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Palm (*Elaeis guineensis* L.) kernel cake in diets for dairy cows

Torta de dendê (*Elaeis guineensis* L.) em dietas de vacas leiteiras

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Abstract

The objective of the present study was to assess the effect of different dietary inclusion levels of palm (*Elaeisguineensis* L.) kernel cake (PKC) for lactating dairy cows on feed intake, nutrient digestibility and milk production. Diets containing 0, 113, 228, 342g of PKC/kg dry matter were formulated and fed to eight crossbred (Holandês x Zebu) dairy cows with mean weight of 382kg at 60-90 days of lactation. The cows were used in a double 4 x 4 Latin square design. Each experimental period lasted for 15 days, with 11 days adaptation and four days sampling. Increasing the levels of PKC in the diet reduced the intake of dry matter (DM), crude protein (CP), hemicellulose, non-fibrous carbohydrates (NFC) and total digestible nutrients (TDN). The NDF intake was higher at the 113g/kg PKC inclusion level compared to other treatments. There was linear decreasing effect on fat corrected milk with the inclusion of PKC. There was linear reduction in digestibility of dry matter(DM) and total carbohydrate (TC), but no effect was observed on the NDF and ADF digestibility. Linear increase was observed on crude protein (CP), NFC and ether extract (EE) digestibility. The digestibility of these nutrients probably increased because of the longer retention time of the digest in the rumen caused by reduced DM intake. The addition of PKC decreased the nutritive value of the diets, which subsequently reduced linearly milk production.
Key words: Biodiesel, by-products, milk production, palm kernel cake, digestibility, *Elaeis guineensis L*

Resumo

O objetivo do presente trabalho foi avaliar o efeito da inclusão (0.0; 113,4; 227,8 e 341,7 g/kg de matéria seca) da torta de dendê (TD) em dietas para vacas leiteiras lactantes sobre o consumo, digestibilidade aparente da matéria seca e dos nutrientes e produção de leite. Foram utilizadas oito vacas mestiças Holandês x Zebu, primíparas, com peso médio de 382 kg, entre 60 e 90 dias de lactação, distribuídas em duplos quadrados latinos 4 x 4. Cada período experimental teve duração de 15 dias, sendo 11 dias para adaptação e quatro para coletas. Avaliou- se o consumo, expresso em kg/dia, g/kgpv$0^{,75}$ e g/kg PV, a digestibilidade aparente da matéria seca (MS), proteina bruta (PB), fibra em detergente neutro (FDN), fibra em detergente ácido (FDA), hemicelulose (HEM), carboidratos não fibrosos (CNF), extrato etéreo (EE) e nutrientes digestíveis totais (NDT) e a produção de leite corrigida para gordura (PLCG). A inclusão de níveis crescentes de TD na dieta acarretou redução linear no consumo de MS, PB, HEM, CNF e NDT. O consumo de FDN apresentou efeito quadrático e os maiores valores foram observados com o nível de inclusão de TD de 113,4 g/kg MS. Houve efeito linear decrescente sobre a PLCG com a inclusão da TD. Houve redução linear da digestibilidade da MS e dos CT, porém não se observou

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efeito sobre a digestibilidade da FDN e FDA. Observou-se ainda aumento linear da digestibilidade da PB, CNF e EE. O aumento da digestibilidade destes nutrientes provavelmente ocorreu devido ao maior tempo de retenção da digesta no rúmen ocasionado pela redução no consumo de MS. A adição de TD diminui o valor nutritivo das dietas reduzindo linearmente a produção de leite.
Palavras-chave: Agroindústria, biodiesel, digestibilidade, *Elaeis guineensis L.,* produção de leite, subprodutos, torta de dendê

Introduction

The world is searching hard for renewable fuels to substitute fossil fuels such as petroleum. In Brazil the use of biofuel is widely supported by government laws that stipulate the addition of up to 5% bio oil to diesel oil by 2013. Thus an energy matrix was set up where several oilseeds are used to supply the oil, especially the oil palm (***Elaeis guineensis*** L.). The oil palm was introduced to Brazil more than 400 years ago from West Africa where palm trees are indigenous from Senegal to Angola (EMBRAPA, 2005).

