New Zealand Society of Animal Production online archive

This paper is from the New Zealand Society for Animal Production online archive. NZSAP holds a regular annual conference in June or July each year for the presentation of technical and applied topics in animal production. NZSAP plays an important role as a forum fostering research in all areas of animal production including production systems, nutrition, meat science, animal welfare, wool science, animal breeding and genetics.

An invitation is extended to all those involved in the field of animal production to apply for membership of the New Zealand Society of Animal Production at our website www.nzsap.org.nz

View All Proceedings | Next Conference | Join NZSAP

The New Zealand Society of Animal Production in publishing the conference proceedings is engaged in disseminating information, not rendering professional advice or services. The views expressed herein do not necessarily represent the views of the New Zealand Society of Animal Production and the New Zealand Society of Animal Production expressly disclaims any form of liability with respect to anything done or omitted to be done in reliance upon the contents of these proceedings.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

You are free to:

Share— copy and redistribute the material in any medium or format

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

NonCommercial — You may not use the material for commercial purposes.

NoDerivatives — If you remix, transform, or build upon the material, you may not distribute the modified material.

http://creativecommons.org.nz/licences/licences-explained/

The apparent digestibility of palm kernel expeller (PKE) consumed by pasture-fed sheep

J.L. BURKE[1], F.N. DIAS[1], D. PACHECO[2], N. LOPEZ-VILLALOBOS[1], and C.W. HOLMES

[1]Institute of Animal, Veterinary and Biomedical Sciences, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand
[2]AgResearch Grasslands, Private Bag 11-008, Palmerston North 4442, New Zealand

ABSTRACT

Palm kernel expeller (PKE) usage in New Zealand has increased despite little being known about its nutritional role as a supplement in pasture based diets. The chemical composition of PKE is often reported in New Zealand, but the digestibility is not. A digestibility study was conducted with twenty four lambs fed one of four different amounts (0, 15, 30 or 45%) of their dry matter (DM) intake as PKE, plus molasses pellets (PKEM; 90% PKE and 10% molasses) with the remainder of the diet being fresh pasture. Sheep were fed at either maintenance or *ad libitum* during two experimental periods, that differed in pasture quality. Digestibilities were extrapolated linearly to estimate digestible energy concentration and the apparent digestibility of DM, crude protein, neutral detergent fibre and gross energy at any intakes for a diet consisting of 100% PKEM. Overall, the estimated apparent digestibility of DM, crude protein, neutral detergent fibre and gross energy for PKEM at intakes of 670 and 1,214 gDM/lamb/day were 63.0, 52.0, 67.0 and 64.0%, respectively. The values estimated for digestible energy concentration (MJ/kgDM) of PKEM ranged between 12.4-12.7, from which values for metabolisable energy concentration of 10.2 and 10.5 MJME/kgDM could be calculated.

Keywords: apparent digestibility; pasture; palm kernel expeller; intake; sheep.

INTRODUCTION

Palm kernel expeller (PKE) is a solid residue of the palm oil industry which has been used increasingly as a supplement for diets of grazing dairy cows in New Zealand. As a consequence of its relatively low cost and ready availability, it has been used primarily to fill immediate short term deficits. The amount of PKE imported into New Zealand has increased from 1,554 tonnes in 2000 to 1.4 million tonnes in 2010 (Ministry of Agriculture and Forestry, 2010). Despite this widespread usage, there is little published information concerning its nutritive value in grazing systems.

Based on the chemical composition of PKE imported into New Zealand, it can be concluded that PKE contains moderate amounts of crude protein (CP; 14-16 g/100 g dry matter; DM) and metabolisable energy (ME, estimated at 11 MJ/kg dry matter by near infra-red spectroscopy) (de Ruiter *et al*., 2007). Additionally its fat content of 8 g/100g DM suggests it is produced by mechanical extraction (O'Mara *et al*., 1999; Carvalho *et al*., 2005). However data for chemical composition do not take into account any possible interactions between PKE and the rest of the diet. Most of the published data on PKE comes from studies in which animals consumed base diets of conserved forages. Digestibility of PKE has not been measured for animals consuming pasture.

