J. Trop. Agric. and Fd. Sc. 30(2)(2002): 249–257

Growth performance, mineral balance and metabolic profile of growing Sahiwal Friesian cattle as affected by cocoa pod husks (CPH) levels in palm kernel cake (PKC) based diets

(Prestasi pertumbuhan, imbangan mineral dan profil metabolik lembu Sahiwal Friesian yang membesar dan dipengaruhi oleh aras lenggai koko di dalam diet berasaskan hampas isirung kelapa sawit)

H.K. Wong* and M. Wan Zahari*

Key words: growth, metabolic profile, cattle, palm kernel cake, cocoa pod husks

Abstrak

Keputusan daripada ujikaji prestasi pertumbuhan, keperluan nutrien, imbangan mineral dan profil metabolik bagi lembu Sahiwal Friesian yang membesar dan diberi makan diet hampas isirung kelapa sawit (HIKS) dan lenggai koko (LK) dilaporkan. Pengambilan bahan kering tidak berbeza secara ketara antara perlakuan, manakala pengambilan protein kasar boleh cerna, tenaga metabolisme dan kecekapan penukaran makanan berbeza secara ketara antara perlakuan. Nilai protein kasar boleh cerna, tenaga boleh cerna dan tenaga metabolisme menurun dengan peningkatan aras lenggai koko di dalam diet. Nilai kebolehcernaan ketara (%) bagi tenaga, protein dan Ca berbeza secara ketara antara perlakuan, masing-masing 76.0, 69.2 dan 38.2 bagi perlakuan 1; 63.9, 63.2 dan 25.3 bagi perlakuan 2; dan 58.2, 57.7 dan 15.2 bagi perlakuan 3. Selain K, kebolehcernaan P, Ca, Mg, Na dan S menurun dengan peningkatan kandungan LK di dalam diet.

Berat hidup pada tempoh awal dan pertengahan tidak berbeza dengan ketara antara kesemua perlakuan, manakala berat hidup akhir berbeza secara ketara antara perlakuan 1 dengan 3. Keperluan tenaga metabolisme dan kebolehcernaan protein bagi pertumbuhan adalah lebih tinggi bagi perlakuan 1, manakala keperluan tersebut adalah lebih rendah bagi perlakuan 3 jika dibandingkan dengan pengesyoran oleh Kearl.

Status mineral serum pada ternakan adalah mencukupi. Status serum Ca berbeza secara ketara antara perlakuan, manakala status Na sebaliknya. Kepekatan GGT, AP, GOT, CR, CK dan urea di dalam serum berada dalam julat normal bagi lembu fidlot. Aras serum AP dan CK berbeza secara ketara bagi fasa permulaan dan fasa akhir. Walau bagaimanapun, tidak ada perbezaan yang ketara antara perlakuan bagi serum AP dan CK. Kecuali urea, nilai enzim serum meningkat antara fasa (permulaan dan akhir) bagi semua perlakuan. Dari data prestasi pertumbuhan dan kajian imbangan, aras LK sebanyak 30% dicadangkan pada diet yang berasaskan HIKS.

*Strategic Livestock Research Centre, MARDI Headquarters, Serdang, P.O. Box 12301, 50774 Kuala Lumpur, Malaysia
Authors' full names: Wong Hee Kum and Wan Zahari Mohamed
E-mail: hkwong@mardi.my

Abstract
The results of a study on growth performance, nutrient requirements, mineral balance and metabolic profile of growing Sahiwal Friesian cattle fed PKC and CPH diets were reported. Intake of dry matter was not significantly different between treatments, but ME and DP intake and FCR were significantly different between treatments. The DP, DE and ME values of the treatments decreased with increasing CPH levels in the diets. The apparent digestibility values (%) for energy, protein and Ca were significantly different between treatments and were respectively 76.0, 69.2 and 38.2 for treatment 1; 63.9, 63.2 and 25.3 for treatment 2; and 58.2, 57.7 and 15.2 for treatment 3. Except for K, the digestibility of P, Ca, Mg, Na and S decreased with increasing CPH content in the diet.

There were no significant differences in initial and median liveweights between treatments but final liveweights were significantly different between treatment 1 and 3. The ME and DP requirements for growth were higher in treatment 1, but the requirements were lower in treatment 3 when compared to Kearl's recommendations.