Oil palm is cropped in approximately 15 million hectares with an annual financial turnover around $30 billion and the main producing countries are Malaysia, Indonesia and Nigeria (EMBRAPA, 2005). Although it is an economically important feed, little research has been carried out in Brazil to study various by-products from oil palm processing for lactating dairy cows. When using palm kernel cake obtained by solvent extraction in diet for cattle, Chin (2002) obtained 65.1, 72.7 and 69.7 percent for dry matter (DM), organic matter (OM) and crude protein (CP), digestibility, respectively. Carvalho (2006) replaced Tifton 85 grass hay by palm kernel cake in diet for sheep and concluded that dietary inclusion of palm kernel cake should not exceed 30% of the total dry matter diet. Bringel et al. (2011) assessed replacement levels of elephant grass silage by palm kernel cake in diets for sheep and observed maximum dry matter intake at the level of 37.34, 43 and 37.88% inclusion, measured in g/day, %LW and g/kgLW$^{0.75}$, respectively. According to the author, above these levels, the ether extract content and the type of oil present in the palm kernel cake caused reduction in DM intake.

The objective of the present study was to assess the effects of including PKC in the diet of lactating dairy cows on intake and apparent digestibility of DM, nutrients and milk production.

Material and Methodss

The experiment was carried out at the Veterinary Medicine and Animal Science College of the Federal University of Tocantins, municipality of Araguaína-TO, Brazil, situated in the northern region of Tocantins state at 07º12’28” Latitude South and 48º12’26” Longitude West. Four diets (Table 1) containing 0, 113.4, 227.8 and 341.7g of palm kernel cake (PKC)/kg of DM were assessed using eight crossbred cows (Holandês x Zebu) in a double 4 X 4 Latin square design. The PKC was obtained by mechanical pressing of nuts of the oil palm fruit. The experiment consisted of four 15-day experimental periods, with 11 days for adaptation to the diets and four for data collection (SOARES et al., 2004). Eight primaparas crossbred cows (Holstein x Zebu) averaging, 382kg live weight at 60-90 days lactation (DEL) at the start of the experimental period, were used. The diets (Table 1) were calculated to be isoprotein, with 150g/dry matter and to meet the requirements for maintenance and production of 13kg milk/day, with 3.6% fat, according to the NRC (2001) maintaining a 433:567g/kg DM roughage:concentrate ratio. However, the initial sample of PCK analyzed to formulated the diets contained lower crude protein (CP) concentration than the samples analyzed during the experimental period. So due to this alteration in the PCK composition, the diets presented higher CP levels. Sugarcane (*Saccharum officinarum*) was used as roughage, processed in a forage chopper for 1cm particle size.

Table 1. Proportion of feeds and chemical composition of the experimental diets.

Item	Diets (g/kg DM)			
	0	113.4	227.8	341.7
Foods				
Sugarcane	433.0	433.0	433.0	433.0
Soybean meal	143.2	122.6	113.9	99.7
Ground corn grains	393.4	299.8	194.6	94.9
Palm kernel cake	0.0	113.0	228.0	342.0
Novo bovigold[1]	12.1	12.4	12.2	12.2
Urea+ SA[2] (9:1)	18.3	18.8	18.5	18.5
Chemical Composition				
Dry matter (g/kg DM)	610.2	616.0	619.8	622.5
Crude protein (g/kgDM)	151.5	168.0	170.3	166.4
Neutral detergent fiber (g/kg DM)	387.5	410.1	465.8	517.2
Acid detergent fiber (g/kg DM)	177.8	219.5	268.1	304.7
Hemicellulose (g/kg DM)	184.0	197.1	208.0	216.0
Total carbohydrates (g/kg)	769.8	744.8	733.0	720.8
Non-fibrous carbohydrates (g/kg DM)	420.3	344.5	278.2	228.3
Celullose (g/kg DM)	139.8	169.3	201.4	226.2
Lignin (g/kg DM)	33.0	45.4	61.4	73.7
Lignin/ Neutral detergente fiber[3](g/kg DM)	8.52	11.07	13.18	14.25
Ash (g/kg DM)	45.0	44.6	44.2	43.1
INND[4]	19.17	27.26	35.39	43.50
INAD[4]	9.88	13.69	17.52	23.35
Ether Extract (g/kg DM)	33.7	42.6	52.6	69.7
Calcium (g/kg DM)	6.4	3.6	4.2	5.3
Phosphorous (.g/kg DM)	5.0	2.9	3.2	4.3
Total digestible nutrients (g/kg DM)	726.5	706.1	675.8	669.4

