Nutritive value of palm kernel meal in diets for growing rabbits

S. Carrión [a], J.C. De Blas [a,*], J. Méndez [b], A. Caídas [a], P. García-Rebollar [a]

[a] *Departament de Producción Animal, Universidad Politécnica de Madrid, E.T.S. Ingenieros Agrónomos de Madrid, Ciudad Universitaria s/n, 28040 Madrid, Spain*
[b] *COREN, Sociedad Cooperativa Galega, Ourense 32003, Spain*

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A B S T R A C T

The aim of this work was to determine the nutritive value of palm kernel meal (PKM) in diets for growing rabbits. In Experiment 1, 20 New Zealand × Californian growing rabbits 50 d-old were used to determine energy, crude protein, fibre and fat digestibility of PKM. The nutritive value was estimated by the difference method using a basal diet and another diet made by substituting 200 g/kg of basal diet with PKM. Energy, crude protein, ether extract and neutral detergent fibre of PKM digestibilities were, respectively, 0.549 (±0.056, SE), 0.541 (±0.069), 0.850 (±0.048) and 0.430 (±0.101), and the digestible energy concentration was 10.9 MJ/kg (±1.03) DM. In Experiment 2, 412 rabbits were allocated at random to the two experimental diets to measure growing performance. Inclusion of 200 g PKM/kg in the diet did not affect feed or digestible energy intake but decreased slightly (by around 5%) average daily gain ($P = 0.003$) and feed efficiency ($P < 0.001$). Neither mortality nor *Clostridium perfringens* counts in soft faeces were affected by type of diet. Palm kernel meal can be considered a palatable source of fibre, protein and fat for rabbits and can substitute significant amounts of other fibrous ingredients in the diet without adverse effects on growth performance.

1. Introduction

Palm kernel meal (PKM) is a high fibrous coproduct of the oil extraction from seeds of *Elaeis guineensis* Jacq. Most of PKM marketed for animal feed is mechanically extracted (expeller procedure). According to FEDNA (2010) it contains 550–650 g/kg of neutral detergent fibre (NDF), 60–90 g/kg of ether extract (EE) and 140–170 g/kg of crude protein (CP), whereas soluble fibre, starch and sugar concentrations are low (Bach-Knudsen, 1997). Therefore, this ingredient is suitable to meet nutrient requirements of highly productive rabbits (De Blas and Mateos, 2010). However, the inclusion of high levels of PKM in the diet increases fibre content that might lead to a higher passage rate of feed and reduced digestibility and feed efficiency. Otherwise, a decrease of starch to fibre ratio because of PKM inclusion in the diet might decrease fattening mortality (Gutiérrez et al., 2002) because of the lower impact of excess of starch on caecal microbiota. In addition, PKM has a high concentration of medium chain fatty acids (MCFA, C8:0-C14:0), that represent around 700 g/kg of the total fat (INRA, 2002; FEDNA, 2010). It has been suggested that the high concentration of rabbit's milk in these fatty acids might contribute

Table 1
Ingredient composition (g/kg) of the basal diet.

Barley	72.4
Wheat	50.0
Wheat bran	273.5
Sugarcane molasses	36.3
Sugar beet pulp	37.5
Soybean hulls	75.0
Grape seed meal	9.7
Wheat straw	22.8
Lucerne meal	200.0
Sunflower meal, 280 g CP/kg	168.7
Soybean meal, 470 CP/kg	15.0
Lard	18.8
Calcium carbonate	7.2
Sodium chloride	5.7
Choline chloride	0.5
Methionine hydroxyl analog	0.9
L-lysine, 500 g	2.5
L-threonine, 990	0.5
Robenidine premix	1.0
Min-vit premix[a]	2.0

[a] Vitamin and mineral premix supplied per kg of complete diet: vitamin A: 11.390 IU; vitamin D_3: 1.360 IU; vitamin E: 47.6 IU; vitamin K_3: 1.7 mg; Thiamine: 1.7 mg; riboflavin: 4.3 mg; pantothenic acid: 13.6 mg; pyridoxine: 1.7 mg; biotin: 85 μg; folic acid: 850 μg; vitamin B_{12}: 13.6 μg; Fe: 47.6 mg; Cu: 17 mg; Zn: 68 mg; Mn: 22.7 mg; Co: 595 μg; Se: 140 μg; I: 1.2 mg.

to explain the protective effect that a delay of weaning exert on rabbit viability. Also, MCFA may reduce *Escherichia coli* O103 (Gallois et al., 2007) and *Clostridium perfringens* (Romero et al., 2009a) proliferation in faeces and caecal contents, respectively. Accordingly, it could be hypothesized that dietary supplementation with PKM might help to reduce diarrhoea incidence during the fattening period.

