Nutritive values of selected Malaysian agricultural by-products commonly used in cattle rations

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Abstract
A total of ten agricultural by-products commonly used in cattle rations in the central and southern regions of Peninsular Malaysia were evaluated. They included broken rice (BR), rice bran (RB), wheat bran (WB), copra cake (CC) , malt barley (MB), wet brewers grain (WBG), tofu by product (TBP), soy sauce by product (SSBP), sago pith (SP) and palm kernel expeller (PKE). All samples were subjected to chemical analyses followed by in sacco digestibility study using 3 adult male fistulated Brahman crossed bulls. SSBP and WBG had highest CP content of 24.62% and 24.25%, respectively. SSBP also had the highest metabolised energy ($p<0.05$) of 17.49 MJ/kg and also the highest sodium content of 3.26%. WP and RB had significantly higher degradation ($P<0.05$) than other samples at 51.02% and 47.85%, respectively, after 12 h in sacco fermentation. At 24 h in sacco fermentation, WP had significantly the highest ($P<0.05$) degradability at 62.53% followed by RB (58.43%), MB (54.72%), and BR (53.37%). At 48 h, BR had the highest degradation ($P<0.05$) of 73.39% compared to all other samples. It was concluded that different protein and energy sources vary in degradability. A proper combination of these feed sources to meet the ruminant nutrient requirements would increase feeding value of the feed formulation.

Keywords : In sacco, locally available feed source, ruminants

Introduction

Malaysia's major agricultural crops such as rice, coconut and oil palm produce many by- products such as broken rice, rice bran, copra cake and palm kernel expeller that could be used as animal feed. By-products such as wheat pollard, brewers grain and malt barley are derived from imported wheat, barley and other grains that are processed locally to produce flour, alcoholic drinks and other products. Such by-products are often sold for animal feeding. The local ruminant industry depends mainly on locally available agricultural by-products such as rice bran, copra cake, palm kernel cake (PKC), oil palm fronds, sago and broken rice in contrast with the non ruminant industry that depends more on imported materials such as corn and soybean meal (Loh, 2002).

Agricultural by-products generally contain higher fibre that can be utilized by ruminants due to the activity of rumen microbes that are able to ferment fibrous materials of lower nitrogen content and nutrient density (Mirzaei-Agsaghali and Maheri-Sis, 2008). Mixed feed which are formulated using these agricultural by-products can enhance growth performance in ruminants, especially in areas with poor forage quality (DelCurto *et al*., 1990a). Copra cake, palm kernel expeller (PKE), soy waste, tofu waste and brewers grain are good protein sources with CP of 21.5 %, 17.9%, 28%, 15.5% and 26.6%, respectively, whereas wheat pollard, broken rice and sago pith are good energy sources with 10.61 MJ/kg, 13.45 MJ/kg and 10.15 MJ/kg, respectively (Yusoff *et al*., 1990).

Besides the price of these by-products vary according to the different regions in Malaysia. PKE, one of the cheapest sources of energy and protein costs about RM 440-500/tonne in Selangor compared to Negeri Sembilan at RM 860 – RM960/tonne and Melaka at RM 900 to RM 1030 per tonne. Brewer’s grain cost RM 90-120 in Selangor compared to Negeri Sembilan RM 150 – 180 per tonne and Melaka of RM 140 to RM 180 per tonne. The cost of feed is subjected to the availability of the materials in the region (Hazwan *et al.*, 2016). The fluctuation of feed cost in different regions requires good feed formulation programs such as a ‘Web-based Ruminant Feed Formulation and Beef Feedlot Decision Support –System’ developed by MARDI to formulate feed by meeting nutrient requirements at least cost (Marini *et al*., 2015). However, it is important to study the nutritive values of these feed materials before a formulation is to be made to further aid decision making in farmers in the choice of feed at the lowest cost to obtain an optimum growth performance.

The feeding values of the ingredients evaluated were compiled earlier by Devendra (1979) and more recently by Yusoff *et al*. (1990). The values of the nutrient composition of these agricultural by-products need to be updated to accommodate with the advancement in agricultural product processing technology. As an example, the oil content of PKE, the most commonly used feed ingredient, is generally valued between 5-8% (Alimon, 2005). However, Tang (2001) reported it to vary from 4.5 to 17.3% This would greatly influence its nutritive value and diet inclusion rates. The nutrient qualities of agricultural by-products are also affected by other factors such as season as well as organic and inorganic materials (Mirzaei-Agsaghali and Maheri-Sis, 2008). Thus, more current studies are warranted to study the feeding value of locally available agricultural by products in Malaysia to ensure its proper utilization at optimal costs. This study was conducted to establish the chemical and nutritive values of commonly available agricultural by-products in the central and southern regions of Peninsular Malaysia to enable the utilization of accurate values in the formulation of ruminant diets.