[1]Novo Bovigold (levels/kg product): P-60g; Ca- 200g; Mg- 20g; S-20g; Na- 70g; K-35g; Cu-700mg; I-40mg; Co-15mg; Fe-700mg; Mn-1.600mg; Zn-2.500mg; Se-19mg; Cr-10mg; F-600mg; BHT-0.125g; VitA-200.000UI; VitE- 1.500UI; VitD3-50.000UI; [2]S A – Ammonia sulfate; [3]Lignin participation in the NDF; [4] Expressed in percentage of the total N.
Source: Elaboration of the authors.

The cows were kept in individual 12m² stalls with an earth floor fitted with individual covered feeders and plastic drinkers. The feed was offered as a complete mixture, twice a day (9 a.m. and 5 p.m.), and allowed 5 to 10% leftovers. The quantities of diet offered and the leftovers were recorded daily and sampled and stored in plastic bags for freezing. Compound samples per animal were made for analysis on the four collection days. The roughage (sugarcane) and the concentrated foods (palm kernel cake, corn and soybean meal) were also analyzed individually (Table 2).

After the collection period, the samples were pre-dried in a forced air oven at 55°C for 72 hours, ground in a sieve with 1mm mesh and stored for later analysis.

Dairy cows were milked by hand in the presence of calf, twice a day, at 6:30 a.m. and 4:30 p.m. Before milking, the teats were washed with chlorinated water and dried with paper towel. After milking, the teats were cleaned and sealed with a glycerin and iodine (0.6%) solution (1:1). The somatic cell count (SCC) was monitored every 15 days throughout the experimental period. Variations were observed between 20.060 and 57.3 110 cells/ml but the count remained below 200.000 cells/ml that indicates subclinical mastitis (FONSECA; SANTOS, 2000).

Table 2. Chemical composition of the foods.

Item	Ingredients			
	Corn	**Soybean Meal**	**Palm Kernel Cake**	**Sugarcane**
Dry Matter (g DM/kg)	887.7	872.3	925.4	270.0
Crude Proteín (g/kgDM)	90.6	458.5	154.2	21.5
Neutral detergent fiber (g/kgDM)	149.4	153.9	716.7	560.3
Acid detergent fiber (g/kgDM)	58.2	99.8	441.4	329.1
Hemicellulose (g/kgDM)	91.2	54.1	275.3	231.2
Non-fibrous carbohydrates (g/kgDM)	749.7	293.0	134.7	387.7
Total digestible nutrients (g/kgDM)	871.3	810.7	616.1	634.2
Cellulose (g/kgDM)	47.3	87.4	289.8	256.6
Lignin (g/kgDM)	8.8	10.9	162.3	67.8
Ash (g/kgDM)	15.5	64.1	37.5	24.2
INND[1] (% Total N)	9,50	4,90	80.16	34,00
INDA[2] (% Total N)	3,80	2,81	37,24	18,43
Ether extract (g/kgDM)	42.3	19.1	108.6	24.0
Calcium (g/kgDM)	0.6	2.3	3.4	2.0
Phosphorous (g/kgDM)	3.2	5.8	5.6	0.6

DM – dry matter; [1]INND – Insoluble nitrogen in neutral detergent; [2]INDA – Insoluble nitrogen in acid detergent.
Source: Elaboration of the authors.