The objectives of this research were to determine the nutritive value (fibre, protein and energy digestibility) of PKM in diets for growing rabbits and to test the effects of a 200 g/kg dietary inclusion on fattening performance, mortality or proliferation of *C. perfringens* in the hindgut.

2. Material and methods

Animals were handled according to the principles for the care of animals in experimentation published by Boletin Oficial del Estado, BOE (2005).

2.1. Diets

A basal diet (BD) was formulated according to the nutrient recommendations of De Blas and Mateos (2010) for fattening rabbits. Another isonutritive diet (PKMD) was formulated by substituting (wt:wt) 200 g/kg of the basal diet with PKM. Lysine and threonine levels were slightly increased in the basal diet with respect to the requirements to take into account the relatively low content of these amino acids in PKM. The ingredient composition of the basal diet is shown in Table 1. The chemical composition of the sample of PKM used and of the two experimental diets is presented in Table 2. Rabbits had *ad libitum* access to feed and water during the whole trial. Neither feed nor drinking water was medicated with antibiotics. However, a coccidiostat (robenidine) was added to all the experimental feeds.

2.2. Experiment 1

A digestibility trial was conducted according to the European Reference Method (Perez et al., 1995). Twenty New Zealand White × Californian rabbits 50 d-old weighing 1.55 ± 0.13 (SD) kg were used. Animals were allotted randomly to the diets (10 rabbits per diet). Rabbits were housed in metabolism wire cages that allowed separation of faeces and urine.

The rabbits were kept in a closed building with partial environmental control, under a 12–12 h light–dark schedule. Following a 15-d period of adaptation to each diet, feed intake was recorded and total faecal ouput collected during four consecutive days. Faeces produced daily were stored at −20 °C, then dried at 80 °C for 48 h and ground for their analyses. Feeds and faeces were analysed for dry matter (DM), CP, EE, NDF, acid detergent fibre (ADF), acid detergent lignin (ADL), CP insoluble in NDF (NDICP) and gross energy to determine apparent nutrient digestibility. The nutritive value of PKM was calculated by difference between the digestible nutrient contents of the basal and the 200 g PKM/kg diets.

Table 2
Chemical composition of the experimental diets and palm kernel meal (g/kg, as fed basis).

	PKM[a]	BD[b]	PKMD[c]
Dry matter	900	895	907
Ash	44.7	94.8	86.0
Crude protein	162	151	155
ADICP[d]	28.6	7.4	10.2
NDICP[e]	137	34.1	47.6
Starch	10	136	99
Neutral detergent fibre	619	359	416
Acid detergent fibre	312	178	204
Acid detergent lignin	91.2	46.6	53.4
Acid detergent cutin	61.9	15.1	18.9
Crude fibre	172	157	164
Ether extract	63.3	33.9	38.4
Gross energy (MJ/kg)	17.9	16.3	16.8
Lysine[f]	4.80	7.61	7.05
Methionine[f]	2.78	3.44	3.36
Threonine[f]	4.61	6.04	5.82
Calcium	2.04	8.28	7.02
Phosphorous	5.78	5.20	5.47

[a] PKM: palm kernel meal.
[b] BD, basal diet
[c] PKMD, included 800 g BD and 200 g PKM/kg.
[d] Acid detergent insoluble crude protein.
[e] Neutral detergent insoluble crude protein.
[f] Values calculated according to FEDNA (2010).

2.3. Experiment 2

Four hundred and thirty two New Zealand × Californian growing rabbits (originating from strains genetically improved at the Universidad Politécnica of Valencia, Spain) were used. Animals were weaned at 35 d of age, blocked by litter and assigned at random to each experimental diet. Ninety six rabbits (48 per treatment) were housed individually whereas the remaining three hundred and thirty six were caged (600 mm × 500 mm × 300 mm high) in groups of three (56 collective cages per treatment). Experimental conditions were maintained as in Experiment 1. Feed intake and average daily gain of the rabbits from weaning up to 63 d of age were recorded in the individual cages, exclusively. Mortality was controlled daily throughout the experimental period both in individual and collective cages.

Samples of soft faeces were taken from ten rabbits (1.64 ± 0.28 kg) per treatment housed in collective cages two weeks after weaning. To collect soft faeces, rabbits were moved 5 d before to individual metabolism cages and fitted a neck collar which avoided soft faeces ingestion. Collars were made on transparent plastic (33.0 g and 330 mm of diameter on average) and were put from 8:00 to 12:00 a.m. Two consecutive determinations were made, one after a 3-d 50% feeding restriction with respect to previous level of intake and a second after a 3-d *ad libitum* feeding. *C. perfringens* enumeration in soft faeces was performed according to Romero et al. (2009b) in oder to predict the concentration of this bacteria in the caecum. This technique analyses all the toxinotypes of *C. perfringens.*

2.4. Chemical analysis

Procedures of the AOAC (2000) were used to determine the concentrations of DM (934.01), ash (967.05), EE (920.39), and starch (amyloglucosidase-α-amylase method, 996.11). Nitrogen was measured by combustion (method 986.06; AOAC, 2000). Concentrations of NDF, ADF, ADL and acid detergent cutin (ADC) were determined sequentially by using the filter bag system (Ankom Technology, NY) as described by Mertens (2002), AOAC (2000) (procedure 973.187) and Van Soest et al. (1991). The proportion of NDICP and that of CP insoluble in ADF (ADICP) was determined according to Licitra et al. (1996). Gross energy content was measured in an isoperibol bomb calorimeter (Parr 1356, Parr Instrument Co., Moline, IL).