Materials and Methods

Samples of locally available agricultural by-products were taken from ruminant farms in the states of Selangor, Negeri Sembilan, Melaka and Johor (Hazwan *et.al*, 2016). Two replicates (samples at 500 g each) of rice bran, broken rice, copra cake, wheat pollard, brewers’ grain, soy sauce waste, palm kernel expeller, tofu waste, sago pith and malt barley were taken. The feed stuffs were then sent for chemical analyses at the Technical Service Centre of MARDI. Acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL) were analyzed according to the method of Van Soest *et al*. (1991). Hemicellulose was calculated as the difference between NDF and ADF, while that of cellulose as the difference between ADF and ADL. Total Digestible Nutrient (TDN) and Metabolisable Energy (ME) were calculated based on a regression equation for cattle described by Harris *et al*. (1972) based on feed classes and comparison between previously published data by Devendra (1979) and more recently by Yusoff *et al*. (1990).

Rumen in sacco degradation (digestibility) study was conducted on samples of rice bran, broken rice, copra cake, wheat pollard, brewers' grain, soy sauce waste, palm kernel expeller, tofu waste, sago pith and malt barley. Three fistulated Brahman crossbred bulls weighing from 400 to 450 kg were maintained in individual pens in MARDI Kluang, Johor. The fistulated bulls were adapted to a diet of 30% commercial palm kernel pellet (PKP), concentrate of 7.14 MJ/kg ME and 14.49 % CP and also fed with 70% chopped Napier grass for a period of 10 d prior to commencement of the study. Samples taken from the farms were dried at 60 °C for 72 h, ground to 2.5-3.0 mm (Ørskov, Hovell and Mould, 1980) and 5 g of each sample were weighed and inserted into semi permeable in sacco bags. Feed samples were inserted into 6.5 x 5.5 cm^2 bags with porosity of 40 µm (Ørskov *et al*., 1980). At each period, 3 replicates of 4 samples were inserted into each bull for ruminal incubation. Samples were inserted at periods of 8, 12, 24, 48, 72 and 96 h. Control samples at 0 h were washed, dried and weighed.

After the incubation period, samples were removed and washed under running water for 5 min until the flowing water from the sample bag appeared translucent. The samples were carefully washed to remove rumen materials that were attached to the bag such as feed materials and ruminal fluid with microbes. The washing of samples was done within 4 to 5 h after incubation to prevent any further fermentation of the samples. Samples were then oven dried at 75 °C for 72 h and weighed (Akhirany et al., 2013; Ørskov et al., 1980).

Dry matter in sacco degradation data were analyzed with SPSS 10 using analysis of variance (ANOVA) (Table 4) and inserted into a curve (Graph 1 and Graph 2) that is expressed mathematically using the equation described by Ørskov and McDonald (1979) as follows:

$$Y = a + b\,(1 - e^{(-ct)})$$

where

Y= Percent of feed degradation by rumen microbes at time t (incubation time)

a = Fraction of soluble

b = Insoluble but potentially degradable fraction

c = Rate of degradation of feed

a + b = Potential degradation, including material that escaped from the bag without degradation, expressed in percentage.

Results and Discussion

Table 1. Chemical composition of selected feed materials*

Nutrient component[2]	TBP[1]	PKE	SP	MB	WBG	CC	SSBP	WP	RB	BR
GE(MJ/kg)	16.70 ±0.14	15.67 ± 0.01	13.32 ± 0.22	15.71 ± 0.05	19.31 ± 0.10	16.63 ± 0.10	17.31 ± 1.29	16.87 ± 0.03	20.01 ± 0.02	15.47 ± 0.01
CP (%)	4.94 ±0.19	8.51 ± 0.02	0.52 ± 0.04	12.02 ± 0.20	24.62 ± 0.23	21.21 ± 0.00	24.25 ± 0.37	13.26 ± 2.77	12.73 ± 0.18	10.01 ± 0.11
CF (%)	33.43 ± 1.43	29.89 ± 0.22	3.42 ± 0.45	13.66 ± 1.21	21.50 ± 0.39	26.42 ± 0.36	14.65 ± 0.17	10.05 ± 0.44	7.85 ± 0.48	0.77 ± 0.13
ADF(%)	42.98 ± 0.82	48.16 ± 0.75	5.25 ± 0.01	11.00 ± 0.04	32.58 ± 1.17	35.11 ± 1.27	27.73 ± 0.06	11.99 ± 0.36	10.55 ±1.07 [c]	1.04 ± 0.02
NDF (%)	68.11 ± 1.26	61.62 ±0.78	23.45 ± 1.25	27.52 ± 0.49	73.41 ± 0.21	72.71 ± 1.35	35.96 ± 0.80	39.47 ± 1.61	22.1 ± 0.01	55.03 ± 11.37
EE (%)	0.12 ± 0.01	2.00 ± 0.06	0.07 ± 0.04	2.67 ± 1.68	5.98 ± 0.63	7.45 ± 0.23	8.80 ± 0.99	2.09 ± 0.02	18.76 ±0.18	0.20 ± 0.01
NFE (%)	53.52 ± 0.87	45.94 ± 0.47	93.97 ± 0.52	67.85 ± 3.10	43.71 ± 0.48	36.84 ± 0.24	42.00 ± 1.53	69.98 ± 2.32	51.87 ± 0.33	88.27 ± 0.26
Ash (%)	5.2 ± 0.13	4.71 ± 0.07	2.03 ±0 .01	3.81 ± 0.02	4.20 ± 0.02	8.09 ± 0.12	10.31 ± 0.01	4.64 ± 0.03	8.81 ± 0.15	0.76 ± 0.03