Milk production corrected for 4% fat (MPCF) was assessed and recorded using digital scales, during the morning and afternoon milking, from 11^{th} and 15^{th} day of each experimental period. Milk production (MP) corrected for 4% fat (MPCF) was calculated by the equation proposed by the NRC (2001) where: MPCF = 0.4 x (kg milk produced) + 15 x (% fat) x (kg milk produced).

The analyses of DM, ash, ether extract (EE), total nitrogen (TN), neutral detergent fiber (NDF) and neutral detergent fiber corrected for ash and protein (NDF_{ap}), acid detergent fiber (ADF), lignin, calcium and phosphorus in the foods, leftovers and feces were carried out according to Silva and Queiroz (2002). The non-fibrous carbohydrate (NFC) values were obtained using the equation: NFC = 1000 – [(g/kg DM CP – g/kg DM CP of the urea + g/kgDM urea) + NDF_{ap} + g/kgDM EE + g/kgDM ash],(HALL, 2001) and the total carbohydrates were determined using the equation: 1000 – (g/kgDM CP + g/kgDM EE + g/kgDM ashes) according to Sniffen, Oconnor and Van Soest (1992).

The TDN was estimated for the different diets by the equation: $TDN_{OBS} = CP_{digestible} + (EE_{digestible} \times 2,25) + NDF_{digestible} + NFC_{digestible}$ (SNIFFEN; OCONNOR; VAN SOEST, 1992). Intake was determined as the difference between total diet offered and the leftovers (based on the DM).

Dry matter and nutrient digestibility was obtained by indigestible neutral detergent fiber (NDFi), used as an internal indicator from the feces, food and leftover samples. The NDFi was determined according to Cochran et al. (1986). The FDNi levels in the feces and food samples (roughage and concentrate ingredients) and the leftovers were obtained after in situ incubation for 240 hours. After determining the NDF the fecal production of each animal was calculated.

The feces production (FP) was calculated by the formula PF (kg/MS/day) = (intake of FDNi/%FDNi in the feces)*100. The apparent digestibility (AD) of the nutrients was calculated by the formula AD (%) = [(ingested nutrient – excreted nutrient)/ingested nutrient] x 100.

The statistical analyses were carried out using the Statistical Analysis System computer program (SAS, 2007). The regression model was used to test the linear and quadratic effects of palm kernel cake levels included in the diet.

Results and Discussion

The dry matter intake (DM) decreased linearly (P<0.01) with PKC inclusion in the diets (Table 3). It was observed that for each 1g of PKC included in the diets, there was a reduction in the DM of 0.15, 1.72 and 0.3 expressed in kg/day, g/KgLW$^{0.75}$ and g/kg LW, respectively.

Linear reduction in DM intake was also observed by Carvalho (2006) where Tifton-85 grass (*Cynodon dactylon* L.) hay was replaced by PKC in sheep diet. Rodrigues Filho et al. (1996) observed reduction in DM intake in sheep fed diets containing 297g of PKC/kg DM

Contrary to the present study, Bringel et al. (2011), assessed DM intake of diets for sheep when PKC was added to elephant grass silage and observed increase in DM intake up to 373g/kg DM addition level, and after this level intake decreased. After this level, the ether extract content and the type of oil present in the PKC may have caused reduction in DM intake.

DM intake can be affected by EE level in the diet and although the mechanisms are not clear by which this happens, it is known that effects on rumen fermentation, intestinal motility, food acceptability, intestinal hormone release and liver fat oxidation are involved in this process (ALLEN, 2000). The effect of EE on voluntary intake is a function not only of EE level added, but also on its physical form, the type of fat and mineral content of the diet and relative proportion of fiber in the diet (ZEOULA et al., 1995).