The animals had adequate serum mineral status. There were significant differences in serum Ca status but no significant differences were observed for Na status between all three treatments. The concentration of serum GGT, AP, GOT, CR, CK and urea were within the normal range for feedlot steers. Significant differences in serum AP and CK were observed for the start and end phases within treatments. There were, however, no significant differences in serum AP and CK between treatments. Except for urea, serum enzyme values increased between phases for all treatments. Based on the growth performance and balance trial data, a CPH inclusion of 30% is proposed for PKC based diets.

Introduction

Malaysia is the world's biggest producer of palm oil with a planted area of 3.3 million hectares in 1999. One of the major by-products of the oil palm industry is palm kernel cake (PKC) with a total production of 1 624 134 tonnes in 1999 (Anon. 1999) of which 1 245 493 tonnes (76.7%) was exported. The main export market is the Netherlands which imported 1 072 240 tonnes. Malaysia is also the world's seventh biggest producer of cocoa beans, producing 70 262 tonnes in 2000. Cocoa production peaked in 1990 at 247 000 tonnes (Anon. 2000) and since then has declined. With an extraction rate of 70%, it is estimated that 162 000 tonnes of cocoa pod husks (CPH) are available as feed for ruminant livestock.

The use of PKC and CPH in ruminant feeding systems locally has been widely reported (Bacon and Anselmi 1986; Mustaffa-Babjee et al. 1986; Jalaludin et al. 1991). For the poultry sector, a lot of research interest is being focused on bioconversion of PKC to produce high quality feed with the use of selected fungi strains and microbial enzymes (Noraini et al. 2002). For ruminants, although there are many reports on PKC and CPH nylon bag degradation studies (Miyashige et al. 1987; Wong and Wan Zahari 1992; and Wong et al. 1992), in vivo digestibility studies (Wong and Wan Zahari 1997), there has, however, been very few studies on the effect of these feeds on the mineral balance, metabolic profile and nutrient requirements of growing cattle. The objective of this study was to determine the growth performance, nutrient requirements, mineral balance and metabolic profile of growing cattle fed PKC and CPH based rations.

Materials and methods

Twelve randomly blocked Sahiwal Friesian bull calves (4 animals/treatment) weighing approximately 84 kg were kept in individual pens and fed *ad lib* PKC expeller based rations. The rations on dry matter basis were as follows: Treatment 1 (T1), PKC; Treatment 2 (T2), 70% PKC + 30% CPH and Treatment 3 (T3), 50% PKC + 50% CPH for a period of 125 days. The diets were supplemented with 500 IU vitamin A per kg dry matter. The animals had free access to water and mineral licks for the duration of the experiment. The fresh CPH were collected and kept in a cold room (4 °C) until used. The CPH were chopped into 1–3 cm pieces daily with a cocoa pod crusher and then fed to the cattle. The animals were weighed individually at the beginning, in the middle and at the end of the performance trial.

Daily feed intake of each animal was recorded over the duration of the growth performance period which was also used as the adaptation phase for a digestibility trial. Blood samples were collected into silicone coated 10 mL tubes (20 mL per animal) by jugular puncture from every animal at the start and at the end of the feeding trial. The blood samples were then centrifuged and the serum collected on the same day for later laboratory analysis. The concentration of serum metabolites between phases (start and end) and treatments were compared. Serum minerals were prepared according to the method of Fick et al. (1976) and analysed by ICP emission spectrophotometry. Other serum metabolites (gamma-glutamyl transferase (GGT), alkaline phosphatase (AP), glutamic oxalacetic transaminase (GOT), creatinine (CR), creatine kinase (CK) and urea) were measured with diagnostic kits purchased from Hoffmann La-Roche (Basle).

In the last week of the trial, the total collection procedures were used to measure daily feed intake, feed residue and faecal output. The techniques of the balance trial were as described by Schnieder and Flatt (1975). Mean apparent digestibility coefficients of energy, protein and minerals from the PKC and CPH based rations were determined. Chemical analyses of feed and faecal samples were as those recommended by AOAC (1975). Data were subjected to analysis of variances using SAS (1979).