[1]TBP Tofu by product, PKE palm kernel expeller, SP sago pith, MB malt barley, WBG wet brewers' grain, CC copra cake, SSBP soy sauce by product (press), WP wheat pollard, RB rice bran, [1]BR broken rice
[2] DM Dry matter (%), GE gross energy (MJ/kg), CP crude protein (%), CF crude fibre (%), ADF acid detergent fibre (%), NDF neutral detergent fibre (%), EE either extract (%), NFE nitrogen free extract (%)
*Mean and standard error (SE)

Table 2. Chemical composition and feeding value of feed materials*

Nutrient component[2]	TBP[1]	PKE	SP	MB	WBG	CC	SSBP	WP	RB	BR
TDN (%)	46.50 ± 0.28	49.84 ± 0.39	89.44 ± 0.49	55.92 ± 10.88	68.75 ± 1.03	65.20 ± 0.77	69.62 ± 0.77	65.50 ± 3.51	46.81 ± 1.2	87.81 ± 0.22
ME (MJ/kg)	6.76 ± 0.05	7.31 ± 0.06	13.83 ±0.08	8.31 ± 1.79	10.43 ± 0.17	9.84 ± 0.13	10.57 ± 0.13	9.89 ± 0.58	6.82 ± 0.20	13.57 ± 0.04
ADL (%)	8.39 ± 0.12	19.93 ± 4.30	2.47 ± 0.60	6.91 ± 0.36	8.10 ± 0.62	15.47 ± 0.82	7.62 ± 1.05	5.70 ± 0.59	4.86 ± 0.66	1.22 ± 0.18
Cellulose (%)	11.03 ±0.86	28.33 ±5.04	2.78 ± 0.59	4.10 ± 0.40	24.49 ± 1.79	19.64 ± 2.09	20.12 ± 1.11	6.29 ± 0.24	5.69 ± 0.41	0
Hemicellulose (%)	20.53 ±0.68	13.46 ±0.03	18.20 ± 1.24	16.52 ± 0.53	40.83 ± 1.38	37.60 ± 0.08	8.23 ± 0.86	27.99 ± 1.50	11.55 ± 1.06	53.99 ± 11.35

[1]TBPTofu by product, PKE-palm kernel expeller, SP-sago pith, MB-malt barley, WBG-wet brewers grain, CC-copra cake, SSBP-soy sauce by product (press), WP-wheat pollard, RB-rice bran, [1]BR-broken rice
[2]TDN-Total Digestive Nutrient (%), ME-metabolised energy (MJ/kg), ADL-acid detergent lignin (%)
*Mean and standard error (SE)

Table 3. Mineral composition of feed materials*

Nutrient component [2]	TBP[1]	PKE	SP	MB	WBG	CC	SSBP
Ca %)	0.10± 0.01	0.27± 0.00	0.26± 0.02	0.15± 0.01	0.46± 0.01	0.10± 0.00	0.39± 0.02
Ph (%)	0.11± 0.01	0.40± 0.01	0.04± 0.01	0.35± 0.00	0.74± 0.01	0.47± 0.06	0.17± 0.01
Mg (%)	0.06± 0.00	0.24± 0.01	0.05± 0.00	0.11± 0.00	0.22± 0.01	0.33± 0.02	0.05± 0.00
K (%)	0.99± 0.00	0.56± 0.01	0.34± 0.02	0.59± 0.01	0.04± 0.00	2.25± 0.12	0.26± 0.01
Na (%)	0.02± 0.01	0.01± 0.00	0.08± 0.00	0.04± 0.00	0.02± 0.00	0.15± 0.01	3.26± 0.04
S (%)	0.15± 0.01	0.17± 0.01	0.10±0.01	0.35± 0.00	0.76 ±0.02	0.75 ±0.04	0.63 ±0.01
Co (ppb)	228.07± 8.46	122.27± 1.30	23.43± 11.52	50.57± 2.26	11.31± 0.54	897.71± 47.77	55.61± 4.86
Se (ppb)	1081.61± 910.45	534.08± 0.30	ND	ND	274.14± 150.83	ND	371.06±19.41
Cu (ppm)	5.15±0.08	20.89 ±0.54	1.03± 0.11	4.28± 0.08	11.17± 0.17	30.93± 7.93	50.41± 0.45
Fe (ppm)	932.24 ±100.45	2680.09± 150.39	31.01± 9.90	211.05± 5.74	158.26± 3.68	7364.56± 604.08	123.91± 4.08
Mn (ppm)	118.00 ±0.06	224.00± 13.00	58.84± 2.41	42.43± 1.25	36.18± 0.42	108.99± 26.77	14.50± 0.34
Zn (ppm)	29.26± 1.61	39.96± 0.29	20.60± 1.44	39.75± 0.02	94.79± 3.06	3586.50± 3476.15	66.19± 1.40
Al (ppm)	0.01± 0.01	0.03± 0.01	4.82± 0.39	46.70± 1.64	9.54± 0.65	285.82± 16.02	57.93± 6.16