Palm oil contains 475g/kg lauric acid (12C) and 164g/kg myristic acid (14C) (HARTLEY, 1977 cited by FURLAN JÚNIOR et al., 2006). According to Palmquist and Mattos (2006) these acids are amphipathic nature, that is, they are soluble in both organic solvents and water and therefore they are more toxic and have high potential to inhibit intake.

EE contents in the diets (Table 1) at the highest PKC levels (inclusion of 227.8 and 341.7g/kg) showed levels (52.6 and 69.7) above the maximum recommended level (50g/kg total diet).

Thus after this level, the lipids may negatively affect nutrient intake, either by regulatory mechanisms that control food intake or by the limited capacity of the rumen to oxidize fatty acids (PALMQUIST; MATTOS, 2006). However, it was observed that the inclusion level of 117.4g/kg PKC (Table 1), the EE contents of the diet was less than 50g/kg DM and the DMI was already decreasing (Table 3), showing that the type of oil present in the PKC may partially explain the linear reduction of DMI.

The increase in the lignin/NDF ratio in the diets (Table 1) as PKC was included may also justify the reduction in DMI as a result of the negative effect of lignin on the extension and principally on the digestion rate of the NDF, that increased the retention time in the reticulum-rumen and consequently reduced NDF intake (JUNG; ALLEN, 1995). Oliveira et al. (2007) observed a similar result to that of the present study when they replaced corn with coffee hulls in diets for dairy cows, where the high lignin participation in the NDF contributed to reducing the DMI.

According to Van Soest (1994), the insoluble nitrogen in neutral detergent (INND), that is however soluble in acid detergent, seems to have considerable digestibility, but this nitrogen has slower digestion rates than the fraction soluble in neutral detergent. Insoluble nitrogen in acid detergent (INAD) corresponds to the C fraction in the CORNELL system and is considered unavailable because it has proteins associated to lignin and tannins. Including PKC raised the INND and INAD contents in the diets (Table 1) thus decreasing the crude protein

(CP) available and may have reduced the DMI because it altered the protein-energy synchronism.

In the present study including PKC incresead the NDF, ADF, lignin, INND and INAD contents in the diets that consequently caused a linear reduction in the TDN content. The low quality of the fiber and reduction in NFC content (Table 1) may have prevented the animals from compensating the low energetic level with greater DMI.

The reduction registered in the DMI has been indicated as the main obstacle to using by-products in diets to dairy cows, due the NDF, ADF, INND, INAD and lignin contents are high. Table 1 shows inclusion PKC raised all these components in the diet, thus justifying reduction in DMI.

CP intake (CPI) decreased linearly ($P<0.01$) with PKC inclusion. For each 1g/kg DM of PKC included in the diets there was a reduction in CPI of 0.002kg/day; 0.025g/KgLW$^{0.75}$ and 0.06g/kg LW (Table 3). A 33% reduction in CP (kg/day) at the level of 341.7g/mg PKC inclusion was shown by regression equation compared to the standard diet.

Although the CP contents of the diet were above the recommended value (150g/mg CP) in the formulation (Table 1), the high INND and INAD contents of PKC may have damaged the protein balance in the rumen and contributed to reduction in microbial protein synthesis and DMI. According to Silva et al. (2005), protein concentration and quality in the diet can affect intake by ruminants.

NDF intake (NDFI) presented quadratic effect ($P<0.05$) and the maximum intake observed by the regression equation (Table 3), in kg/day, g/kgLW$^{0.75,}$ and g/kg LW, with 133g/kg, 158g/kg and 143g/kg PKC inclusion, respectively. The regression equation showed that NDFI was 13.5g/kg LW, at the PKC inclusion level of 143g/kg DM of total diet.

Mertens (1987) reported NDF of 12g/kg LW ±1g LW, for lactating dairy cows, but in Brazil several author have reported FDNI between 13.0 and 17.3g/kg LW (SOARES et al., 2004), probably because of the adaptation of the animals to tropical forage grasses. Thus it is suggested that other factors, but not the NDF content of the diets, maybe acting to reduce the DMI.