Results

Fresh CPH is high in moisture content (16.6% DM) and it is thus bulky when fed in this form while palm kernel cake is suitable for use in ruminant feeding systems *(Table 1).* The K content in CPH is very high while adequate in PKC for cattle production. Both PKC and CPH are low in Na content while S content for both feeds are adequate. The P content in CPH is insufficient for cattle maintenance, while P content is adequate in PKC. The Ca and Mg content of both feeds are adequate for moderate cattle production.

There were significant differences ($p < 0.05$) between treatments (T) for digestibility of energy and protein *(Table 2)*. Treatment 1

Table 1. Chemical composition of palm kernel cake and cocoa pod husk (% DM basis)

Feed	DM	GE	CP	P	K	Ca	Mg	Na	S
PKC	91.2	4.193	16.7	0.573	0.795	0.56	0.299	0.068	0.219
CPH	16.6	3.875	8.6	0.093	5.235	0.328	0.419	0.021	0.211

PKC = ADF 52.3%, NDF 78.1%; CPH = ADF 50.2%, NDF 58.6%
GE = Gross energy (Mcal/kg)
The chemical composition of the diets were as follows:
Treatment 1: Similar to PKC
Treatment 2: DM 69.1%, CP 14.3%, GE 4.098 Mcal/kg
Treatment 3: DM 54.1%, CP 12.7%, GE 4.034 Mcal/kg

(T1) had the highest PKC level and the highest digestibility of energy and protein and digestibility decreased with increasing levels of CPH in the diet.

Except for K, the digestibility of P, Ca, Mg, Na and S decreased with increasing CPH content in the diet *(Table 2)*. Digestibility of K and Na was highest for all three treatments indicating high availability of these minerals from PKC and CPH feeds. The Ca content in PKC and CPH showed the lowest digestibility and hence was the least available mineral. The digestibility of Ca was significantly different ($p < 0.05$) between all three treatments. Significant differences ($p < 0.05$) in mineral digestibility were observed for P, K, Ca, Mg, Na and S between T1 and T3. With the exception of Ca, the digestibility of P, K, Mg, Na and S were not significantly different ($p > 0.05$) between T1 and T2. There were significant differences ($p < 0.05$) in the digestibility of Ca, Na and S between T2 and T3.

The nutritive value of the diets on a per kilogramme basis is significantly higher ($p < 0.05$) for T1 than for T2 and T3 *(Table 3)*. The nutritive value of T2 is also significantly higher ($p < 0.05$) than T3. This was reflected in the highest values for digestible protein, DE and ME for T1. Increasing the levels of CPH decreased the nutritive value of the diets.

There were no significant differences ($p > 0.05$) in dry matter intake (DMI) between the treatments *(Table 4)* over the feeding period. However, ADG was significantly higher ($p < 0.05$) in T1 compared to T2 and T3. Intakes of ME and DP, and FCR were significantly different ($p < 0.05$) between all three treatments. There were no significant differences ($p > 0.05$) in initial and median liveweights between treatments but final liveweights were significantly different ($p < 0.05$) between T1 and T3.

Table 2. Apparent digestibility coefficient of nutrients in PKC and CPH based diets in all three treatments

	T1	T2	T3
Energy	76.0x	63.9y	58.2z
Protein	69.2x	63.2y	57.7z
P	64.2x	45.6xy	33.6y
K	85.7x	90.1xy	93.7y
Ca	38.2x	25.3y	15.2z
Mg	48.1x	38.2xy	30.0y
Na	94.8x	89.5x	79.2y
S	62.8x	56.8x	46.3y

x, y, z, significant differences ($p < 0.05$) between treatments

Table 3. Mean nutritive value in all three treatments for SF cattle

	T1	T2	T3
Digestible protein (g/kg)	115.6x	90.2y	73.0z
DE (Mcal/kg)	3.187x	2.621y	2.349z
ME (Mcal/kg)	2.613x	2.149y	1.926z

x, y, z, significant differences ($p < 0.05$) between treatments

Table 4. Growth performance, DMI, feed conversion and ME intake of SF cattle fed PKC and CPH based diets in all three treatments

