry matter (DM), organic matter (OM), total nitrogen, ether extract (EE), neutral detergent fibre (NDF) of food and the remainder and of the feces, in addition to estimates of acid detergent fibre (ADF) and lignin of food, were performed according to Silva and Queiroz (2002). Hemicellulose was calculated as the difference between NDF and ADF and the lignin, determined in 72% H_2SO_4. Values of neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) were determined in the residues obtained after processing the samples with neutral detergent and acid, respectively, following the procedures of Pereira and Rossi J nior (1994), which allow the attainment of neutral detergent fibre free from ash and protein (NDFap). Total carbohydrates (TC) were calculated according to Sniffen *et al*. (1992). Nonfibrous carbohydrates (NFC) were determined according to Weiss (1998), using the calculation NFC (%) = 100 - (%NDFap + %CP + EE + %ash).

Statistical analysis

Data were analyzed using the GLM (General Linear Models) and REG (Regression) procedures (SAS, 2004). The choice of regression models was determined by the degree of adjustment, based on the coefficient of determination (adj-R^2), with the significance of the regression tested by the F test, and the significance of regression coefficients tested using the t-test.

Results and Discussion

Intake

The forage mass during the experiment was, on average, 8.72 kg DM/ha, with an average supply of 8.32% of live bodyweight (BW) in forage DM. The intake of DM and OM (Table 4) were influenced by the percentage of Palm kernel cake (PKC) in the supplement, with the mean values of 11.34 kg/day, 2.5% BW, and 115.14 g/kg$^{0.75}$ for DM and 10.01 kg/day, 2.16 BW, and 100.04 g/kg$^{0.75}$ for OM, respectively. The decrease observed in intake of the palm kernel cake can be explained by the possibly lower palatability and the high fibre content of the pie. The same behaviour of reduction of consumption was observed by other authors such as Macome (2011) and Costa *et al.* (2010), who worked with levels of up to 75% in concentrated feed for calves aged between 60 and 120 days.

The intake of crude protein (CP) decreased in a linear fashion depending on the percentage of Palm kernel cake in the supplement, ranging from 1.10 to 0.87 kg/day, 0.25 to 0.19% BW, and 11.27 to 8.70 g/kg$^{0.75}$. Intake of the dietary supplement was found to decrease significantly with higher percentages of Palm kernel cake. An increase in the percentage of Palm kernel cake in the supplement resulted in decreased intake of CP, and an increase in the intake of EE ranged from 0.30 to 0.40 kg/day.

The intake of DM (Table 4) was influenced by the percentage of Palm kernel cake in the supplement, as opposed to Silva *et al*. (2009), who found that dietary supplementation had no effect on DM intake. This difference could be attributed to the body weight of the cows used in the experiments [437 kg (±59.7) *vs* 520 kg (±40.0)], as heavier dairy cows often exhibit a greater DM intake.

Crude protein intake exhibited a linear decrease that may be attributed to a lower intake of the supplement with the higher percentages of Palm kernel cake. This relationship, in addition to the linear increase in EE intake as the percentage of Palm kernel cake in the supplement increases, is consistent with Rodrigues Filho *et al*. (2001), who attribute the linear relationship between the percentages of Palm kernel cake and the intake of CP, EE and TDN to the inclusion of the outer fibrous layers of the palm fruit in the production of oil and the composition of the Palm ker-

Table 1. Chemical composition of the experimental ingredients and the forage of Massai grass.

	Food used			
	Palm kernel cake	Soybean meal	Corn grain	Forage
Dry matter, %	93.20	89.55	89.26	28.46
Organic matter, % DM	97.87	98.82	98.32	92.50
Ash, % DM	2.13	1.18	1.68	7.50
Crude protein, % DM	9.98	46.64	7.53	6.58
Ether extract, % DM	12.23	5.50	1.34	2.75
NDF, % DM	71.13	16.44	19.52	79.70
NDFap, % DM	63.56	10.54	11.56	75.73
iNDF, % DM	40.82	1.66	9.53	23.32
NIDN (TN%), % DM	46.87	10.04	19.75	21.98
ADF, % DM	55.73	7.18	4.69	38.60
ADIN (TN%), % DM	17.72	3.58	3.94	16.06
Lignin, % DM	17.03	5.91	3.80	12.39
Cellulose, % DM	38.71	1.27	0.89	26.21
Hemicellulose, % DM	7.83	3.36	6.87	37.13
Silica, % DM	0.46	-	-	-
Neutral detergent insoluble ash, % DM	2.84	-	-	-
Nonfibre carbohydrates, % DM	12.10	36.14	79.59	7.73
Total carbohydrates,% DM	68.86	36.23	80.33	76.63

DM, dry matter; NDFap, neutral detergent fibre corrected for ash and protein; iNDF, indigestible neutral detergent fibre; NIDN, neutral detergent insoluble nitrogen; TN%, percentage of total nitrogen; ADF, acid detergent fibre; ADIN, acid detergent insoluble nitrogen; AsDN, neutral detergent insoluble ash.