Some studies have reported that inclusion of PKC in ruminant diets can reduce the DM intake that would be associated to the low acceptability of PKC by the animals, mainly when Tifton grass 85 hay was substituted with PKC in sheep diet (CARVALHO, 2006). Silva et al. (2000) worked with PKC inclusion levels in concentrate for 62-120 day-old steer and reported that high fiber content of this by-product (70% NDF) and low palatability as causes of reduction in DMI. In the present study, the greater participation of PKC was visible in the leftovers that reinforced a reduction in the DMI caused by its low palatability.

The FDAI was not influenced ($P>0.05$) by PKC inclusion in the diets. PKC inclusion raised the ADF contents of the diets but the animals could probably select the less fibrous components, even though they were presented in the total diet, witch may have contributed to the constant FDAI observed in the present study.

Total carbohydrate (TC) and non-fibrous carbohydrates (NFC) intake decreased linearly ($P<0.01$) with PKC inclusion in the diets (Table 3). For each 1 g of PKC inclusion there was a reduction in the CTI of 0.12, 1.42 and 0.3 in kg/day, g/kg LW$^{0.75,}$ g/kg LW, respectively. This probably occurred due to the reduction in DMI. Including PKC reduced the NFC contents of the diets that justified the reduction in the NFCI.

Table 3. Intake, milk production, regression equations, significances (linear and quadratic) and coefficient of determination (R^2).

Item	Palm kernel cake levels (g/kg)				Regression	Significance		R^2
	0.0	113.4	227.8	341.7		Linear	Quadratic	
kg/day								
DMI[1]	11.82	12.79	9.04	7.21	$\hat{Y}$= 12.85 – 0.15x	0.0001	0.08	0.43
PCI[2]	1.82	2.19	1.54	1.18	$\hat{Y}$ = 1,88+0.02x-0.001x²	0.0006	0.01	0.46
NDFI[3]	4.06	5.12	4.19	3.68	$\hat{Y}$= 4.18+0.08x-0.003x²	0.23	0.03	0.18
ADFI[4]	2.39	2.67	2.38	2.18	$\hat{Y}$ = 2.40	0.47	0.40	Ns
NFCI[5]	5.27	4.62	2.68	1.79	$\hat{Y}$ = 5.44 – 0.10x	0.0001	0.63	0.79
TCI[6]	9.14	9.51	6.66	5.26	$\hat{Y}$ = 9.81 – 0.12x	0.0001	0.12	0.51
EEI[7]	0.43	0.57	0.50	0.51	$\hat{Y}$ = 0.50	0.42	0.19	Ns
TDNI[8]	8.57	9.01	6.10	4.83	$\hat{Y}$ = 9.66 – 0.11x	0.0001	0.10	0.48
g/KgBW$^{0.75}$								
DMI	134.88	145.38	103.56	83.29	$\hat{Y}$ = 146.25 – 1.72x	0.0001	0.06	0.47
CPI	20.80	24.97	17.68	13.64	$\hat{Y}$ = 23.59 – 0.25x	0.0004	0.008	0.35
NDFI	46.30	58.15	48.01	42.52	$\hat{Y}$= 47.64+0.95x-0.03x²	0.23	0.02	0.19
ADFI	27.28	30.29	27.32	25.15	$\hat{Y}$ = 27.51	0.99	0.76	Ns
NFCI	60.14	52.68	30.67	20.69	$\hat{Y}$ = 62.08 – 1.23x	<0.0001	0.64	0.83
TCI	104.32	108.17	76.17	60.76	$\hat{Y}$ = 111.74 – 1.42x	<0.0001	0.10	0.56
EEI	4.91	6.50	5.76	5.90	$\hat{Y}$ = 5.76	0.35	0.17	Ns
TDNI	102.40	108.97	77.47	64.50	$\hat{Y}$ = 110.11 –1.27x	<0.0001	0.08	0.52
g/kg BW								
DMI	30.3	32.7	23.3	1.88	$\hat{Y}$ = 32.9 – 0.3x	<0.0001	0.06	0.48
PCI	4.6	5.6	4.0	3.0	$\hat{Y}$ = 5.3 – 0.06x	<0.0003	0.007	0.35
NDFI	10.4	13.0	10.8	9.6	$\hat{Y}$ = 10.7+0.2x-0.007x²	0.24	0.02	0.19
ADFI	6.1	6.8	6.2	5.7	$\hat{Y}$ = 6.2	0.53	0.43	Ns
NFCI	13.5	11.8	6.9	4.6	$\hat{Y}$ = 13.9 – 0.2x	<0.0001	0.67	0.83
TCI	23.5	24.3	17.1	13.7	$\hat{Y}$ = 25.1 – 0.3x	<0.0001	0.09	0.57
EEI	1.1	1.4	1.3	1.3	$\hat{Y}$ = 1.2	0.33	0.16	Ns
TDNI	22.0	23.0	15.7	12.6	$\hat{Y}$ = 24.7 – 0.2x	<0.0001	0.08	0.53
MPCF (kg/day)	7.85	8.96	7.22	6.86	$\hat{Y}$ = 8.43 – 0.04x	<0.0001	0.08	0.32