	T1	T2	T3
Mean DMI (kg/d)	3.50	3.68	3.63
Mean ADG (kg/d)	0.760x	0.691y	0.647y
ME intake (Mcal/d)	8.754x	7.908y	6.998z
FCR	4.61x	5.32y	5.61z
Initial liveweight (kg)	83	84	85
Median liveweight (kg)	130.5	127	125
Final liveweight (kg)	178x	170xy	165y
DP intake (g/d)	387.2x	331.9y	265.3z

x, y, z, significant differences ($p < 0.05$) between treatments

The ME and DP required for growing Sahiwal Friesian cattle is shown in *Table 5* with ME and DP values calculated from Kearl's nutrient requirement equations. To achieve ADG of 0.76 kg, the ME and DP intake for T1 was higher than the Kearl's recommendations. For T2, DP required was higher and ME required was less than the Kearl's recommendations. For T3, the ME and DP required were less than the Kearl's recommendations.

Data on the serum mineral content *(Table 6)* showed that the animals had adequate mineral status. Within treatments, there were significant declines (p <0.05) in P and Ca status between the start and end phase for all three treatments. However, there were no significant differences (p >0.05) between phases within treatments in Mg status. Within all treatments, P and Ca status declined between the start and end phases. There were also significant differences (p

Table 5. Comparison of ME and DP required for growing SF cattle with Kearl's nutrient recommendations in all three treatments

	T1	T2	T3
Mean wt	130.5	127	125
Metabolic wt	38.61	37.83	37.38
Mean ME intake/day (Mcal/d)	8.754	7.908	6.998
ADG (kg/d)	0.760	0.691	0.647
Mean ME intake/$W^{0.75}$ (kcal/ $W^{0.75}$)	226.73	209.04	187.21
Kearl's recommendation			
ME for wt gain (Mcal)	8.5206	7.996	7.678
Difference in ME required (Mcal, %)	+0.233	−0.088	−0.680
(Actual and Kearl's)	(2.74%)	(–1.10%)	(–8.85%)
DP intake (g)	387.2	331.9	265.3
Kearl's recommendation	339.3	320.8	309.2
DP for wt gain (g)			
Difference in DP required	+47.9	+11.1	−43.9
(g, %) (Actual and Kearl's)	(14.1%)	(3.4%)	(–14.2%)

Table 6. Serum mineral status of Sahiwal Friesian cattle fed PKC and CPH based diets in all three treatments

Serum mineral	Phase	T1	T2	T3
P (mg/100 mL)	Start	11.7a	10.9a	11.1a
	End	9.8b	8.5b	8.2b
	Mean	10.7x	9.7y	9.6y
K (mg/100 mL)	Start	36.6a	38.2	37.1
	End	32.1b	36.1	36.5
	Mean	34.3x	37.1y	36.8y
Ca (mg/100 mL)	Start	13.1a	12.4a	12.3a
	End	12.3b	11.4b	9.9b
	Mean	12.7 x	11.9y	11.1z
Mg (mg/100 mL)	Start	2.6	2.8	2.3
	End	3.1	2.4	2.1
	Mean	2.8x	2.6x	2.2y
Na (mg/100 mL)	Start	431	428	439a
	End	420	395	381b
	Mean	425.5	411.5	410.0

a,b significant differences (p <0.05) between phases within treatment
x, y, z significant differences (p <0.05) between treatments

Table 7. Serum enzyme and urea status of Sahiwal Friesian cattle fed PKC and CPH based diets in all three treatments

Serum metabolite	Phase	T1	T2	T3
Gamma-glutamyl transferase (GGT)	Start	11.9	9.2a	8.6
(IU/L)	End	16.7	14.7b	13.1
	Mean	14.3x	11.9xy	10.8y
Alkaline phosphatase (AP)	Start	61.0a	57.3a	64.0a
(IU/L)	End	86.0b	92.0b	89.0b
	Mean	73.5	74.6	76.5
Glutamic oxalacetic transaminase (GOT)	Start	25.2a	26.8	29.1
(IU/L)	End	37.0b	39.7	39.9
	Mean	31.1	33.2	34.5
Creatinine (CR)	Start	1.42a	1.20	1.38
(IU/L)	End	1.60b	1.39	1.55
	Mean	1.51x	1.29y	1.46xy
Creatine kinase (CK)	Start	29.2a	33.6a	30.9a
(IU/L)	End	70.5b	67.8b	65.2b
	Mean	49.8	50.7	48.0
Urea (mg/100 mL)	Start	28.7a	27.3a	29.6
	End	39.5b	35.2b	28.3
	Mean	34.1x	31.2xy	29.0y

a, b significant differences ($p < 0.05$) between phases within treatment
x, y, significant differences ($p < 0.05$) between treatments

<0.05) in Ca status between all three treatments. However, there were no significant differences ($p > 0.05$) between treatments in Na status.