Table 2. Percentage composition of the dietary supplement.

	Percentage of Palm kernel cake, % DM			
	0	25	50	75
Ingredients, % DM				
Corn grain meal	80.17	59.65	39.14	18.63
Soybean meal	13.99	9.50	5.02	0.53
Palm kernel cake	0.00	25.00	50.00	75.00
Mineral mix	3.00	3.00	3.00	3.00
Urea	2.57	2.57	2.57	2.57
Ammonium sulfate	0.27	0.27	0.27	0.27
Total	100	100	100	100

DM, dry matter.

Table 3. Chemical composition of dietary supplement.

	Palm kernel cake, % DM			
	0	25	50	75
Dry matter, %	89.86	90.88	91.69	92.53
Organic matter, % DM	98.48	98.88	99.28	99.68
Crude protein, % DM	19.96	18.86	17.71	16.56
Ether extract, % DM	1.81	4.36	6.91	9.45
Ash, % DM	1.52	1.12	0.72	0.32
Neutral detergent fibre, % DM	10.79	25.73	40.65	55.57
Indigestible NDF, % DM	7.92	16.10	24.25	32.41
Nonfibre carbohydrates, % DM	71.69	56.13	40.40	24.70
Total carbohydrates, % DM	69.83	68.95	67.92	66.90
Total digestible nutrients, % DM	78.74	75.50	72.07	68.67
Metabolizable energy, Mcal/kg	3.40	3.00	2.60	2.55
Liquid energy lactation, Mcal/kg	2.20	1.92	1.64	1.60

DM, dry matter; NDF, neutral detergent fibre.

nel cake. Intake of NDF, TDN, and TC were not influenced by the percentage of Palm kernel cake in the supplement (P>0.05) while the intake of EE had a positive linear relationship (P<0.05) and NFC had a negative linear relationship with the percentage of Palm kernel cake in the supplement (P<0.05), both behaviours due to the chemical composition of palm kernel cake.

The intake of NFCs with the supplement with the highest percentage of Palm kernel cake (75%) was only 41% of the intake of the dietary supplement with the lowest percentage of Palm kernel cake (0%). Palm kernel cake is considered to have high levels of NDF (71.13%), which is negatively correlated with energy, and therefore, one would expect that the physical mechanisms of satiety would mediate the intake of forage and the supplement. Such a mediating effect was not verified, however, as there was no suppression of overall intake of DM and OM, which may have occurred because the animals are at pasture and in a position to select forage containing a form of NDF that is more easily consumed. The absence of a change in forage NDF intake and the lack of an effect of the percentage of Palm kernel cake in the supplement on TDN uptake support this conclusion.

The NFC, which comprises the fraction of carbohydrates which are more readily available for rumen fermentation, was significantly reduced with the inclusion of Palm kernel cake in the supplement, which reflects the decrease of energy in the diets resulting from the addition of Palm kernel cake. In a study that substituted 20, 40, 60, and 80% DM with PK in a dietary supplement in lactating goats, Andrade Sobrinho (2010) found a linear decrease in the intake of NFC. At the highest level of substitution of Palm kernel cake (80%), NFC intake was found to be only 10% of that at the greatest dietary intake level. Working with various amounts of Palm kernel cake in the diet of sheep, Nunes *et al*. (2011) also found no effects of Palm kernel cake supplementation on the intake of DM, OM, and TDN.

Dry matter intake (DM), crude protein within the supplement (CPs), total crude protein (CPt), ether extract within the supplement (EEs), total ether extract (EEt), neutral detergent fibre within the supplement (NDFc), total nonfibrous carbohydrates (NFCt), total carbohydrate within the supplement (TCs), and total digestible nutrient content within the supplement (TDNs) (Table 5) were influenced by the percentage of Palm kernel cake in the supplement (P<0.05). EE intake increased linearly while the intake of NFC decreased linearly with an increase in the percentage of Palm

Table 4. Average daily intake of dietary fractions expressed in kilograms per day, percentage of live bodyweight and metabolic size for dairy cows at pasture subjected to a dietary supplement containing Palm kernel cake.