*Mean and standard error (SE)

[1]TBP Tofu by product, PKE palm kernel expeller, SP sago pith, MB malt barley, WBG wet brewers' grain, CC copra cake, SSBP soy sauce by roduct (press)

[2]Ca Calcium (%), Ph phosphorus (%), Mg magnesium (%), K potassium (%), Na sodium (%), S sulphur (%), Co cobalt (ppb), Se selenium (ppb), Cu copper (ppm), Fe ferum (ppm), Mn manganese (ppm), Zn zinc (ppm), Al aluminium (ppm)

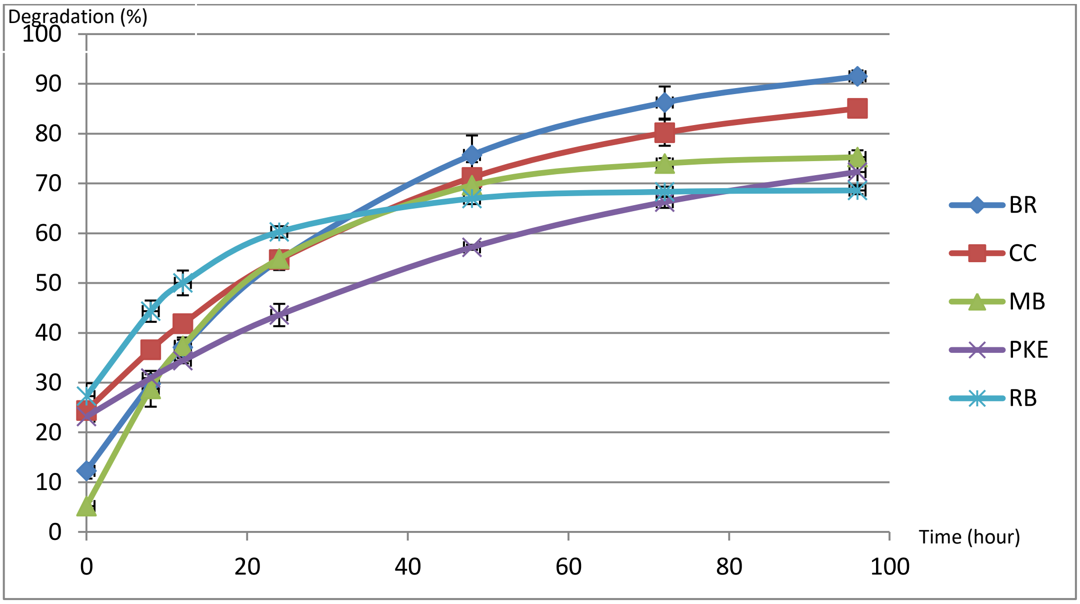
Table 4 : In sacco degradation of feed materials at different incubation times (%)*