The concentration of serum GGT, AP, GOT, CR, CK and urea were within the normal range for feedlot steers. There were, however, significant differences ($p < 0.05$) in serum AP and CK for the start and end phases within treatments. However, there were no significant differences in serum AP and CK between treatments. Except for urea, serum enzyme values between phases increased for all treatments *(Table 7).*

For serum GGT, only T2 showed significant differences ($p < 0.05$) between phases. T3 had the lowest serum GGT and was significantly different ($p < 0.05$) from T1.

For serum GOT, only T1 showed significant differences ($p < 0.05$) between phases. There were, however, no significant differences ($p > 0.05$) in serum GOT between treatments.

For serum creatinine, only T1 showed significant differences ($p < 0.05$) between phases. T2 had the lowest serum creatinine and was significantly different ($p < 0.05$) from T1.

Serum urea values increased significantly ($p < 0.05$) between the start and end phases for T1 and T2, and declined for T3. Between treatments, T3 had the lowest serum urea and was significantly different ($p < 0.05$) from T1.

Discussion

The chemical composition of PKC and CPH were comparable to data published previously (Jalaludin et al. 1991; Wong et al. 1992; Wong and Wan Zahari 1992, 1997). Although dry matter intake was higher (but not significantly different, $p > 0.05$) in CPH supplemented diets compared to T1, intake of ME was significantly higher in T1 compared to T2 and T3. Animals generally consume feed to satisfy energy requirements first, and higher intake of CPH supplemented diets to achieve higher ME intake may be unlikely due to the bulkiness of CPH which resulted in rumen fill and thus affect further feed intake.

As the recommended dietary level of Na and S are 0.08% and 0.1% (NRC 1984) respectively, the Na contents for both feeds were below the recommended level. Na was highly deficient in CPH and marginally so in PKC, and supplementation is thus required when using these feeds for cattle production. Although CPH is deficient in P content, when included in PKC based diets, there is sufficient P to meet the suggested dietary recommendations of 0.18% (Kearl 1982; NRC 1984).

The decline in digestibility of the energy and protein component of the CPH supplemented treatments was comparable to data reported earlier (Wong and Wan Zahari 1997) and suggest that energy and protein in CPH is less digestible and thus of lower nutritive value than that of PKC.

The digestibility of a mineral rather than the mineral content of a diet is more important in determining mineral availability. Digestibility of minerals in feedstuffs can vary greatly and sources of variation include types of plant, portion of plant fed, stage of maturity and agronomic practices (NRC 1984). Mineral requirements are also influenced by animal factors such as age, weight, type and level of production. Na and K in these feeds have the highest digestibility and thus are highly available to the animal. The higher digestibility of K with increasing CPH levels in the diet suggests that K in CPH is more available than K from PKC.

The digestibility of P, Ca, Mg, Na and S decreased with increasing CPH content in the diet suggesting that these minerals from CPH were less digestible and hence less available compared to PKC. The availability of the minerals from T1 is higher than the values reported earlier (Wong and Moh Salleh 1989) from balance trials in sheep. The difference in Ca balance compared to the earlier study is very large with a reported digestibility value of 6.8%. Significant differences (p <0.05) in Ca digestibility between treatments are reflected in the serum Ca status of the cattle. Ca digestibility was the lowest for all three treatments here, indicating that feed Ca from PKC and CPH is the least available mineral. It is suggested that Ca be supplemented to CPH based diets for long-term production.