[1]- dry matter intake; [2]- crude protein intake, [3]- neutral detergent fiber intake; [4]- acid detergent fiber intake; [5]- non-fibrous carbohydrate intake; [6]- total carbohydrate intake; [7]- ether extract intake; [8]- total digestible nutrients intake; [9]- milk production corrected for 4 % fat.
Source: Elaboration of the authors.

There was no effect (P>0.05) of PKC inclusion on EE intake (EEI) that may explain in part the decrease in the DMI observed. In spite of the increase in EE content as PKC was included in the diets, the EE remained constant. Thus the regulatory effects of fat on DMI may have occurred. When reviewing the factors that regulate intake in ruminants, Silva (2006) emphasized that fat can inhibit fiber digestion in the reticulum-rumen with possible effects on its distention. As fat is a potent cholecystokinin (CCK) stimulator, there is evidence that it contributed to satiety.

TDN intake, expressed in kg/day, g/kgLW$^{0.75}$ and g/kg LW decreased linearly (P<0.01) with PKC inclusion in the diets. For each 1g PKC included there was reduction in TDN of 0.11; 1.27 and 0.2 expressed in kg/day; g/kgLW$^{0.75}$;g/kg LW, respectively. The TDNI at the highest PKC inclusion level (341.7g/kg DM) was 38.9, 39.4 and 27.6% lower when compared to the standard diet for the respective intakes in kg/day, g/kgLW$^{0.75}$ and g/kg LW.

The reduction in TDN was probably one of the factors that interfered in production corrected for fat that decreased linearly with PKC addition (Table 1). The reflection on milk production is one of the main aspects to be observed when assessing by-products in replacement to the conventional foods, because it directly affects the income of the farms. One should further be aware that animals with smaller intakes tend to lose weight and damage the reproductive indices of the herd. In the present study the Latin square design did not permit this type of assessment because of the short period.

DM digestibility (DMD) decreased linearly with PKC inclusion (Table 4) and this reduction may have been due to the high NDF, ADF, lignin, INND and INAD contents observed in the diets containing PKC.

In spite of the reduction in DMD, the values found (Table 4) were considered high compared to the DMI values observed, that showed that the low DMI contributed to the increase in the DMD, due to the possible increase in retention time in the rumen as reported by Ellis et al. (1983), since digestibility is a function of the degradation rates and time that the food is exposed to the rumen microbial activity (DOREAU; DAYWARA, 2003).

CP digestibility (CPD) increased linearly ($P<0.05$) with PKC inclusion in the diet, in spite of the increases in the INND and INAD contents. This result may have occurred due to the probable increase in the rumen retention time of the digest as reported above. Similarly, Bringel et al. (2011), assessed digestibility of diets with increasing PKC levels in sheep and concluded that the high retention of the digest in the rumen resulting from the reduced DMI resulted in best digestibility of the fiber fraction and made the protein more available (complexed to the cell wall).

