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Fermentation Kinetics of Some Oil Palm By-Products as Ruminant Feeds

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Abstract

The ruminant industry in Malaysia is still not self-sufficient where smallholder farmers keep the majority of ruminant livestock. Limited pasture and poor quality forages urge them to find alternative feedstuffs which are cheaper, of satisfactory nutritive value and available throughout the year. Oil palm by-products meet these criteria, however their fermentation kinetics in the rumen need to be evaluated. The *in vitro* fermentation kinetics of selected oil palm by-products, namely the oil palm fronds (OPF), palm kernel cake (PKC) and decanter cake (DC) were evaluated using the *in vitro* gas production technique. The by-products were assessed at inclusion levels of 100% (raw 100% by-product), 15% (15% by-product + 85% concentrate feed, w/w) and 30% (30% by-product + 70% concentrate feed, w/w). The *in vitro* fermentation of the oil palm by-products was carried out in 100 mL sealed syringes with 0.25 g of substrate and 25 mL of rumen fluid-buffer mixture (1:4 v/v), which were incubated at 39°C under anaerobic condition for 48 h. Evaluation of the fermentation kinetics was performed based on the following parameters, namely gas production, rumen pH, protozoal population, volatile fatty acid (VFA) and long chain fatty acid (LCFA) profiles compared with concentrate feed which acted as the control. The decanter cake (DC) at inclusion levels of 15% and 30% yielded similar gas production, rumen pH, VFA, and total unsaturated fatty acid profile as the concentrate feed. However, the 15% and 30% DC significantly increased the total C18:1 *trans* fatty acids ($p<0.05$) compared to the concentrate and the other by-products. It is concluded that the decanter cake showed the greatest potential to be included into ruminant livestock feed which should reduce feed costs, although the increase in the unhealthy *trans* fatty acids must be taken into account.

Keywords: Fermentation kinetics, *in vitro* gas production, oil palm by-products, rumen fermentation, rumen protozoa

Introduction

Oil palm (*Elaeis guineensis* Jacq.) is widely cultivated as a source of vegetable oil in Malaysia, Indonesia and Thailand. The extensive oil palm industry provides an abundant supply of oil palm by-products such as oil palm fronds (OPF), trunks, empty fruit bunches, palm oil mill effluent, palm kernel cake (PKC), decanter cake (DC), and palm press fibre (PPF). Oil palm by-products have the potential to be included as concentrate substitutes in compound feed formulation for ruminants. The major constraint in the Malaysian ruminant industry where most of the ruminant livestock is owned by smallholder farmers is the lack of supply of quality feed throughout the year, especially during peak cropping periods. The aim of this study was to investigate the suitability of OPF, PKC, and DC as ruminant feeds by measuring the *in vitro* fermentation kinetics and their effects on rumen parameters.

Materials and Methods

An evaluation of the *in vitro* fermentation kinetics of oil palm fronds (OPF), palm kernel cake (PKC), and decanter cake (DC) and concentrate feed as the control was carried out. Each substrate was evaluated as raw (100% by-product), 15% (15% by-product + 85% concentrate feed, w/w) and 30% (30% by-product + 70% concentrate feed, w/w) compared to the control (100% concentrated fed). The *in vitro* fermentations were performed simultaneously in triplicate using a single source of rumen fluid inoculum. Another triplicate with rumen fluid inoculum containing no substrate was incubated in the batch as blanks (negative control). Pooled rumen content were collected from four rumen-fistulated Kacang crossbred goats (45.0±2.0 kg BWt; 11-12 months old) under the same feeding regime (fed twice daily at 09:00 and 17:00 h. with 70 % commercial goat concentrate and 30 % oil palm frond, w/w). Twenty-five millilitres of rumen fluid and bicarbonate-phosphate buffer mixture (1:4 v/v) were introduced along with 0.25g of substrate into a 100 mL air-tight plastic syringe and incubated at 39˚C for 48 hours under anaerobic conditions. The *in vitro* gas production of each feedstuff was measured according to the method of Fievez *et al*. (2005). The rumen liquor pH was measured immediately after the incubation period with a Mettler-Toledo pH meter (Mettler-Toledo Ltd., England). Protozoal counts in the rumen liquor were carried out using a haemocytometer, following the improved Neubauer ruling and identification procedure outlined by Towne *et al*. (1990) and Hungate (1966). The volatile fatty acid profile and the long chain fatty acid profile of the rumen liquor were determined using a 5890 Hewlett-Packard Gas-Liquid Chromatograph (Hewlett-Packard, Avondale, PA) and an Agilent 7890N Gas-Liquid Chromatograph, respectively. All data were analysed by the least-squares means method using the GLM procedures of SAS®. Significantly different means were then further differentiated using the least significant difference (LSD) comparison procedures.

All statistical tests were conducted at 95 % confidence level. Data were analyzed using the model $Yij=\mu+Ti+\varepsilon ij$ where Yij is the observation from treatment i, j, the replication; μ, the overall mean; Ti, the mean of treatment and εij, the residual effect.