	Palm kernel cake, % DM				SEM	P value	
	0	25	50	75		Linear	Quadratic
Dry matter							
kg/day	11.68	11.58	11.32	10.77	0.5661	0.2442	0.6886
% BW	2.63	2.55	2.49	2.33	0.1156	0.0701	0.7675
$g/kg^{0.75}$	120.38	117.01	114.97	108.18	5.1619	0.0998	0.7414
Organic matter							
kg/day	10.28	10.02	9.83	9.90	0.4651	0.5191	0.7282
% BW	2.16	2.21	2.17	2.10	0.1050	0.6062	0.5744
$g/kg^{0.75}$	101.30	101.96	99.75	97.14	4.5803	0.4761	0.7231
Crude protein°							
kg/day	1.10	1.06	0.96	0.86	0.0449	0.0003	0.4900
% BW	0.25	0.24	0.22	0.19	0.0115	0.0002	0.1830
$g/kg^{0.75}$	11.26	10.89	9.97	8.70	0.4109	0.0001	0.2784
Ether extract#							
kg/day	0.30	0.36	0.40	0.40	0.2004	0.0004	0.1067
% BW	0.06	0.08	0.09	0.09	0.0040	0.0001	0.0488
$g/kg^{0.75}$	3.05	3.68	4.13	4.06	0.1814	0.0001	0.0569
Neutral detergent fibre							
kg/day	7.11	7.39	7.78	7.84	0.0413	0.1855	0.7952
% BW	1.60	1.61	1.72	1.70	0.0863	0.3201	0.8289
$g/kg^{0.75}$	73.19	75.04	79.00	78.65	3.9000	0.2497	0.7801
Nonfibre carbohydrates§							
kg/day	2.59	2.19	1.60	1.08	0.0612	0.0001	0.3374
% BW	0.59	0.48	0.35	0.24	0.0171	0.0001	0.8559
$g/kg^{0.75}$	26.74	22.37	16.13	10.84	0.6494	0.0001	0.4824
Total carbohydrates							
kg/day	8.75	8.65	8.47	8.09	0.4415	0.2769	0.7513
% BW	1.94	1.90	1.86	1.76	0.0903	0.1356	0.7832
$g/kg^{0.75}$	90,36	87.94	86.11	81.31	4.0039	0.1112	0.7679
Total digestible nutrients							
kg/day	6.88	6.68	6.49	6.08	0.4050	0.1589	0.8059
% BW	1.55	1.46	1.44	1.31	0.0801	0.3095	0.7859
$g/kg^{0.75}$	71.03	67.83	66.10	61.13	3.6335	0.0683	0.8080

BW, body weight; °$\hat{Y}$=1.118 - 0.0032 PKC, R^2 = 0.9657; $\hat{Y}$=0.26 - 0.00083 PKC, R^2=0.8963; $\hat{Y}$=11.50 - 0.035 PKC, R^2=0.9479; #$\hat{Y}$=0.3140 + 0.00014 PKC, R^2=0.8337; $\hat{Y}$=0.007 + 0.0003 PKC, R^2=0.82; $\hat{Y}$=3.21 + 0.014 PKC, R^2=0.8252; $\hat{Y}$=2.6369 - 0.21 PKC, R^2=99.50; $\hat{Y}$=0.6013 - 0.0047 PKC, R^2=0.9980; $\hat{Y}$=27.11-0.2157 PKC, R^2=0.9960.

kernel cake, which was also observed by Nunes *et al*. (2011) in their study of the inclusion of Palm kernel cake in the diet of sheep. However, a positive linear relationship was found between NDF intake and increasing amounts of Palm kernel cake, which was not observed in this study. The intake of dry matter in the supplement (DMs), crude protein in the supplement (CPs), total crude protein (CPt), ether extract in the supplement (EEs), total ether extract (EEt), neutral detergent fibre in the supplement (NDFs), total nonfibrous carbohydrates (NFCt), total carbohydrates in the supplement (TCs), and total digestible nutrients in the supplement (TDN) (Table 5) were influenced by the percentage of Palm kernel cake in the supplement. Palm kernel cake exhibited an additive effect on these nutritional fractions, by which an increase in Palm kernel cake corresponded to a lower intake of these fractions.

The effect of increasing amounts of Palm kernel cake on EE was in contrast to this finding, as the increase in Palm kernel cake caused an increase in EE ingestion due to the increase in the percentage of supply (Table 3), the proportion of EE in DM intake, and the predominance of saturated fatty acids, which aided in maximizing efficiency of digestion and absorption and the best passage through the posterior digestive tract. The lack of an effect of Palm kernel cake supplementation on the coefficient of digestibility of EE (Table 5) reflects this occurrence.

Coefficients of digestibility

The coefficients of digestibility for dry matter (CDDM), organic matter (CDOM), crude protein (CDCP), nonfibrous carbohydrates (CDNFC), and total carbohydrates (CDTC) were significantly reduced ($P<0.05$) with increased percentages of Palm kernel cake in the supplement. However, the digestibility of ether extract (CDEE) and neutral detergent fibre (CDNDF) were not affected (Table 6), even though the fibre constituents were different compared to corn and soybean (the treatment with 0% of palm kernel cake), with a higher lignin content (Table 1).