2.5. Statistical analyses

Data of fattening and digestibility trial were analysed as a completely randomised block design with type of diet and litter (block) as main effects by using the General Linear Model (GLM) procedure of SAS. The cage was used as experimental unit in the analysis of the mortality in collective cages. *C. perfringens* counts and fattening mortality data were analysed using generalized linear models with the GENMOD procedure of SAS (SAS Institute, 1990). A paired test was done to compare microbial counts after restriction and after *ad libitum* feeding within each animal.

Table 3
Apparent digestibility coefficients of the experimental diets.

Digestibility coefficient	BD[a]	PKMD[a]	SEM[b]	P
Dry matter	0.584	0.559	0.0043	0.004
Organic matter	0.588	0.564	0.0045	0.006
Gross energy	0.587	0.573	0.0052	0.09
Crude protein	0.738	0.688	0.0070	0.001
Ether extract	0.827	0.859	0.0051	0.002
Neutral detergent fibre	0.240	0.295	0.0080	0.003
Acid detergent fibre	0.136	0.174	0.0091	0.02
Acid detergent lignin	0.085	0.030	0.0084	0.002
NDICP[c]	0.627	0.633	0.013	NS

[a] BD, basal diet; PKMD, basal diet substituted with 200 g/kg of palm kernel meal.
[b] Standard error of means ($n = 10$)
[c] Neutral detergent insoluble crude protein.

The standard error of the nutritive value of PKM estimated by difference was calculated according to the following formula (Villamide, 1996):

$$SE = \frac{1}{SR}\frac{\sqrt{V(PKMD)}}{n_{PKMD}} + \frac{(1-SR)^2\,V(BD)}{n_{BD}}$$

where V(PKMD) and V(BD) are the variances of the values obtained for the basal diet substituted with 200 g PKM/kg and for the basal diet, respectively, SR is the substitution rate of basal diet with PKM and n_{PKMD} and n_{BD} the number of animals fed each diet.

3. Results

3.1. Digestibility trial

Type of diet affected the apparent faecal digestibility of all nutrients studied (Table 3). Substitution of the basal diet with a 200 g PKM/kg decreased ($P < 0.05$) DM, organic matter and CP digestibility and tended ($P = 0.09$) to decrease that of energy, but increased those of ether extract, NDF and ADF. Hemicellulose (estimated as NDF-ADF) and cellulose (as ADF-ADL) digestion efficiencies increased ($P < 0.05$) with PKM inclusion (0.412 vs. 0.342, SD = 0.044; and 0.223 vs. 0.153, SD = 0.079, respectively). Digestibility of NDICP was not modified by PKM inclusion. Litter had a significant effect ($P < 0.05$) on all the nutrient digestibilities, except on that of EE.

The nutritive value of PKM was calculated (Table 4) by difference from the digestibility values of the experimental diets, assuming that no interactions occurred between the basal diet and the supplement. Mean digestible energy (DE) content and gross energy digestibility of PKM were 10.9 MJ/kg DM and 0.549. A high digestion efficiency (0.850) was estimated for the EE content of PKM, whereas those of NDF and CP were low (0.430 and 0.541, respectively). Digestibility of NDICP was close to that of total CP (0.473), which agrees with the high proportion of NDICP on total CP (0.846). Estimated apparent digestibility of hemicelluloses and cellulose was 0.692 (±0.097, SD) and 0.503 (±0.125), respectively.

3.2. Fattening trial

The inclusion of 200 g PKM/kg in the diet did not affect feed and DE intake or mortality, but decreased average daily gain by 4.8% ($P = 0.003$) and feed efficiency by 5.5% ($P = 0.001$) (Table 5). Counts of *C. perfringens* in the soft faces were not affected by dietary PKM but increased ($P < 0.05$) in both treatments when animals were fed *ad libitum* after a feed restriction.

Table 4
Apparent nutrient digestibility (g/g) and digestible energy content (g/kg DM basis) of palm kernel meal determined by difference.