Feeding growing cattle diets with higher ME and DP as in T1 resulted in better ADG and FCR compared to T2 and T3. Diets with higher ME and DP may not be the most economical nor the most applicable, and the finishing liveweight in T2 was not significantly different (p >0.05) from T1. A comparison of the actual performance data achieved by growing cattle here and the nutrient requirements as predicted by Kearl's equations showed that T2 was closest to the recommendations. There is an excess of ME and DP of 2.74% and 14.1% respectively for T1 while there is a deficit of 8.85% and 14.2% respectively for T3. Nutrient requirements recommendations are averages taken from many studies and variations from the mean are to be expected. It is suggested that production for T3 can be enhanced with protein supplementation as suggested by earlier studies (Wong and Abu Hassan 1988; Wong and Wan Zahari 1997). The NRC (1984) recommends an ME of 9.048 Mcal/d for 136 kg steer with ADG of 0.68 kg. These recommendations are 3.36% and 14.4% respectively higher than the mean ME intake in T1 and T2. Using the prediction equations of Kearl's, a 136 kg steer with ADG of 0.68 kg would require only 8.358 Mcal/d. It is suggested that from the study here, Kearl's recommendations may be more suitable for growing cross-bred cattle fed PKC and CPH diets.

The mineral status of the growing cattle is within the normal range for feedlot cattle (McDowell 1976; Huntington 1983; Wong and Wan Zahari 1991; Wan Zahari et al. 1995) indicating that the feeding regime used here is more than adequate for production. Mineral status as reflected in blood content of minerals is very useful in detecting deficiencies in cattle (McDowell,

1976) and can enhance livestock feeding management.

There were increases in blood enzymes levels of GGT, AP, GOT, CR and CK for the duration of the feeding trial, but these levels were still well within the normal range for feedlot cattle (Huntington 1983; Tudor and Inkerman 1987; Wong and Wan Zahari 1991). The blood enzymes GGT, CK and CR are biochemical indicators of liver, muscle and kidney functions respectively. Serum GOT is a biochemical indicator of liver and muscle function while AP is a biochemical indicator of liver, bone and gut functions. Feeding PKC and CPH diets over the experimental duration did not cause any deleterious biochemical effects on the cattle. However, the rise in serum enzymes from the start to the end phase is an indication of mild biochemical effects and longer term monitoring of these enzymes would give a clearer picture as to the suitability of these diets for longer feeding periods. Blood urea levels indicate N circulating levels from protein digestion and a decline was observed in the urea status for T3. The decline in serum urea in T3 may suggest inadequate feed protein and the lower protein digestibility of CPH resulting in less available protein for production.

Researchers (Wong and Wan Zahari 1992) have suggested an inclusion level of 50% and 30% PKC in diets for cattle and sheep respectively. Previous studies (Bacon and Anselmi 1986; Wong and Wan Zahari 1997) suggested that CPH inclusion levels could range from 30–50% in diets for ruminants. Based on the growth performance and balance trial data from this study as well as comparisons with Kearl's recommendations, it is suggested that a CPH inclusion level of 30% is more appropriate. Palm kernel cake supplemented with either CPH or other fibrous feeds can be practical rations for feedlot cattle as reported here and by other studies (Mustaffa-Babjee et al. 1986; Bacon and Anselmi 1986; Jalaludin et al. 1991). As the feed value of CPH deteriorate rapidly after harvesting (Wong and Abu Hassan 1988), ways to preserve the feeding value of fresh CPH is necessary (Wong et al. 1988).

References

Anon. (2000). Malaysian cocoa industry in general. Statistics. Malaysian Cocoa Board

—— (1999). Overview of palm oil industry. Annual statistics 1999. Malaysian Palm Oil Board

AOAC (1975). *Official methods of analysis* 12th ed., Assoc. Off. Anal. Chem. 1094 p. Washington D.C.: Assoc. Off. Anal. Chem. Press

Bacon, A. and Anselmi, J. (1986). The utilization of a ration based on cocoa-pod husks by cattle in feedlot. *Proc. 8th Ann. Conf. MSAP*, p. 94 – 6. Serdang: MSAP

Fick, K.R., Miller, S.M., Funk, J.D., McDowell, L.R. and Houser, R.H. (1976). *Methods of mineral analysis for plant and animal tissue*. p. 78. Gainvesville: Univ. of Florida

Huntington, G.B. (1983). Feedlot performance, blood metabolic profile and Ca status of steers fed high concentrate diets containing several levels of calcium. *J. Anim. Sci*. ***56(5):*** 1003–11