Palm kernel cake is a supplemental ingredient with a high content of NDF (71.3%), and iNDF (40.82%) (Table 1). Therefore, a decrease in the digestibility of a diet containing Palm kernel cake at increasing amounts can be expected. CDDM, CDOM, CDCP, CDCNF, and CDCT decreased with the addition of Palm kernel cake while CDEE (73.71%) and CDNDF (55.45%) were not affected. In a study with sheep, Carvalho *et al*. (2006) substituted Tifton hay with 15, 30, and 45% Palm kernel cake and observed no effect on the digestibility of DM, OM, CP, NDF, and TC. This result was in contrast to the observed effects within this study; however, as displayed by this study, CDNDF was not influenced.

There were no significant effects of the level

Table 5. Average intake of dry matter, organic matter, crude protein, ether extract, neutral detergent fibre, nonfibrous carbohydrates, total carbohydrates, total digestible nutrients of the supplement, forage, and total intake in kg/day for lactating cows at pasture supplemented with Palm kernel cake.

	Palm kernel cake, % DM				SEM	P value	
	0	25	50	75		Linear	Quadratic
DMs°	2.69	2.73	2.28	1.66	0.2383	0.0001	0.6960
DMf	8.99	8.85	9.04	9.11	0.1004	0.2857	0.4982
DMt	11.68	11.58	11.32	10.77	0.5661	0.2442	0.6886
OMs#	1.17	1.61	1.56	1.34	0.2383	0.4627	0.0013
OMf§	9.11	8.41	8.27	8.56	0.3508	0.3633	0.0210
OMt	10.28	10.02	9.83	9.90	0.1205	0.5191	0.7282
CPs^	0.50	0.49	0.39	0.27	0.0386	0.0001	0.6947
CPf	0.60	0.57	0.57	0.60	0.0198	0.4936	0.5689
CPt$	1.10	1.06	0.96	0.87	0.0209	0.0003	0.4900
EEs°°	0.05	0.12	0.16	0.16	0.0252	0.0002	0.6212
EEf	0.25	0.24	0.25	0.24	0.0065	0.3652	0.7916
EEt##	0.30	0.36	0.41	0.40	0.0260	0.0004	0.1067
NDFs§§	0.29	0.70	0.93	0.92	0.1480	0.0003	0.5647
NDFf	6.82	6.70	6.86	6.92	0.0882	0.3612	0.4791
NDFt	7.11	7.40	7.79	7.84	0.1097	0.1855	0.7952
NFCs^^	1.93	1.53	0.92	0.41	0.0627	0.0003	0.5891
NFCf	0.67	0.66	0.68	0.67	0.0085	0.2869	0.3244
NFCt$$	2.60	2.19	1.60	1.08	0.0555	0.0001	0.3374
TCs°°°	1.88	1.88	1.55	1.11	0.1602	0.0004	0.2861
TCf	6.87	6.77	6.92	6.98	0.0783	0.4452	0.7652
TCt	8.75	8.65	8.47	8.09	0.1008	0.2769	0.7513
TDNs###	2.12	2.06	1.65	1.14	0.1631	0.0003	0.6319
TDNf	4.76	4.62	4.84	4.94	0.1137	0.5964	0.6716
TDNt	6.88	6.68	6.49	6.08	0.0827	0.1589	0.8059
2RV:C	77:23	76:24	80:20	85:15	-	-	-

DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; NFC, nonfibrous carbohydrates; TC, total carbohydrates; TDN, total digestible nutrients; s, supplement; f, forage; t, total intake. °DMs, $\hat{Y}$ = 2.871 - 0.0142 Palm kernel cake (PKC), R^2 = 0.85; #OMs, $\hat{Y}$ = 1.1852 + 0.0217 PKC - 0.0003 PKC2, R^2 = 0.96; §OMf, $\hat{Y}$ = 9.1043 + 0.0369 PKC - 0.0004 PKC2, R^2 = 0.99; ^CPs, $\hat{Y}$ = 0.5313 - 0.0032 PKC, R^2 = 0.91; $CPt, $\hat{Y}$ = 1.1181- 0.0032 PKC, R2 = 0.96; °°EEs, $\hat{Y}$ = 0.06661 + 0.0015 PKC, R2 = 0.84; ##EEt, $\hat{Y}$ = 0.315 + 0.0014 PKC, R^2 = 0.82; §§NDFs, $\hat{Y}$ = 0.3923 + 0.0085 PKC, R^2 = 0.83; ^^NFCs, $\hat{Y}$ = 1.9725 - 0.0207 PKC, R^2 = 0.99; $$NFCt, $\hat{Y}$ = 2.64 - 0.0206 PKC, R^2 = 0.99; °°°TCs, $\hat{Y}$ = 2.00 - 0.0106 PKC, R2 = 0.87; ###TDNs, $\hat{Y}$ = 2.243 - 0.0134 PKC, R^2 = 0.91. RV:C, relation forage/supplement.