Overseas studies have reported the *in vivo* organic matter digestibility (OMD) of PKE when mixed with conserved forages such as hay, to be 65% (O'Mara *et al*., 1999), 75% (Moss & Givens, 1994), and 79% (Carvalho *et al*., 2005). *In vitro* procedures have also been used to predict OMD of PKE. However most of the common enzymatic methods underestimate the digestibility of PKE (O'Mara *et al*., 1999). The amount of PKE in the diet could also affect its digestibility as reported by Carvalho *et al*. (2005) who described a positive linear correlation between OMD and the inclusion of increasing amounts of PKE in a diet composed of dehydrated alfalfa.

The objective of this research was to estimate the apparent *in vivo* digestibility of DM, CP, neutral detergent fibre (NDF), and gross energy (GE) and concentration of digestible energy (DE), of PKE when fed with fresh pasture to sheep at maintenance and *ad libitum.*

MATERIALS AND METHODS

An *in vivo* experiment was conducted in two periods at Massey University, Palmerston North, New Zealand from late September until early December 2007. Twenty-four Romney-Suffolk ram lambs, 5-6 months of age and of similar live weight (LW) (29.1 kg ± 2.5), were used in the experiment. During both experimental periods the same 12 lambs were offered one of the four diets with three lambs per diet, comprising freshly-cut pasture and increasing amounts of PKE (0, 15, 30 and 45% of the diet on an as fed basis), fed at either maintenance or *ad libitum*.

The original objective was for the diets to be composed of pasture and PKE only. However, during the pre-trial period most of the lambs experienced difficulties in consuming loose PKE due to its low palatability and small particle size. Therefore, the PKE was offered as a pellet blend composed of 90% PKE and 10% molasses (PKEM). As a consequence the final diets were composed of pasture and PKEM at four different amounts (0, 15, 30 and 45% of the diet on an as fed basis).

Feeds and sampling procedures

Following a pre-trial period, 24 lambs were selected for the experiment, based on their consumption of PKEM. The same lambs were used in both experimental periods, except for two lambs in the pasture-only treatment that were replaced due to ill health, unrelated to the dietary treatments.

After the pre-trial period all lambs were taken off pasture, housed in a large barn, and allocated randomly to individual metabolism crates and introduced to their diets over seven days. Fresh pasture was cut daily between 06:00 h and 07:30 h with a sickle bar mower at a height of approximately 5 cm above ground level. The pasture fed to the lambs in the first and second experimental periods was taken from two different paddocks. At the time of harvesting the pasture appeared to be at a similar stage of maturity and quality. The PKEM pellets offered in both experimental periods was supplied in one batch by Denver Stock Feeds Ltd., Palmerston North.

Approximately 35% of the diet was offered in the morning (09:00 h) and 65% in the afternoon (17:00 h). The morning feed was given to the lambs immediately after being weighed, while the remaining pasture was weighed for each lamb in the morning and the bins kept in a chiller at 4°C until feeding time in the afternoon when PKEM was added. Water was offered *ad libitum.*

On the last day of the adaptation period harnesses were fitted for faecal collection. During the experimental period, the amounts of feed offered, feed refused and faeces excreted were weighed and recorded over a seven-day experimental period, and the lambs weighed at the beginning and at the end of each experimental period.

During both experimental periods, samples of pasture offered were taken daily and duplicate sub-samples used for DM determination. Only two samples of the offered PKEM were taken during the experiment, one from each period. Duplicate sub-samples were used for DM determination where pasture and PKE samples were dried for 48 hours at 100°C.

During each seven-day experimental period the amount of faeces excreted by each lamb were recorded daily before the morning feed and representative aliquots taken from each lamb and stored at -20°C. Prior to analysis, the daily sub-samples of faeces were thawed, mixed proportionally and bulked for each animal and frozen again. Prior to refreezing, a sub-sample of faeces for each animal was taken for DM determination by drying in an oven for 72 hours at 100°C.