PKC inclusion did not affect the NDFD and ADFD and mean digestive energy coefficients observed were 0.4792 and 0.4152, respectively. Metabolic factors are probably related to reduction in intake because the fibrous fraction digestibility was not affected by PKC presence. These results are according those reported by Vilela et. al. (2003) when they assessed different supplements in crossbred lactating dairy cows fed with sugarcane. These researchers observed NDF of 0.4621 and ADF of 0.4221 for the treatment containing wheat bran.

The lignin content increased from 33.0g/kg DM in the standard diet to 73.7g/kg DM in the diet containing 341.7g de PKC/kg DM. Thus it was expected that the higher lignin contents would negatively affect fiber digestibility because (SILVA; LEÃO, 1979), stated that the lignin content was negatively related to fiber digestibility.

The non-fibrous carbohydrate digestibility (NFCD) presented quadratic response, with reduction in the digestibility as far as the 11 g/mg DM inclusion level and a slight increase after this level. Although the NFC content in the diets decreased with PKC inclusion, the reduction in DMI resulted in a compensatory effect because with smaller intakes there was high use of the food by the rumen microorganisms, probably because of the highest retention time of the digest in the rumen and thus there was high nutrients digestibility.

Bringel et al. (2011) observed quadratic effect when replaced elephant grass silage by PKC in diets and the NFCD tended to stabilize at levels of 400 and 600g/mg DM PKC. The authors justified these results due to the low dry matter intake at these levels, which resulted in best use of the foods by rumen microorganisms.

The regression equation (Table 4) showed growing linear increase in the ether extract digestibility (EED) from 0.0037 units for each 1g/kg DM of PKC added to the diet, probably associated to the greater retention time of the digest in the rumen. Carvalho (2006) assessed the digestibility of diets with hay replaced by PKC and also observed linear EED response.

Table 4. Coefficient of digestibility of the nutrients, regression equations, coefficient of determination (R^2).

Item	Palm kernel levels (g/kg)				Regression	Significance		R²
	0.0	113.4	227.8	341.7		Linear	Quadratic	
DMD[1]	0.7224	0.6951	0.6701	0.6725	$\hat{Y} = 0.7162 - 0.0015x$	0.01	0.33	0.18
PBD[2]	0.7115	0.7311	0.7509	0.7613	$\hat{Y} = 0.7134 + 0.0014x$	0.04	0.80	0.12
NDFD[3]	0.4655	0.4826	0.4750	0.4940	$\hat{Y} = 0.4792$	0.46	0.96	Ns
ADFD[4]	0.4683	0.4060	0.3800	0.4066	$\hat{Y} = 0.4152$	0.16	0.18	Ns
HEMD[5]	0.4989	0.5612	0.5999	0.6213	$\hat{Y} = 0.5095 + 0.0035x$	0.005	0.50	0.23
NFCD[6]	0.9542	0.9473	0.9542	0.9803	$\hat{Y} = 0.9545 - 0.0014x + 0.00006x^2$	0.02	0.04	0.26
EED[7]	0.8427	0.8930	0.9313	0.9534	$\hat{Y} = 0.8496 + 0.0032x$	00001	0.35	0.50

1- Digestible Dry matter; 2- Digestible Crude protein; 3- Digestible Neutral Detergent fiber; 4- Digestible Acid detergent fiber; 5- Digestible Hemicellulose; 6- Digestible Non-fibrous carbohydrate; 7- Digestible Ether extract
Source: Elaboration of the authors.

Conclusion

Inclusion of palm kernel cake decreased the nutritive value of diets for lactating dairy cows, because of the reduced intake of dry matter and nutrients such as crude protein, non-fibrous carbohydrates and total digestible nutrients, as well as, milk production.

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