of Palm kernel cake supplementation on CDEE, contrary to that which was observed by Carvalho *et al*. (2006), who found a linear increase in the coefficient of digestibility of EE. CDEE values in both studies were high (73.71 and 80.17%, respectively), which indicated that the pool of lipid components, which comprise this fraction in diets containing Palm kernel cake, display satisfactory levels of digestive utilization. Lauric (C12:O) and palmitic (C16:O) saturated fatty acids together comprise 55.4% of the FA total within Palm kernel cake (Table 7).

A negative correlation was found between intestinal absorption and the amount of saturated fatty acids. Conversely, the intestinal absorption of saturated sources increases in the concomitant presence of intestinal fatty acids (AGI), principally oleic acid (13.85% of FA in Palm kernel cake), according to Lima (2011). According to Chalupa *et al*. (1986), CDEE behaviour may be attributed to an occurrence in which the amount of Palm kernel cake did not affect CDEE because of the greater emulsification effect of FA in the small intestine. This finding has been corroborated by Palmquist and Jenkins (1980), who reported that the emulsification of fats in the intestine of ruminants was dependent on the action of lysolecithin and oleic acid.

Blood parameters

No significant effect of the percentage of Palm kernel cake on glucose (GLY) ($P>0.05$) were found (mean value of 58.75 mg/dL). he relationship between the percentage of Palm kernel cake in the supplement and urea nitrogen (UN) in serum was quadratic ($P<0.05$) (Figure 1).

The average values for UN in serum for supplements with 0, 25, 50, and 75% Palm kernel cake were found to be 12.71, 13.20, 13.09, and 9.6 mg/dl, respectively. The supplement with 75% Palm kernel cake was found to always show the lowest UN concentration.

Post-prandial UN concentrations at 0, 2, 4, and 6 hours (Table 8) had a quadratic relationship with the percentage of Palm kernel cake in the supplement ($P<0.05$), with the values of UN ranging from 13.85 to 9.59 mg/dL.

Dairy cows have a high demand for glucose, which is supplied mainly by gluconeogenesis to maintain an equilibrium in plasma glucose concentrations. Maintenance of blood glucose concentration is related to stability in the concentrations of glucose in ruminants (Freitas J nior *et al*., 2010) and is under rigorous homeostatic control (Herdt, 2000).

The average GLY was found to be 58.75 mg/dL for all of the levels of Palm kernel cake inclusion, which is consistent with bench-

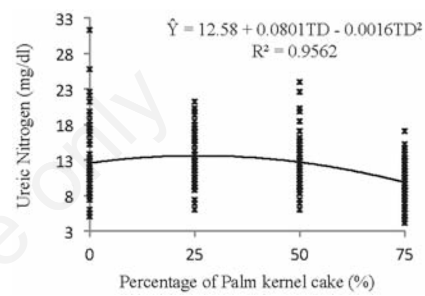

Figure 1. Serum ureic nitrogen (mg/dL) of dairy cows at pasture subjected to supplementation with Palm kernel cake.

Table 6. Apparent coefficients of digestibility for dry matter, crude protein, ether extract, neutral detergent fibre, and nonfibrous carbohydrates of dairy cows at pasture subjected to supplementation with Palm kernel cake.

	Palm kernel cake, % DM				SEM	P value	
	0	25	50	75		Linear	Quadratic
CDDM, %	55.56	53.60	50.0	49.35	1.39	0.0008	0.6286
CDOM, %	61.81	59.60	56.93	54.3	1.46	0.0003	0.8809
CDCP, %	71.00	68.44	68.99	60.98	1.24	0.0001	0.3035
CDEE, %	71.89	71.30	76.93	74.74	2.16	0.1483	0.7127
CDNDF, %	53.88	57.22	55.22	55.86	1.99	0.6625	0.5000
CDNFC, %	66.61	47.93	50.58	36.31	3.26	0.0001	0.5036
CDTC, %	59.62	55.32	55.45	50.95	1.64	0.0009	0.9524

PKC, palm kernel cake; CDDM, apparent coefficient of digestibility for dry matter: $\hat{Y}$=55.46-0.090 PKC R2=0.9406; CDOM, apparent coefficient of digestibility for organic matter: $\hat{Y}$=61.94-0.101 PKC R^2=0.9982; CDCP, apparent coefficient of digestibility for crude protein: $\hat{Y}$=71.78-0.118 PKC R^2=0.7533; CDEE, apparent coefficient of digestibility for ether extract; CDNFC, apparent coefficient of digestibility for nonfibrous carbohydrates: $\hat{Y}$=63.60-0.353 PKC R^2=0.8331; CDTC, apparent coefficient of digestibility for total carbohydrates: $\hat{Y}$=59.22-0.103 PKC R^2=0.8905.