Chemical analyses

Pasture offered, pasture refused, and faeces excreted were freeze-dried. Once dried, the feed and faecal samples were ground through a 1mm sieve, and analysed for several components using standard feed test methods (Association of Official Analytical Chemists, 2005). The measurements were total nitrogen (N) (Method 968.06), ash (Method 942.05) and ether extract (EE) (Method 991.36). Results for nitrogen content were expressed as CP where CP = N x 6.25. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were measured by the method of Robertson and van Soest (1981). Gross energy (GE) was measured by adiabatic bomb calorimeter (Gallenkamp, Loughborough, UK).

Statistical analyses

All data were analysed using the MIXED procedures of the statistical analysis system (SAS, 2008; version 9.2).

Daily PKEM DM intake, total daily DM intake (g) and total daily intake adjusted for metabolic live weight ($LW^{0.75}$) (g/g $LW^{0.75}$) in each experimental period and feeding level were analysed using the MIXED procedure with a linear model that included the effects of percentage of PKE in the diet (0, 15, 30 and 45%). Daily PKEM DM intake and total daily DM intake (g) and total daily intake adjusted for metabolic live weight (g/g $LW^{0.75}$) during each experimental period are presented as the mean of three lambs ± standard error.

The digestibility of all dietary components for individual lambs offered 0 to 45% PKE in the diet were analysed using a random regression approach (MIXED procedure) to estimate by extrapolation the apparent digestibility of DM, CP, NDF and GE and concentration of DE of a diet consisting of 100% PKEM. Intake and proportions of PKEM in the diet were used as regressors, with animal as the random component. As a result of pasture quality differing between experimental periods, separate regression equations were obtained for each experimental period. Comparisons between least squares means were made at low or high feeding levels to determine differences between experimental periods.

TABLE 1: Dry matter (DM) content, chemical composition and gross energy content of pasture and PKEM (pellets containing 90% palm kernel expeller and 10% molasses) offered during Period 1 and Period 2.

Component	Period 1		Period 2	
	Pasture	PKEM	Pasture	PKEM
Dry matter (%)	15.4	91.1	20.7	91.1
Crude protein (%)	20.0	15.8	12.9	16.7
Neutral detergent fibre (%)	43.6	66.3	49.2	64.0
Ether extract (%)	3.8	9.1	3.0	9.5
Starch and sugars (%)[1]	22.4	1.6	26.4	2.2
Ash (%)	10.2	7.2	8.5	7.6
Gross energy (MJ/kg)	18.2	19.5	18.0	19.3

RESULTS

Chemical composition

The chemical analyses of pasture and PKEM used in both experimental periods are presented in Table 1. For both experimental periods, the chemical composition of PKEM was similar but there were differences in the quality of the pasture. The pasture harvested in Period 1 was of better quality than the pasture harvested during Period 2 as measured by the lower concentration of NDF and higher concentrations of CP, EE, ash and GE, and higher *in vivo* digestibilities. Actual *in vivo* digestibility values for pasture in Period 1 and Period 2 were 75 and 68 % for DM, 71 and 59% for CP, 80 and 67% for NDF, 72 and 65% for GE and 13.2 and 11.8 MJ/kgDM for DE concentration.

Intake

Daily DM intake in experimental Period 1 and Period 2, expressed as g and g/kg $LW^{0.75}$, are presented in Table 2. In Period 1, lambs fed diets *ad libitum* had a mean intake 1.8 times their metabolisable energy maintenance requirements, while in Period 2 the average intake for the *ad libitum* treatments was 1.5 times their metabolisable energy maintenance requirements. In both periods, for lambs fed at maintenance, no significant differences between diets were found for total DM intake and DM intake adjusted for metabolic live weight. However, in Period 1, for lambs fed *ad libitum*, total DM intake adjusted for metabolic live weight was significantly lower ($P < 0.05$) for the pasture-only diet than for all three diets containing PKEM (Table 2).