Feed materials[1]	Incubation time (h)						
	0	8	12	24	48	72	96
TBP	10.86 ± 0.93 ^{b}	35.67 ±1.79 ^{cd}	38.40 ±0.38 ^{e}	49.38 ±1.20 ^{de}	63.32 ±0.43 ^{cd}	74.79 ±2.10 ^{de}	75.39 ± 0.57 ^{cde}
PKE	22.93 ±0.57 ^{d}	31.73 ±0.75 ^{c}	35.50 ±0.53 ^{cd}	40.98 ±2.24 ^{c}	57.15 ±0.50 ^{b}	68.92 ±1.15 ^{cd}	70.71 ±2.65 ^{bcd}
SP	15.12 ±0.49 ^{c}	23.40 ±1.13 ^{b}	22.41 ±0.90 ^{b}	32.91 ±1.30 ^{b}	43.66 ±2.43 ^{a}	61.56 ±2.43 ^{b}	67.32 ±2.35 ^{b}
MB	4.40 ±1.05 ^{a}	30.74 ±3.58 ^{c}	36.87 ±1.21 ^{de}	54.72 ±1.52 ^{ef}	67.96 ±2.42 ^{ef}	74.50 ±1.07 ^{de}	76.09 ±1.36 ^{de}
WBG	5.60 ±0.15 ^{a}	13.03 ±0.33 ^{a}	17.00 ±1.00 ^{a}	27.56 ±1.93 ^{a}	39.14 ±2.15 ^{a}	50.80 ±2.08 ^{a}	53.87 ±2.35 ^{a}
CC	22.80 ±1.57 ^{d}	38.85 ±1.05 ^{d}	43.45 ±1.05 ^{f}	51.82 ±0.99 ^{e}	72.23 ±3.06 ^{f}	79.38 ±2.62 ^{ef}	85.59 ±1.58 ^{f}
SSBP	18.06 ±0.85 ^{c}	30.33 ±0.35 ^{c}	32.86 ±0.67 ^{c}	44.66 ±2.42 ^{cd}	67.89 ±3.66 ^{ef}	77.03 ±3.05 ^{e}	80.66 ±1.62 ^{ef}
WP	27.37 ±1.32 ^{e}	48.62 ±0.90 ^{e}	51.02 ±1.00 ^{g}	62.56 ±2.26 ^{g}	66.79 ±1.16 ^{ef}	67.75 ±1.38 ^{bcd}	70.02 ±1.63 ^{bc}
RB	25.89 ±2.59 ^{de}	49.16 ±2.14 ^{e}	47.85 ±2.49 ^{g}	58.43 ±1.14 ^{fg}	66.05 ±1.11 ^{ef}	68.07 ±1.05 ^{bcd}	70.45 ±0.76 ^{bc}
BR	9.70 ±1.56 ^{b}	31.89 ±2.61 ^{c}	40.12 ±1.98 ^{ef}	53.37 ±1.99 ^{ef}	73.39 ±3.92 ^{f}	85.41 ±3.22 ^{f}	93.42 ±1.18 ^{g}

[1]TBP tofu by product, PKE palm kernel expeller, SP sago pith, MB malt barley, WBG wet brewers grain, CC copra cake, SSBP soy sauce by product (pressed), WP wheat pollard, RB rice bran, BR broken rice

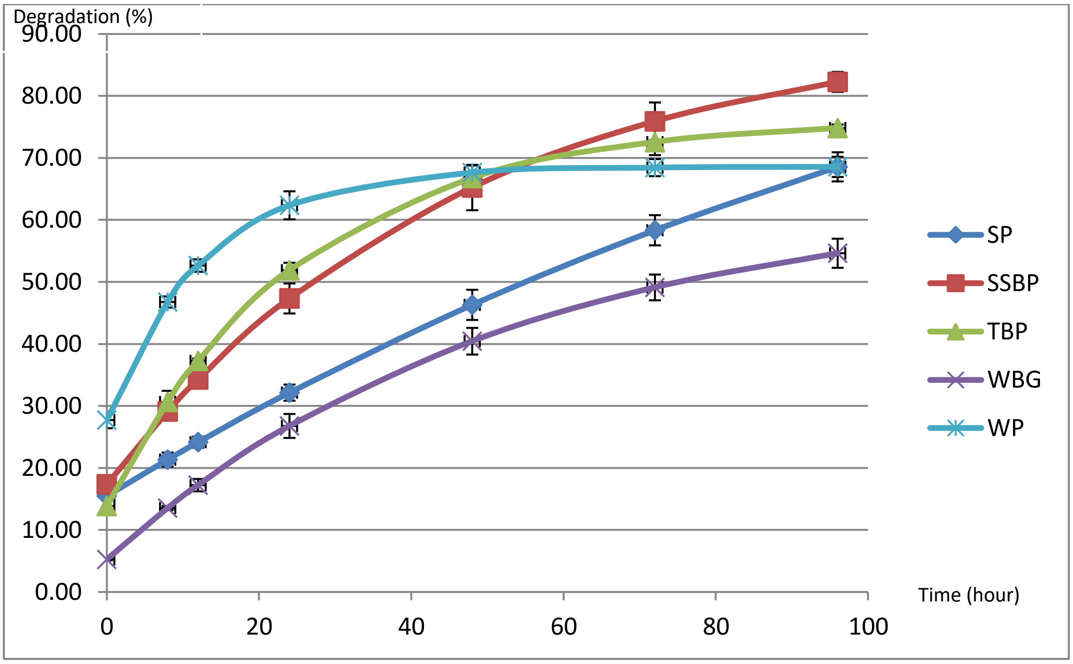
*Mean and standard error (SE)

Values with different letters within columns are significantly different at $p < 0.05$



Graph 1 : In sacco degradation of feed materials at different incubation times fitted into equation described by Ørskov and McDonald (1979)

*MB malt barley, CC copra cake, RB rice bran, [1]BR broken rice, PKE palm kernel expeller



Graph 2 : In sacco degradation of feed materials at different incubation times fitted into equation described by Ørskov and McDonald (1979)

*TBP tofu by product, SP sago pith,WBG wet brewers grain,
SSBP soy sauce by product (pressed), WP wheat pollard