Table 7. Fatty acids profile in palm kernel cake, dietary supplement, and forage, expressed as a percentage of total fatty acids.

	Palm kernel cake	Palm kernel cake levels, % DM				Forage
		0	25	50	75	
Fatty acid fractions, % FA						
Caprylic	3.77	0.05	2.43	4.88	5.39	0.00
Capric	3.48	0.07	2.16	3.90	4.35	0.00
Lauric	47.40	0.46	24.44	39.81	45.49	0.00
Myristic	16.67	0.30	8.53	12.45	14.61	4.29
Palmitic	8.00	12.49	9.24	7.53	7.67	41.82
Stearic	2.86	2.24	4.15	2.61	2.77	6.18
Oleic	13.85	34.74	22.43	15.11	13.73	6.75
Linoleic	2.65	45.05	17.90	8.03	5.04	9.41
α-Linolenic	0.00	0.00	0.00	0.00	0.00	29.95

FA, total fatty acids.

Table 8. ***Post-prandial*** **blood glucose levels at zero, two, four, and six hours of lactating cows at pasture subjected to supplementation with Palm kernel cake.**

	Palm kernel cake, % DM				SEM	P value	
Hours *post-prandial*	0	25	50	75		Linear	Quadratic
0	54.43	53.12	60.25	49.37	3.61	0.4952	0.2385
2	62.50	61.68	63.43	58.18	3.61	0.4903	0.5406
4	64.25	59.12	65.25	60.31	3.61	0.7257	0.9794
6	60.31	51.93	62.56	52.29	3.62	0.4084	0.7946

SEM values are expressed in mg/dL.

marks reported by Rebhun and Chuck (2000) for lactating cows (45.00 to 75.00 mg/dL). Values for GLY in this study were found to be lower than those reported by Freitas Júnior *et al*. (2010) (58.75 and 75.4 mg/dL) in their study that monitored blood glucose levels in dairy cows on a diet supplemented by a lipid. This difference may be attributed to changes in rumen fermentation caused by the use of Palm kernel cake, which could decrease the concentration of rumen propionate that reaches the liver and thereby reduce the stimulation for gluconeogenesis and reduce levels of blood glucose. However, GLY was not found to be influenced by Palm kernel cake supplementation. Glucose is of fundamental importance in energy metabolism in dairy cows, because of the synthesis of lactose, with the major demand occurring in the period after birth, which even surpasses the demand at the peak of lactation (Gandra, 2009).

The average concentration of glucose of 58.75 mg/dL was higher than that observed by Vendramin *et al*. (2006), whose studies with Jersey cows found that average blood glucose concentrations ranged from 47.7 to 48.9 mg/dL; however, both studies fell within the physiological norm as described by Rebhun and Chuck (2000).

The quadratic relationship of UN in serum showed that the relationship between the levels of protein and energy in experimental diets remained balanced, as the concentration of nitrogen of metabolic origin in the blood correlates with the utilization of protein from the diet, the energy intake from the diet, and the interaction between these factors. The supplement containing 75% Palm kernel cake always showed the lowest average concentration of UN. This result may be due to the linear effect of the decrease in intake of CP from the supplement at 75% Palm kernel cake, resulting in a lower net intake and a lower metabolic utilization of CP. *Post-prandial* UN levels at 0, 2, 4, and 6 hours (Table 8) had a quadratic relationship with the Palm kernel cake concentrations, and values ranged from 13.85 to 9.59 mg/dL. These values were smaller than those discovered in dairy cows by Freitas Júnior *et al*. (2010), which had UN values ranging from 19.81 to 13.24 mg/dL. According to Lucci *et al*. (2006), expected values of UN are between 8 and 14 mg/dL, in agreement with the range discovered in this study, while Correia *et al*. (2010) reported concentrations of UN in serum of up to 30 mg/dL in cows fed with palm kernel cake.

The quadratic effect of UN concentration in serum at the collection points after the meal can be attributed to the advance of *post-prandial* time. This is due to the increased absorption of nitrogen, causing a greater concentration within the blood, which may peak two to four hours after a meal. In studying the inclusion of Palm kernel cake at varying levels in the diet of sheep, Nunes *et al*. (2011) observed a quadratic effect of *post-prandial* levels of UN, and the authors attributed this to the advancement of *post-prandial* time.