During Period 1, average feed refusals were 1% (0.3-3%) and 5% (1-14%) of the feed offered for maintenance and *ad libitum*, respectively, while in Period 2, they were 2% (1-13%) and 28% (11-33%) for maintenance and *ad libitum*, respectively.

Apparent *in vivo* digestibility

The regression equations for the apparent digestibility of dietary components and DE concentration, regressed on DM intake and % PKEM in the diet (Table 3), were used to estimate values for digestibilities and DE/kgDM for the two feeding levels, in both periods. The values for daily DM intakes measured in Period 1 at maintenance (670 g/lamb) and *ad libitum* (1,214 g/lamb; Table 2) were used in all these calculations (Table 4). For PKEM, estimated digestibilities ranged between 61-64% for DM, 49-55% for CP, 65-68% for NDF and 63-66% for GE. Digestible energy concentration

TABLE 2: Dry matter (DM) intake of PKEM (pellets containing 90% palm kernel expeller and 10% molasses; g/day), pasture DM (g/day), total DM intake (g/day and g/kg of metabolic live weight ($LW^{0.75}$)/day) of lambs fed diets containing different amounts of PKEM at maintenance and *ad libitum* in Periods 1 and 2. Each value is the mean of three lambs ± standard error of the mean (SEM). Bolding of P values indicates significance ($P \leq 0.05$).

Intake measurement	Proportion of PKEM in diet				SEM	P value	Proportion of PKEM in diet				SEM	P value
	0%	15%	30%	45%			0%	15%	30%	45%		
	Period 1 - Maintenance						Period 1 – *Ad libitum*					
PKEM DM intake (g/day)	-	133[c]	235[b]	347[a]	15.2	<0.01	-	215[c]	430[b]	608[a]	18.7	<0.01
Pasture DM intake (g/day)	602[a]	566[a]	439[b]	358[c]	15.0	<0.01	1154[a]	1035[b]	819[c]	594[d]	25.3	<0.01
Total DM intake (g/day)	602	699	674	705	32.7	0.10	1154	1250	1249	1202	26.2	0.08
Total DM intake (g/kg $LW^{0.75}$.day)	47.7	50.1	49.2	51.5	0.09	0.09	78.8[b]	86.5[a]	84.6[a]	85.7[a]	1.38	0.01
	Period 2 – Maintenance						Period 2 – *Ad libitum*					
PKEM DM intake (g/day)	-	113[c]	224[b]	330[a]	6.2	<0.01	-	215[c]	389[b]	599[a]	40.1	<0.01
Pasture DM intake (g/day)	831[a]	800[a]	658[b]	510[c]	25.9	<0.01	1333[a]	1096[b]	987[b]	702[c]	59.7	<0.01
Total DM intake (g/day)	831	913	882	840	30.5	0.28	1333	1311	1376	1301	56.7	0.80
Total DM intake (g/g $LW^{0.75}$.day)	58.8	60.6	60.0	57.2	1.34	0.37	82.4	83.3	83.4	82.4	4.17	1.00

[a, b, c, d] Means with different superscripts within rows within periods differ significantly ($P < 0.05$).

TABLE 3: Multiple linear regression equations ± standard error of estimate, for regression of apparent digestibility (%) and digestible energy (DE) concentration (MJ DE/kgDM) of diets containing different amounts of PKEM (pellets containing 90% palm kernel expeller and 10% molasses), and fed at maintenance and *ad libitum* (kg dry matter/day) during two experimental periods. Bolding of P values indicates significance ($P \leq 0.05$).