SSBP showed ME of 10.57 MJ/kg (Table 2) and CP of 24.25% (Table 1). A previous study on SSBP reported ME of 7.18 MJ/kg and a higher CP of 28% (Yusoff *et al*., 1990). SSBP is a by-product of soy sauce manufacturing which involves a fermentation process of soybean, wheat, water and salt. The process of fermentation eliminates trypsin inhibitors and decreases the peptide size of the soybean meal which helps to increase protein content (Mar, 2013). This by-product also showed the highest sodium content of 3.26% (Table 3). According to Mar *et al*. (2013), there was about 18% salt content in the production of soy sauce. High sodium in feed causes an increase in sodium concentration of the blood which causes an increase of water consumption. It was also revealed that SSBP contained the highest copper content of 50.41 ppm (Table 3) which might be toxic to sheep if given in large amount (Alimon, 2005). SSBP can be added up to 15% of DM basis (Uddin *et al*., 2010) into the total feed formulation but should be done with caution due to the high sodium and copper content in the feed.

A previous report of in sacco study on energy feed source on Brahman Thai cattle revealed the highest maximum potential degradable fraction of broken rice at 99.79% and an effective degradability of dry matter at 61.10% at 48 h (Chumpawadee *et al*., 2011). In the same study, rice bran showed maximum potential degradability at 74.94% and an effective degradability of dry matter at 66.20% at 48 h. At 48 h degradation the present study revealed a higher DM loss of broken rice and rice bran of 73.39% and 66.05% (Table 4), respectively. It was also noted that there was a difference in NDF values in the study in broken rice and rice bran at 55.03% and 22.1%, respectively, compared to 9.28% and 20.29%, respectively, shown from the current samples (Table 1). The differences may be due to the harvesting process or the rice variety used in the region which may also alter degradation properties of the material. Our study also showed that degradation remained high after 24 h and a plateau could not be seen in some of the materials such as CC, BR, PKE, SSBP, SP and WBG (Graphs 1 and 2) when compared to a previous study (Chumpawadee *et al*., 2011). These errors might have been contributed by several factors such as bag pore size, sample size, grinding, diet of host animal, species of animal, sample time, incubation time, and washing method (Olivera, 1998).

Hemicelluloses undergo a shorter pathway of digestion to produce the final product of pyruvate compared to cellulose due to its more complex structure. The digestion of cellulose depends on the degree of lignification of the material due to its condensed structure (McDonalds, 2002). Our studies revealed the highest hemicelluloses (Table 2) of 53.99% in BR followed by BG (40.83%), WP (27.99%), SP (18.20%), MB (16.52%) and RB (11.55%). BR also contained lower ADL content (Table 2) of 1.22% which also produced the significantly ($P<0.05$) highest degradation at 48 h at 73.39% (Table 4). It was also noted that other carbohydrate by-products such as WP (62.56%) had significantly ($P<0.05$) high degradation at 24 h. RB (58.43 %) and MB (54.72 %) also showed higher degradation at 24 h (Table 4) compared to other materials. Results in Table 2 also showed that these materials had lower ADL content (RB:4.86%, WP:5.70% and MB: 6.91%). Lower lignin content in feed materials might have improved degradation of the feed.

Due to the fast digestion of these carbohydrate by-products, it produces risk of acidosis in ruminants. Chronic and subclinical cases of acidosis may lead to long term damage to the intestinal wall (Owens et al., 1998) that may regress the growth of animals in the long term. There are several pathways in the breakdown of pyruvate that produces propionic acid. However, the pathway of lactate and acrylate is highly correlated to the fast digestion of concentrates which consist of highly ingestible carbohydrates, mainly starch leading to acidosis (McDonalds, 2002). Our study revealed fast digestion of BR (73.39 %), CC (72.23 %), MB (67.96%), SSBP (67.89%), WP (66.79%) and RB (66.05%) at 48 h (Table 4).

Besides limiting the inclusion of these materials in feed, coating feed materials with fat would also aid in reducing incidence of acidosis by slowing down the breakdown of these feeds (Huffman *et al*., 1992). It is suggested in lactating cattle, 2-8% of crude palm oil (CPO) can be included in the diet to increase milk yield (Wan Zahari and Alimon, 2005). However, inclusion of high palm oil (100 gm/kg diet) in feed should be cautioned as it can reduce dry matter intake, greater fat deposition and lower carcass muscle proportion in sheep (Lough *et al*., 1993). Fermentation pathway as mentioned earlier can lead to lactic acid production when large amount of highly digestible starch and sugar are present in the formulation. Thus, in order to balance the digestion in the rumen, selection of different carbohydrate sources would complement each other (Van Soest *et al*., 1991). PKE had a degradability of 40.98% at the first 24 h and reached 75.39% (Table 4) at 96 h post in sacco which showed that this material did not undergo rapid digestion by the rumen microbes. In addition to PKE having high NDF value of 61.62% (Table 1), particle size of the fiber source also played an important role in salivary secretion that would aid in increasing rumen pH (Mertens, 1997).