Jalaludin, S., Jelan, Z.A., Abdullah, N. and Ho, Y.W. (1991). Recent development in the oil palm by-products based ruminant feeding system. In: *Recent advances on the nutrition of herbivores*, (Ho, Y.W., Wong, H.K., Abdullah, N. and Tajuddin, Z. A., ed.) p. 34 – 44. Serdang: MSAP

Kearl, L.C. (1982). *Nutrient requirements of ruminants in developing countries.* 381 p. Utah: International Feedstuffs Institute Press

McDowell, L.R. (1976). Mineral deficiencies and toxicities and their effect on beef production in developing countries. In: *Beef cattle production in developing countries*. (Smith, A.J., ed.), p. 216–41. Edinburgh: Univ. Edinburgh

Miyashige, T., Abu Hassan, O., Mohd. Jafaar, D., Wong, H.K., Nakagawasai, H., Kamo, M. and Oshio, S. (1987). Utilization of palm press fibre and other agricultural by-products as feeds for ruminants. MARDI-TARC Collaborative Study. 67 p. July 1987

Mustaffa-Babjee, A., Hawari, H. and Rosli, M.R. (1986). Palmbeef: A value added product of palm kernel cake. *Proc. 8th Ann. Conf. MSAP*, p. 92–3. Serdang: MSAP

Noraini, S., Suraini A.A. and Gan, S.H. (2002). Effect of pH and temperature on the production of *B*-mannanase by local fungal isolate (F2). *Proc. 24th Ann. Conf. MSAP*, p. 39–40. Serdang: MSAP

NRC (1984). *Nutrient requirements of beef cattle*. 6th revised ed. National Research Council. Washington DC: National Academy Press

SAS (1979*). SAS users guide*. North Carolina: SAS Institute Inc.

Schnieder, B.H. and Flatt, W.P. (1975). *The evaluation of feeds through digestibility experiments*. Athens: University of Georgia Press

Tudor, G.D. and Inkerman, P.A. (1987). Intensive production of large ruminants on cassava or bagasse based diets. In: *Ruminant feeding systems utilizing fibrous agricultural residues – 1986*. (Dixon, R.M. ed.) p. 83–93. Canberra: IDP

Wan Zahari, M., Wong, H.K. and Nor Ismail, M.S. (1995). Kajian terhadap pemakanan mineral bagi ternakan ruminan di Malaysia. *Laporan MARDI no. 180*. p. 19. Serdang: MARDI

Wong, H.K. and Abu Hassan, O. (1988). Nutritive value and rumen fermentation profile of sheep fed on fresh or dried cocoa pod husk-based diets. *MARDI Res. J.* ***16(2):*** 147–54

Wong, H.K., Abu Hassan, O. and Nantha, K. (1988). The effects of drying, ensilage and alkali treatment on *in vitro* digestibility of cocoa pods. In: *Ruminant feeding systems utilizing fibrous agricultural residues-1987*. (Dixon, R.M. ed.) p. 161–64, Canberra: IDP

Wong, H.K. and Moh Salleh, R. (1989). Mineral balance of solvent extracted palm kernel cake in sheep digestibility trials. *Proc. 12th Ann. Conf. MSAP*, p. 47–51. Serdang: MSAP

Wong, H.K. and Wan Zahari, M. (1991). The Vitamin A and blood metabolites status of steers fed rice straw and oil palm by-products rations. *Proc. 3rd International Symposium on the Nutrition of Herbivores*, p. 101. Serdang: MSAP

—— (1992). Characterisation of oil palm by-products as feeds for ruminants. *Proc. 15th Ann. Conf. MSAP*, p. 58–61. Serdang: MSAP

—— (1997). Nutritive value of palm kernel cake and cocoa pod husks for growing cattle. *J. Trop. Agric. and Fd. Sci.* ***25(1):*** 125–31

Wong, H.K., Zainur, A.S. and Wan Zahari, M. (1992). The effects of *Saccharomyces cerevisiae* on the degradation of cocoa and oil palm by-products in the rumen of Kedah-Kelantan cattle. *Proc. 15th Ann. Conf. MSAP*, p. 83–6. Serdang: MSAP

Accepted for publication on 10 October 2002