Period	Regression equation	R^2
	Dry matter digestibility (%)	
1	$Y = 77.7 (\pm 1.6^{\mathbf{P<0.01}}) - 2.4 (\pm 1.5^{P=0.13})$Intake $- 0.12 (\pm 0.02^{\mathbf{P<0.01}})$%PKEM	0.63
2	$Y = 73.1 (\pm 2.0^{\mathbf{P<0.01}}) - 4.4 (\pm 1.7^{\mathbf{P=0.02}})$Intake $- 0.07 (\pm 0.02^{P=0.18})$%PKEM	0.41
	Crude protein digestibility (%)	
1	$Y = 72.9 (\pm 2.4^{\mathbf{P<0.01}}) - 1.6 (\pm 2.4^{P=0.52})$Intake $- 0.20 (\pm 0.04^{\mathbf{P=0.00}})$%PKEM	0.58
2	$Y = 69.7 (\pm 3.2^{\mathbf{P<0.01}}) - 10.1 (\pm 2.8^{\mathbf{P<0.01}})$Intake $- 0.08 (\pm 0.04^{P=0.18})$%PKEM	0.51
	Neutral detergent fibre digestibility (%)	
1	$Y = 83.6 (\pm 1.8^{\mathbf{P<0.01}}) - 3.4 (\pm 1.8^{P=0.07})$Intake $- 0.14 (\pm 0.03^{\mathbf{P<0.01}})$%PKEM	0.68
2	$Y = 71.4 (\pm 2.3^{\mathbf{P<0.01}}) - 3.8 (\pm 2.0^{P=0.74})$Intake $- 0.01 (\pm 0.03^{P=0.84})$%PKEM	0.14
	Gross energy digestibility (%)	
1	$Y = 76.3 (\pm 1.7^{\mathbf{P<0.01}}) - 3.4 (\pm 1.7^{P=0.05})$Intake $- 0.093 (\pm 0.026^{\mathbf{P<0.01}})$%PKEM	0.49
2	$Y = 71.2 (\pm 2.0^{\mathbf{P<0.01}}) - 5.4 (\pm 1.8^{\mathbf{P=0.01}})$Intake $- 0.021 (\pm 0.026^{P=0.46})$%PKEM	0.33
	Digestible energy concentration (MJ kg/DM)	
1	$Y = 13.9 (\pm 0.3^{\mathbf{P<0.01}}) - 0.6 (\pm 0.3^{P=0.06})$Intake $- 0.008 (\pm 0.004^{P=0.09})$%PKEM	0.27
2	$Y = 12.6 (\pm 0.4^{\mathbf{P<0.01}}) - 0.8 (\pm 0.4^{\mathbf{P=0.04}})$Intake $+ 0.007 (\pm 0.005^{P=0.19})$%PKEM	0.30

TABLE 4: Calculated values ± standard error of the mean for apparent *in vivo* digestibility (%) and digestible energy concentration (MJ kg/dry matter) of PKEM (pellets containing 90% palm kernel expeller and 10% molasses) fed at either maintenance or *ad libitum*. Daily intakes used to calculate values for maintenance (670 gDM/lamb) and *ad libitum* (1,214 gDM/lamb) were the average of the intakes of lambs fed in Period 1 (Table 2).

Measurement	Maintenance intake (670 gDM/lamb/day)			*Ad libitum* intake (1,214 gDM/lamb/day)		
	Period 1	Period 2	P value	Period 1	Period 2	P value
Digestibility of:						
Dry matter (%)	64 ± 2	63 ± 2	0.86	63 ± 2	61 ± 2	0.55
Crude protein (%)	52 ± 3	55 ± 4	0.52	51 ± 3	49 ± 3	0.73
Neutral detergent fibre (%)	67 ± 2	68 ± 3	0.73	65 ± 2	66 ± 2	0.75
Gross energy (%)	65 ± 2	66 ± 2	0.81	63 ± 2	63 ± 2	0.93
Digestible energy concentration (MJ kg dry matter)	12.7 ± 0.4	12.8 ± 0.5	0.57	12.4±0.3	12.4 ± 0.4	0.55

was 12.7-12.8 MJ/kgDM at the maintenance intake and 12.4 MJ/kgDM at the *ad libitum* intake.