Previous research has shown that PKE has a significantly higher degradable protein of 61% and 60.2% compared to pasture samples and a significantly lower soluble protein of 25.58% and 35.5% compared to the pasture samples (Dias *et al*., 2008). Total palm kernel cake (PKC) diet can be given to cattle with no adverse effect. In goats, PKC can be fed up to 50% with no adverse effect and a maximum inclusion of 30% can be given in sheep (Wan Zahari and Alimon, 2005). The limitation was done due to the presence of high copper content in PKC (Alimon, 2005). Our study revealed copper content of 20.89 ppm (Table 3). A slower degradation of PKE was observed at 48 h at 57.15 % (Table 4) which may be related to the higher NDF and ADL presence of 61.62% (Table 1) and 19.93% (Table 2), respectively. PKE was able to achieve ME of 8.14 MJ/kg and CP of 8.51% (Table 1) which were lower compared to a previous study of 9.80 MJ/kg and 15.3 %, respectively (Yusoff *et al.,* 1990). The variation in quality of PKE must be taken into account during formulation as it may alter the final protein and energy content.

Our findings also revealed high in sacco degradation of CC of 72.23% at 48 h (Table 4). Copra cake or copra meal is a by-product of the extraction of coconut oil. The residual coconut oil present in CC tends to be toxic to protozoa in the rumen which in turn enhances bacterial proteolysis by ameliorating effect on amino acids for glucose synthesis which improves degradation and nutrient supply to the host (Hennessey *et al*., 1989). Chemical analysis of copra cake revealed higher ether extract content of 7.45% (Table 1) which indicated high lipid content. A previous study revealed even higher either extract content of 12.7 % (Yusoff *et al*., 1990). CC also had higher hemicellulose value of 37.60% compared to cellulose of 19.64% (Table 2) which showed that the fibre content might be rapidly degradable due to the shorter breakdown pathway. Yusoff et al. (1990) also reported crude protein of CC of 21.5% and ME of 9.99 MJ/kg. Our result showed similar CP value of 21.21% and ME of 9.84 MJ/kg

(Table 1), showing that it is a very good source of protein and energy for ruminants.

Wet brewer's grain and tofu by product are known to have low dry matter content of 25.4% and 17.0%, respectively (Yusoff *et al*., 1990). A decrease in dry matter intake of 91 g/45 kg of body weight was seen with an increase for every 10% moisture content of the total diet (Schingoethe *et al*., 1988). WBG showed a much lower degradability of 27.56% compared to 49.38% of TBP which might be due to the higher calculated cellulose and hemicellulose of WBG of 20.49 % and 40.83 %, respectively (Table 4), compared to TBP of 11.03% and 20.53%, respectively (Table 2). However, WBG and SSBP also had among the highest CP content of 24.62% and 24.25%, respectively, showing that these two materials could be used as good protein sources in ruminant feeding. It was suggested that WBG should be limited to approximately 4 to 9 kg per calf per day and incorporated with other materials of higher dry matter content to reduce the amount of water in the final feed (Thomas *et al*., 2010). SP had high energy content of 13.83 MJ/kg but also had the lowest CP content of 0.52%. A previous study showed similar energy content of 13.61 MJ/kg and higher CP content of 1.3% (Yusoff *et al.*,1990) compared to the present study. Thus SP can be used as an energy source but should be limited in the feeding mixture due to its high moisture content and needs to be combined with a high protein source. Low moisture in the final feed formulation will not only improve feed intake of the animal but also improve storage of the formulated feed.

Conclusion

It was observed that SSBP, PKE and CC had high feeding value based on protein and energy content as well as in sacco degradation. Rice by-products such as WB, RB and BR should be used with caution due to the risk of highly degradable energy source that may lead to acute or chronic acidosis. WBG, TBP and SP have very low DM content, however WBG can be used as a good protein source and SP can be used as a good energy source. However these high moisture feeds need to be combined with other feed materials to complement their low dry matter content. However, the present information will help to give indication of the feeding value of these locally available agricultural by-products in order to improve feed formulation for ruminants in Malaysia.

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References

Akhirany, N., Ismartoyo, Jusoff, K., Natsir, A., and Ako, A. 2013. The digestibility, degradation and index value of four local feeds for goats. World Applied Sci. J. 26(26): 60–66. Retrieved from http://doi.org/10.5829/idosi.wasj.2013.26.nrrdsi.26011.

Alimon, A. R. 2005. The nutritive value of palm kernel cake for animal feed. Palm Oil Dev. 40: 12-14.

DelCurto, T., Cochran, R. C., Corah, L. R., Beharka, A. A., Vanzant, E. S., & Johnson, D. E. (1990). Supplementation of dormant tallgrass-prairie forage: II. Performance and forage utilization characteristics in grazing beef cattle receiving supplements of different protein concentrations. J. Anim. Sci. 68(2), 532–542. http://doi.org/10.2527/1990.682532x

Dias, F.N. Pacheco, D. and C.W. Holmes, J. L. B. 2008. In sacco digestion kinetics of palm kernel expeller (PKE). Proceedings of the New Zealand Grassland Association, 70: 259–264.