There was no observable excess or shortage of nitrogenous compounds for maintenance and production through metabolism, as indicated by the values for UN, because the protein intake of cows in this experiment was as expected. However, one must consider that a Holstein x Gir crossbreed was utilized, with a potential production of less than one could expect from a purebred, producing, on average, 9.69 kg of milk at 3.44% fat and 2.84% protein. Concentrations of urea nitrogen vary linearly with the level of milk production (Lucci *et al*., 2006). Therefore, lower yields require a lower demand for nitrogenous compounds within the diet, resulting in less excretion of metabolic by-products.

The values of urea nitrogen observed in this study (13.85 to 9.59 mg/dL) are not related to the occurrence of reproductive problems, since cows with a blood UN level above 19 mg/dL have lower conception rates compared with those with lower blood UN values. It was suggested by Butler (2004) that the excess crude protein or rumen degradable protein could affect the reproduction of cows through an increase in blood UN concentrations. A decrease in conception rate could occur from changes in the endometrium, since the uterine pH would be reduced at higher UN concentrations (Santos, 2005). The metabolic parameters of blood glucose and urea nitrogen remained within normal physiological limits. The predominance of saturated fatty acid intake and EE intake within the supplemented diet was a beneficial result of Palm kernel cake supplementation, as the energy density of the diet was increased with a minimal influence on rumen metabolism, due to the predominance of saturated fatty acids in the small intestine in which animal metabolic systems are integrated. However, because the percentage of Palm kernel cake in the supplement was found to negatively correlate with parameters related to energy, a suppressive effect would be expected on the intake of nutritionally important fractions such as CP and NFC, as well as the coefficients of digestibility for DM, OM, CP, NFC and TC. The high fibre content (NDF, 71.13%) and the expressive content of lignin (17.03%), that comprise a difficult material degradation, associated with the low NFC (12.10%) of Palm kernel cake, create the need for a greater period of residence in the rumen in order to provide a greater degree of breakdown.

Therefore, lower percentages of Palm kernel cake in the supplement result in a greater availability of nutrients.

Conclusions

The decrease in digestibility of nutritionally important fractions such as NFC and CP indicate that Palm kernel cake is not a suitable ingredient in a dietary supplement for lactating cows at pasture. The blood parameters indicate that the inclusion of Palm kernel cake does not influence the energy metabolism of dairy cows at pasture as the observed metabolic levels of blood glucose and urea nitrogen were within the accepted physiological norms.

Thus, the best level of inclusion of palm kernel cake in the supplement to dairy cows on pasture is zero, because any level above this results in depression in digestibility of importants nutritionally fractions and reduces the consumption of concentrate.

References

Andrade Sobrinho, L.E.C., 2010. Palm kernel cake (Elaeis guineensis Jacq.) replacing the supplement based on corn and soybean meal in feed for lactating goats. Degree Diss., Universidade Federal do Reconcavo da Bahia, Brazil.

Butler, W.R., 2006. Relationships of negative energy balance with fertility. Adv. Dairy Technol. 17:35-46.

Carvalho, G.G.P., Pires, A.J.V., Veloso, C.M., Silva, R.R., Mendes, F.B.L., Souza, D.R., Pinheiro, A.A., 2006. Ruminal degradability of concentrate and agroindustrial by-products. Arch. Zootec. 212:397-400.

Chalupa, W., Vecciarelli, B., Elser, A.E., Kronfeld, D.S., Sklan, D., Palmquist, D.L., 1986. Ruminal fermentation in vitro of long chain fatty acids. J. Dairy Sci. 69:1293-1303.

Cochran, R.C., Adams, D.C., Wallace, J.D., Galyean, M.L., 1986. Predicting digestibility of different diets with internal markers: evaluation of four potential markers. J. Anim. Sci. 63:1476-1483.

Correia, B.R., Oliveira, R.L., Jaeger, S.M.P.L., Bagaldo, A.R., Carvalho, G.G.P., Oliveira, G.J.C., Lima, F.H.S., Oliveira, P.A., 2011. Intake, digestibility and ruminal pH os steers fed diets with pies coming from biodiesel to replacement saoybean meal. Arq. Bras. Med. Vet. Zoo. 63:356-363.

Costa, D.A., Ferreira, G.D., Araújo, C.V., 2010. Consumo e digestibilidade de dietas com níveis de torta de dendê para ovinos. Rev. Bras. Saude Prod. Anim. 11:783-792.

Freitas Júnior, J.E., Rennó, F.P., Silva, L.F.P., Gandra, J.R., Maturana Filho, M., Foditsch, C., Venturelli, B.C., 2010. Blood parameters of dairy cows supplemented with different sources of fat. Cien. Rural 40:950-956.

Gandra, J.R., 2009. Evaluation of the use of monensin sodium in diets for dairy cows: productive performance and residues in milk. Degree Diss., University of São Paulo, Brazil.

Herdt, T.H., 2000. Ruminant adaptation to negative energy balance. Vet. Clin. N. Am. 16:215-230.