In Period 1, with pasture of considerably higher digestibility than that of the PKEM, increasing amounts of PKEM in the diet resulted in linear decreases in the apparent digestibility of DM, CP, NDF and GE of the diet ($P < 0.01$). Digestible energy concentration of the diet also decreased similarly. In contrast, in Period 2 with the digestibility of pasture being similar to that of PKEM, the higher amounts of PKEM in the diet had only small and insignificant effects on diet digestibilities, except for DM ($P < 0.05$). In marked contrast to Period 1, DE concentration increased in the diets with increasing amounts of PKEM in Period 2 (Table 3).

DISCUSSION

This appears to be the first experiment carried out to determine the total tract apparent digestibility of PKE chemical components in ruminants consuming a basal diet of fresh pasture. However, because of the inability of the lambs to consume the dry and dusty PKE, it was made into a pellet containing 10% molasses and 90% PKE. This

proved to be palatable. Therefore the digestibility of the dietary components in the PKEM pellet have been determined in this study.

These values (Table 4) indicate that PKEM is a moderate quality feed for ruminants grazing pasture. The estimated values for PKE digestibility were similar to those reported by O'Mara *et al*. (1999), where lambs were fed a maintenance diet containing 50% PKE and 50% grass hay and molasses. In that study digestibilities of PKE were 63.2% for DM, 59.7% for CP, 65.6% for NDF, 64.9% for GE and DE concentration was 13.4 MJ/kgDM. The chemical composition of the PKE was similar to that of the PKEM fed in our study, but with a lower value for EE (7.8 versus 9.3 g/100 gDM) and higher values for NDF (80.0 versus 65.2 g/100 gDM) and GE (20.6 versus 19.4 MJ/kgDM). Moss and Givens (1994) have also published *in vivo* digestibility values of 11 samples of PKE in sheep fed a maintenance diet of 50% PKE and 50% hay. They found considerably higher values for digestibilities of CP, NDF, GE and DE concentration (75.0%, 73.0%, 75.0% and 15.3 MJ/kgDM, respectively) than for the PKEM fed in this experiment. However, the average contents of CP, NDF, EE and GE were also higher (17.2, 68.5 and 10.8 g/100 gDM and 20.9 MJ/kgDM) than those reported here (16.3, 65.2 and 9.3 g/100 gDM and 19.4 MJ/kgDM).

In this study increasing amounts of PKEM in the diet resulted in decreases in digestibility values for all chemical components when fed with high quality pasture in Period 1, but had little effect when fed with lower quality pasture in Period 2. This is mainly due to the fact that the digestibility of PKEM was lower than that of the pasture fed in Period 1, but in Period 2 PKEM and the lower quality pasture had similar values for digestibility. In the study of Carvalho *et al*. (2005), lambs were fed maintenance amounts of diets containing dehydrated alfalfa and increasing amounts of PKE. Their reported digestibility values increased linearly with increasing amounts of PKE. Consequently, DM and NDF digestibility and DE concentration of the PKE were estimated to be 75.8%, 79.1% and 14.8 MJ/kgDM. These are higher than was estimated in this study. The PKE was similar to the PKEM fed in this study (CP, 17.2 g/100 gDM; NDF, 66.5 g/100 gDM; EE, 7.4 g/100 gDM and GE, 19.0 MJ/kgDM), while the dehydrated alfalfa diet contained 17.8 g CP/100 gDM, 42.8 g NDF/100 gDM and 17.1 MJ GE/kgDM. This was similar to the high quality pasture in this study, but *in vivo* DM, OMD, NDF digestibility and DE concentration of the dehydrated alfalfa was lower at 61%, 65%, 51% and 10 MJ/kgDM, respectively. Consequently the overall diet digestibility improved when increasing amounts of PKE were fed.

Despite the difference in pasture quality between the two experimental periods, all the estimated values for digestibility of PKEM in both periods were similar to each other, suggesting they are robust estimates.