Hazwan, M. M, Predith. M, and Nasyatul, E.M.H., 2016. Nutrient composition and price fluctuation of local agriculture by-product feedstuff for dairy cattle, Proceeding in Conference of Malaysian Society of Animal Production 2016, pg 132-133.

Hennessey D.W., Kempton T.J. and Williamson P.J. 1989. Copra cake as a supplement to cattle offered a low quality native pasture hay, AJAS, 2(2): 77-84.

Huffman, R. P., R. A. Stock, M. H. Sindt, and D. H. Shain. 1992. Effect of fat type and forage level on performance of finishing cattle. J. Anim. Sci. 70: 3889-3898.

Lough, D.S., Solomon, M.B., Rumsey, T.S., Kahl, S. and Slyter, L.L. 1993. Effects of high-forage diets with added palm oil on performance, plasma lipids, and carcass characteristics of ram and ewe lambs. J. Anim. Sci. 71: 1171–1176.

MacDonald, P., Greenhalgh, J. F. D. , Edward R.A. and Morgan, C. A. 2002. Animal nutrition : Carbohydrate digestion: wheat by-products, Pearson Education,6th Edition, pg 182-187, 574-575.

Mar, T., Lynn, T. M., Aye, K. N., and Khaing, K. M. 2013. Study on the production of fermented soybean sauce by using *Aspergillus oryzae* and *Aspergillus flavus*. J. Scientific and Innovative Res. 2(2): 1–10.

Marini, A.M., Shanmugavelo, S., Rodziah, M., Zaireen, A.R. and Nasyatul, E.M.H. 2014. Web-based Ruminant Feed Formulation and Beef Feedlot Decision Support System. Buku Hari Inovasi MARDI, MSTE 2014, pg 46.

Mertens, D. R. 1997. Creating a system for meeting the fiber requirements of dairy cows. J. Dairy Sci. 80(7): 1463–81. Retrieved from http://doi.org/10.3168/jds.S0022-0302(97)76075-2

Mirzaei, A., and Maheri, S.N. 2008. Nutritive value of some agro-industrial by-products for ruminants - a review. World J. Zoology. 3(2): 40–46. Retrieved from http://www.idosi.org/wjz/wjz3(2)2008/2.pdf.

Olivera, R.M.P. 1998. Use of in vitro gas production technique to assess the contribution of both soluble and insoluble fractions on the nutritive value of forages. MSc Thesis, University of Aberdeen, Scotland.

Ørskov, E. R., Hovell, F. D. and F.Mould. 1980. The use of the nylon bag technique for the evaluation of feedstuffs. Trop. Anim. Prod. 5(3): 195–213.

Owens, F. N., Secrist, D. S., Hill, W. J., and Gill, D. R. 1998. Acidosis in cattle: a review. J. Anim. Sci. 76(1): 275. http://doi.org/10.2527/1998.761275x

Schingoethe, D. J., F. M. Buyers, and G. T. Schelling. 1988. Nutrient needs during critical periods of the life cycle. The Ruminant Animal: Digestive Physiology and Nutrition. Ed. D. C. Church. New Jersey: Prentice-Hall, Inc. 421-447.

Loh, T.C. 2002. Livestock production and the feed industry in Malaysia. Protein sources for the animal industry, FAO Expert Consultation and Workshop, 1–25. Retrieved from http://doi.org/Expert Consultation and Workshop Bangkok, 29 April - 3 May 2002

Thomas, M., Hersom, M., Thrift, T. and Yelich, J. 2010. Wet Brewers Grains for Beef Cattle 1, 1–4, Animal Sciences Department, UF/IFAS Extension. Retrieved from http://edis.ifas.ufl.edu.

Uddin, M. K., Kondo, M., Kita, J., Matsui, H., Karita, S. and Goto, M. 2010. Effect of supplementation of soy sauce cake and vinegar brewer's cake with total mixed ration silage-based diet on nutrient utilization by Holstein steers. J. Food, Agric. and Environ. 8(3-4 Part 1), 282–287.

Van Soest, P. J., Robertson, J. B. and Lewis, B. A., 1991. Polysaccharides in relation to animal nutrition. J. Dairy Sci. 74: 3583–3597. Retrieved from http://doi.org/10.3168/jds.S0022-0302(91)78551-2

Wan Zahari, M. and Alimon, A. R., 2005. Use of palm kernel cake and oil palm by-products in compound feed. Palm Oil Developments, 40:5–9. Retrieved from https://www.researchgate.net/profile/Wan_Zahari_Mohamed/publication/264839732

Yusoff, H.M.S, Sharif, S. and Noormah, M.A., 1990, Nutrient composition of Malaysian feed materials and guides to feeding of cattle and goats, 2nd edition, Department of Veterinary Services, Ministry of Agriculture and Agro-Based Industry Malaysia pg 18-27.