Lima, L.S., Oliveira, R.L., Bagaldo, A.R., Garcez Neto, A.F., Barbosa, L.P., Borja, M.S., 2011. Composition and fatty acid profile of milk from cows on pasture subjected to licuri oil supplement. Rev. Bras. Zootec. 40:2858-2865.

Lucci, C.S., Valvasori, E., Peixoto Júnior, K., Fontolan, V., 2006. Concentrations of nitrogen in the diet, blood and milk of lactating cows in the postpartum period. Rev. Bras. Zootec. 35:258-263.

Macome, F.M., Oliveira, R.L., Bagaldo, A.R., Araújo, G.G.L., Barbosa, L.P., Silva, M.C.A., 2011. Productive performance and carcass characteristics of lambs fed diets containing different levels of palm kernel cake. Rev. MVZ Cordoba 16:2659-2667.

Nunes, A.S., Oliveira, R.L., Borja, M.S., Bagaldo, A.R., Macome, F.M., Jesus, I.B., Silva, T.M., Barbosa, L.P., Garcez Neto, A.F., 2011. Intake, digestibility and blood parameters of lambs in diets containing palm kernel cake. Arch. Zootec. 60:903-912.

Paladines, O., Lascano, C., 1982. Recomendaciones para evaluar germoplasma ajo pastoreio en pequeños potreros. In: O. Paladines and C. Lascano (eds.) Germoplasma forrageiro bajo pastoreio en pequeñas parcelas. Metodologia de evaliacion. Memórias de una reunion de trabajo celebrada en Cali, Colômbia. CIAT Publ., Cali, Colombia, pp 165-183.

Palmquist, D.L., Jenkins, T.C., 1980. Fat in lactation rations: review. J. Dairy Sci. 63:1-14.

Pereira, J.R.A., Rossi Jr., P., 1994. Manual prático de avaliação de alimentos. Fundação de Estudos Agrarios Luiz de Queiroz Agrarian Publ., Piracicaba, São Paulo, Brazil.

Rebhun, W.C., Chuck, G., 2000. Doenças em vacas de leite. Rocca Publ., São Paulo, Brazil.

Rodrigues Filho, J.A., Camarão, A.P., Azevedo, G.P.C., 2001. Utilização da torta de amêndoa de dendê na alimentação de ruminantes. Embrapa Amazônia Oriental Publ., Belém, Brazil.

Rodrigues-Ruiz, J., Belarbi, H., Sánchez, J.L.G., Alonso, D.L., 1998. Rapid simultaneous lipid extraction and transesterification for fatty acid analyses. Biotechnol. Tech.12:689-691.

Santos, J.E.P., 2005. Efeitos da nutrição e do manejo periparto na eficiência reprodutiva de vacas de leite. pp 29-44 in Proc. 8th Nat. Seminar New approaches in the production and reproduction of cattle, Uberlândia, Brazil.

SAS, 2004. User's guide: statistics, ver. 9.1.2. SAS Inst. Inc., Cary, NC, USA.

Silva, C.V., Lana, R.P., Campos, J.M.S., Queiroz, A.C., Leão, M.I., Abreu, D.C., 2009. Intake, apparent nutrient digestibility and performance of grazing dairy cows fed diets with different concentrate levels and crude protein. Rev. Bras. Zootec. 38:1372-1380.

Silva, D.J., Queiroz, A.C., 2002. Análise de alimentos: métodos químicos e biológicos. UFV Imprensa Universitaria Publ., Viçosa, MG, Brasil.

Silva, J.F.C., Leão, M.I., 1979. Fundamentos da nutrição de ruminantes. Livroceres Publ., Piracicaba, Brasil.

Sniffen, C.J., Connor, J.D., Van Soest, P.J., Fox, D.G., RusselL, J.B., 1992. A net carbohydrate and protein system for evaluation of cattle diets. II Carbohydrate and protein availability. J. Anim. Sci. 70:3562-3577.

Vendramin, L., Roos, T.B., Lima Verde, P.M., Schwegler, E., Goulart, M.A., Quevedo, P.S., Silva, V.M. Del P., Burkert, F.A., Timm, C.D., Gil-Turnes, C., Corrêa, M.N., 2006. Condição metabólica e composição do leite de rebanhos de vacas jersey no sul do Rio Grande do Sul, Brasil. Proc. 15th Nat. Congr. of Scientific Initiation, Pelotas, Brazil. Available from: http://www.ufpel.edu.br/nupeec/anexos/467054f94e.pdf

Weiss, W.P., 1998. Estimating the available energy content of feeds for dairy cattle. J. Dairy Sci. 81:830-839.

Williams, C.H., David, D.J., Ismaa, O., 1962. The determination of chromic oxide in feces samples by atomic absorption spectrophotometry. J. Agr. Sci. 59:381-385.