The difference in pasture quality between periods allowed the effect of feeding moderate quality PKEM to high and low quality pasture to be examined. As expected feeding a moderate quality supplement such as PKEM, in association with a high quality pasture, resulted in decreases in overall dietary digestibility values. In this situation, even small increments in the inclusion of PKEM had a significant effect on digestibility. In contrast, when PKEM was fed in conjunction with a low quality pasture there was no effect on the overall diets digestibility. Therefore if farmers were to apply this knowledge when feeding PKEM with pasture at different times of the year they would need to consider the effect it would have on the entire diet.

An estimate of the ME content of PKE can be calculated from this data. For most forages and grains the conversion of DE into ME is estimated using a conversion factor of 0.82 (Nicol & Brookes, 2007), therefore the ME for PKEM may be estimated as being between 10.2-10.5 MJME/kgDM. The pellet contained 10% molasses therefore if the ME of molasses is 12.0 MJ/kgDM (de Ruiter, 2007) the ME of PKE alone in this study can be estimated to be 10.0-10.3 MJ/kgDM. This is lower than the value of 13.1 MJ/kgDM calculated by Moss and Givens (1994) and values of 11.0 MJ/kgDM that have been reported in New Zealand (de Ruiter, 2007). While the current *in vivo* digestibility study, using pasture as a basal diet, may provide a better estimate of ME in PKE than those calculated from *in vitro* systems, further work may be required to provide better estimates of ME for different ruminant species.

CONCLUSIONS

Estimates of digestibility values categorise PKEM as a moderate quality feed, which will decrease the overall DE concentration of the diet when supplementing high quality pastures, and may affect animal performance. In practice, PKE is normally used to fill feed deficits when the pasture quantity and quality is low, and as a consequence intake is limited. In those instances, usage of PKE is not likely to adversely affect the DE concentration of the diet, and may even improve it slightly.

REFERENCES

Association of Official Analytical Chemists, 2005. Official methods of analysis of the Association of Official Analytical Chemists. 18th Edition. Horwitz, W. ed. Association of Official Analytical Chemists, International, Gaithersburg, MD, USA.

Carvalho, L.P.F.; Melo, D.S.P.; Pereira, C.R.M.;Rodrigues, M.A.M.; Cabrita, A.R.J.; Fonseca, A.J.M. 2005: Chemical composition, *in vivo* digestibility, N degradability and enzymatic intestinal digestibility of five protein supplements. *Animal Feed Science and Technology* **119**: 171-178.

de Ruiter, J.M.; Dalley, D.E.; Hughes, T.P.; Fraser, T.J.; Dewhurst, R.J. 2007: Types of supplements: their nutritive value and use. *In*: Pasture and supplements for grazing animals. Rattray, P.V.; Brookes, I.M.; Nicol, A.M. eds. New Zealand Society of Animal Production, Hamilton, New Zealand. Occasional Publication Number 14. p. 97-115.

Ministry of Agriculture and Forestry, 2010: Pastoral monitoring report. http://www.maf.govt.nz.

Moss, A.R.; Givens, D.I. 1994: The chemical composition, digestibility, metabolisable energy content and nitrogen degradability of some protein concentrates. *Animal Feed Science and Technology* **47(3-4):** 335-351.

Nicol, A.M.; Brookes, I.M. 2007: The metabolisable energy requirements of grazing livestock. *In*: Pasture and supplements for grazing animals. Rattray, P.V.; Brookes, I.M.; Nicol, A.M. eds. New Zealand Society of Animal Production, Hamilton, New Zealand. Occasional Publication Number 14. p. 151-172.

O'Mara, F.P.; Mulligan, F,J.; Cronin, E.J.; Rath, M.; Caffrey, P.J. 1999: The nutritive value of palm kernel meal measured *in vivo* and using rumen fluid and enzymatic techniques. *Livestock Production Science* **60(2-3)**: 305-316.

Robertson, J.B.; van Soest, P.J. 1981: The detergent system of analysis. *In*: The analysis of dietary fibre in food. James, W.P.T.; Theander, O. eds. Marcel Dekker, New York, USA. p. 123-158.

SAS, 2008: SAS/STAT Software. Release 9.2. SAS Institute Inc., Cary, North Carolina, USA.