Results and Discussion

Gas production

Significant differences ($p<0.05$) in cumulative gas production were observed between the concentrate (43.00±1.22 mL) and the raw OPF (12.17±0.60 mL), raw PKC (19.83±1.33), raw DC (34.50±1.57 mL), 30% OPF (33.67±2.08 mL) and 30% PKC (36.60±2.25 mL). The 15% OPF, 15% PKC, 15% DC, and 30% DC had similar gas production as the concentrate ($p>0.05$). The results showed that inclusion of the cheaper oil palm by-products as substitutes for the expensive concentrate is highly possible and applicable, without affecting the quality and digestibility of the feed. The DC would be the by-product of choice compared to the PKC since the former can be included up to 30% proportion of the finished feed without affecting significantly the digestibility.

Volatile fatty acid (VFA) production

There is a significant correlation between gas production and VFA production where fermentation end products such as the VFA influence gas production. Differences in total gas production could also be explained by the differences in the total and indiviual VFA produced. The production of acetic and propionic acid for all the treatments was similar. Unlike the PKC and OPF, the inclusion of DC increased ($P<0.05$) the production of butyric acid, which confirmed an earlier report of Hasliza *et al*. (2007) where they fed sheep with different inclusion levels of OPF.

Rumen pH

The high rumen pH, which ranged between 7.01 to 7.20 for all treatments, suggested that the rumen environment was conducive for fermentation by cellulolytic bacteria. There was no significant difference in pH between the by-products and the concentrate (7.09±0.02) except for the raw OPF which yielded a significantly higher rumen pH (7.20±0.01) than the concentrate, and the highest pH among all the treatments. This result was consistent with that of Khamseekhiew *et al*. (2002) who suggested that the high rumen pH was caused by low production of volatile fatty acids due to the low digestibility of OPF. The high fibre fraction of the oil palm by-products could also aid in buffering, thus delaying any decrease in pH (Feng *et al*., 1993).

Rumen protozoa population

Two major protozoa, namely the entodinium and holotrichs, were identified. The *in vitro* fermentations of all by-products produced a significantly higher entodinium population than the concentrate, with raw DC showing the highest population. The holotrich population resulting from fermentation of the concentrate was not significantly different with those for either 30% OPF, raw PKC, 30% PKC, and 15% DC. The raw OPF (0.39±0.10 x10^6/mL), raw DC (0.53±0.08), 15% OPF (0.40±0.04), 15% PKC (0.37±0.07), and 30% DC (0.41±0.04) showed a significantly higher ($p<0.05$) holotrich population than the concentrate (0.16±0.06). Generally, the results demonstrated that the inclusion of the oil palm by-products significantly increased the protozoal population in the rumen environment. This suggests that the concentrate feed may have a defaunation effect against the rumen protozoa. This result confirmed the earlier findings of Ebrahimi (2009) who reported a significant increase in the the rumen protozoal population in goats fed with increased inclusion levels of OPF.

Saturated and unsaturated fatty acids

All the raw by-products at 15% inclusion levels yielded significantly higher total saturated acids (SFA) than the concentrate. The 30% inclusion of PKC yielded a significantly higher SFA but the 30% inclusion of OPF and DC and the concentrate yielded similar amounts of SFA. At 15% inclusion levels, only the OPF (11.47±0.47%) and PKC (13.66±0.26%) yielded significantly lower unsaturated fatty acids (UFA) than the concentrate (16.16±0.48%) while the levels of UFA for the 15% DC and concentrate were similar. At 30% inclusion only the PKC (13.56±0.06 %) yielded significantly lower UFA than the concentrate.

The decanter cake which yielded significantly higher UFA and lower SFA may increase the UFA:SFA ratio in the rumen content resulting in an increased unsaturated fatty content in the ruminant products, such as milk and meat. Hasliza *et al*. (2007) also showed that the inclusion of 30% OPF (w/w/ DM) in complete feed increased the availability of UFA in the rumen. The 30% OPF in this study also produced UFA:SFA ratios similar to the decanter cake. However, the poor nutritive value and digestibility of OPF would compromise its value as a feed ingredient.

Trans fatty acids

Both the 15% DC and 30% DC yielded significantly higher total *trans* fatty acids than the other treatments. The levels of total *trans* fatty acids were lowest for the 30% OPF, followed by raw OPF, 15% OPF, raw PKC and 15% PKC, which all had similar production of *trans* fatty acids. The levels of *trans* fatty acids

in the concentrate, 15% OPF, 30% PKC, and raw DC were similar. The results demonstrated that the DC produced an increased production of the unhealthy total *trans* fatty acids which could increase their deposition and content in the ruminant tissues. It has been hypothesized that an increased human consumption of *trans* fatty acids may increase risks of coronary heart diseases, colon cancer, breast cancer, and prostate cancer (Mensink and Katan, 1990; Stender and Dyerberg, 2004)

Conclusion

Based on the similar gas production, rumen pH and VFA production with the concentrate, and the increased UFA, decreased SFA and hence UFA:SFA ratios compared to the concentrate, the decanter cake at inclusion levels of 15% and 30% showed the greatest potential to be included into ruminant livestock feed which should also reduce feed costs, although the increase in the unhealthy *trans* fatty acids must be taken into account. However, PKC and OPF could also serve as alternative feed supplements to improve ruminal fermentation end products such as an increased protozoal population and modification of rumen pH.

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