	Mean	SEM[a]
Digestible energy concentration	10.9	1.03
Gross energy digestibility	0.549	0.056
Digestible crude protein content	97.3	11.7
Crude protein digestibility	0.541	0.069
Digestible neutral detergent fibre content	299	50.4
Neutral detergent fibre digestibility	0.430	0.101
Digestible NDICP[b] content	72.0	10.0
NDICP digestibility	0.473	0.077
Digestible ether extract content	59.8	2.51
Ether extract digestibility	0.850	0.048

[a] Standard error of means ($n = 10$).
[b] Neutral detergent insoluble crude protein.

Table 5
Effect of 200 g palm kernel meal inclusion/kg diet on performance and mortality during the fattening period (from 35 to 63 d of age).

	BD[a]	PKMD[a]	S.E.M.[b]	P
Individual cages (48 rabbits/treatment)				
Feed intake (g/d)	144	145	1.80	NS
Digestible energy intake (MJ/d)	1.55	1.54	0.047	NS
Average daily gain (g)	50.0	47.6	0.55	0.003
Feed efficiency (g/g)	0.348	0.329	0.0028	0.001
Mortality (%)	8.33	4.17	–	NS
Collective cages (56 cages and 168 rabbits/treatment)				
Mortality (%)	7.60	6.70	–	NS
Clostridium perfringens counting $\times 10^3$				
After a 3-d 50% feed restriction	1.0	3.2	–	NS
After a 3-d *ad libitum* feeding	89.8	114	–	NS

[a] BD, basal diet; PKMD, basal diet substituted with 200 g/kg of palm kernel meal.
[b] SEM, standard error of means.

4. Discussion

The estimated DE content of PKM (10.9 MJ/kg DM) observed in the current study was slightly lower than values assigned to this ingredient by INRA (2002) tables for feed ingredients (11.6 MJ/kg DM). Digestibility coefficients of nutrients in Table 4 permit to extrapolate the current results to other samples with different chemical composition. Apparent faecal digestibility of CP was low (0.541), and below that of lucerne meal (0.67–0.74, Garcia et al., 1995), which might be related to the high proportion of NDICP on total CP in this ingredient (0.85 vs. 0.16 in lucerne meal). Otherwise, digestibility of NDICP (0.473) was close to that of total CP. It is generally assumed that constituents of NDICP are only digested in non ruminant species through caecal flora fermentation. The current results indicate that rabbits are able to recycle a significant amount of this microbial protein through caecotrophy, an effect that might be especially relevant in feeds like PKM where its high NDICP content is parallel to a small proportion of ADICP on NDICP (0.20). Digestibility of NDF was relatively high (0.430) and above those obtained previously for other highly fibrous feeds (Garcia et al., 1999). Accordingly, estimations of hemicelluloses and cellulose digestibility were high with respect to other fibrous ingredients, although the relatively high degree of lignification of NDF in PKM (0.147). However, a high proportion (0.68) of ADL in this feed ingredient was constituted by ADC, which might have less influence than lignin on fibre digestion efficiency (Van Soest, 1994; Garcia et al., 2002).

High levels of inclusion of PKM (up to 200 g/kg) in the diet did not affect feed intake and only decrease slightly growth rate of the rabbits, provided the diet was balanced in essential amino acids. Otherwise, DE content of PKM slightly overestimated its net energy value, as feed efficiency decreased by 5% when 200 g PKM were included/kg diet in despite of a similar DE intake with respect to the basal diet. This result might be explained by the appreciable digestible NDF content of this ingredient that should increase energy fermentation losses (heat plus methane) in the hindgut.

Mortality was relatively low during the fattening trial. A reduction of starch intake (from 19.6 to 14.3 g/d) plus supplementation with 3 g/kg of MCFA in diets including 200 g PKM/kg had no effect on diarrhoea incidence or *C. perfringens* concentration in soft faeces. A recent review of Blas and Gidenne (2010) concluded the low impact of starch intake on digestive health in growing rabbits. Moreover, MCFA had an *in vitro* bactericidal effect on *C. perfringens* (Skrivanova et al., 2005) and enteropathogenic O103 *E. coli* (Gallois et al., 2008). However, Skrivanova et al. (2008) and Gallois et al. (2008) have failed to demonstrate the *in vivo* protection intake against *colibacillosis* in rabbits supplemented with levels of MCFA (10–20 g/kg) even higher than those used in the current study. Otherwise, a significant increase of *C. perfringens* counts in soft faeces was observed following *ad libitum* feeding after a 50% feed restriction. This result emphasizes the importance of avoiding fasting conditions during the fattening period as those ocurring at weaning. Accordingly, further research is needed to develop feed management practices tending to reduce stress and a drastic reduction in feed intake in the post-weaning period.

In conclusion, PKM is a palatable source of fibre, protein and fat for rabbits that might substitute part of the lucerne meal content in fattening diets. Inclusion levels up to 200 g/kg in balanced diets allow to maintain a high growing performance with neither detrimental nor beneficial further effects derived of its characteristical nutrient composition.

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