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Effects of Palm Kernel Expeller and Empty Fruit Bunch Inclusion in Beef Cattle Feed Formulation on *In Vitro* Gas Production and Rumen Fermentation

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ABSTRACT

Oil palm by-products offer significant potential as ingredients in beef cattle feed formulations, providing an alternative to imported feed ingredients. This study evaluated the effects of incorporating palm kernel expeller (PKE) and empty fruit bunches (EFB) at varying levels in beef cattle feed formulations on *in vitro* gas production and rumen fermentation. Six treatments were formulated: T1 = 70% PKE + 5% EFB, T2 = 70% PKE + 10% EFB, T3 = 70% PKE + 15% EFB, T4 = 65% PKE + 5% EFB, T5 = 65% PKE + 10% EFB, and T6 = 65% PKE + 15% EFB. Rumen fluids collected from slaughtered cattle were used for 48-hour incubations. T5 had the highest gas production ($P = 0.0001$), with 99.25 mL/500 mg, exhibited high values for *in vitro* dry matter degradability (*iv*DMD) and *in vitro* organic matter degradability (*iv*OMD), at 55.11% and 69.45%, respectively. Volatile fatty acid (VFA) analysis showed that T1 had a significantly higher ($P = 0.0001$) total VFA (64.29 mM), acetic acid (15.01 mM) and propionic acid (25.34 mM) concentration, respectively. Higher EFB inclusion (T3 and T6) resulted in lower VFA production. Incorporating PKE and EFB in beef cattle feed provides nutritional adequacy and supports favourable rumen fermentation profiles. These findings suggest that incorporating oil palm by-products can improve feed sustainability and reduce feed costs without compromising nutritional quality. Further *in vivo* studies are recommended to assess the impact of these feed formulations on beef cattle performance.

Keywords: Beef cattle nutrition, oil palm by-products, ruminant feedstuffs

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INTRODUCTION

The growing demand for beef production has intensified the search for sustainable and cost-effective feed ingredients, particularly in regions where corn and soybean meal

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are costly or limited. In Malaysia, palm oil by-products such as palm kernel expeller (PKE) and empty fruit bunches (EFB) are promising alternatives for ruminant diets. Although their nutritional potential has been individually studied, limited research has explored their combined effects on rumen fermentation and nutrient degradability. This study evaluates the *in vitro* fermentation characteristics of beef cattle feed pellets containing varying levels of PKE and EFB which could determine their feasibility in sustainable ruminant feeding systems.

Problem Statement

Combining PKE and EFB at optimal ratios could balance energy and fibre supply, improving degradability and fermentation efficiency in ruminant nutrition.

Research Questions

How does the inclusion of PKE and EFB at different levels in beef cattle feed affect *in vitro* gas production, rumen fermentation and VFA production?

MATERIALS AND METHODS

Six diets were formulated using FORMAT software: T1 = 70% PKE + 5% EFB, T2 = 70% PKE + 10% EFB, T3 = 70% PKE + 15% EFB, T4 = 65% PKE + 5% EFB, T5 = 65% PKE + 10% EFB, and T6 = 65% PKE + 15% EFB. Rumen fluid was collected from slaughtered beef cattle and maintained at 39°C under anaerobic conditions. The inoculum was prepared by mixing strained rumen fluid with artificial saliva (Menke, 1988). Gas production was recorded at throughout 48 h. At 48 h, pH was measured, and residues were analyzed for *in vitro* dry matter degradability (*iv*DMD), organic matter degradability (*iv*OMD) and VFA.

RESULTS AND DISCUSSION

Proximate analysis of the developed feed formulations with different inclusion levels of PKE and EFB is shown in Table 1. All of the formulations were isonitrogenous and isocaloric. Crude fibre content was higher in T3 and T6 which contained the highest EFB inclusion level (15%).

Figure 1 shows *in vitro* gas production of the different feed formulations with varying inclusion levels of PKE and EFB. T5 had shown the highest gas production, reaching 99.25 mL/500 mg at 48 h. Inclusion of 65% PKE and 10% EFB offers an optimal fibre-to-fat balance, resulting in maximal microbial degradation and gas production (Kum & Zahari, 2011).

Table 2 shows the effects of PKE and EFB inclusion on *in vitro* rumen fermentation and VFA profiles. T6 showed the highest *iv*DMD (58.40%), while T5 recorded the highest *iv*OMD (69.45%), indicating potential benefits for feed efficiency. T1 produced the highest

Table 1
Proximate analysis of developed feed formulations with different inclusion levels of PKE and EFB

Proximate Analysis	T1	T2	T3	T4	T5	T6
Moisture content (% DM)	8.97 ± 0.05[a]	9.21 ± 0.22[a]	8.14 ± 0.18[c]	7.49 ± 0.24[d]	8.54 ± 0.24[b]	8.31 ± 0.09[bc]
Ash (% DM)	5.26 ± 0.03[b]	5.25 ± 0.02[b]	5.23 ± 0.09[b]	5.68 ± 0.18[a]	5.71 ± 0.04[a]	5.19 ± 0.01[b]
Crude fat (% DM)	8.49 ± 0.11[c]	8.84 ± 0.06[bc]	9.25 ± 0.12[b]	10.80 ± 0.21[a]	7.94 ± 0.48[d]	8.93 ± 0.31[bc]
Crude protein (% DM)	15.99 ± 0.39[ab]	16.07 ± 0.07[ab]	15.37 ± 0.83[b]	16.60 ± 0.40[a]	15.67 ± 0.23[b]	15.46 ± 0.20[b]
Crude fibre (% DM)	18.26 ± 0.53[c]	20.87 ± 0.24[ab]	22.58 ± 1.32[a]	21.50 ± 0.49[a]	19.25 ± 1.20[bc]	22.00 ± 1.45[a]
Gross energy (cal gram^{-1})	4861 ± 6.68[b]	4910 ± 9.15[ab]	4890 ± 13.46[ab]	4922 ± 41.43[a]	4813 ± 24.73[c]	4906 ± 9.42[ab]

Note. T1 = 70% PKE, 5% EFB; T2 = 70% PKE, 10% EFB; T3 = 70% PKE, 15% EFB; T4 = 65% PKE, 5% EFB; T5 = 65% PKE, 10% EFB; T6 = 65% PKE, 15% EFB; DM = dry matter; cal gram^{-1} = calorie gram^{-1}

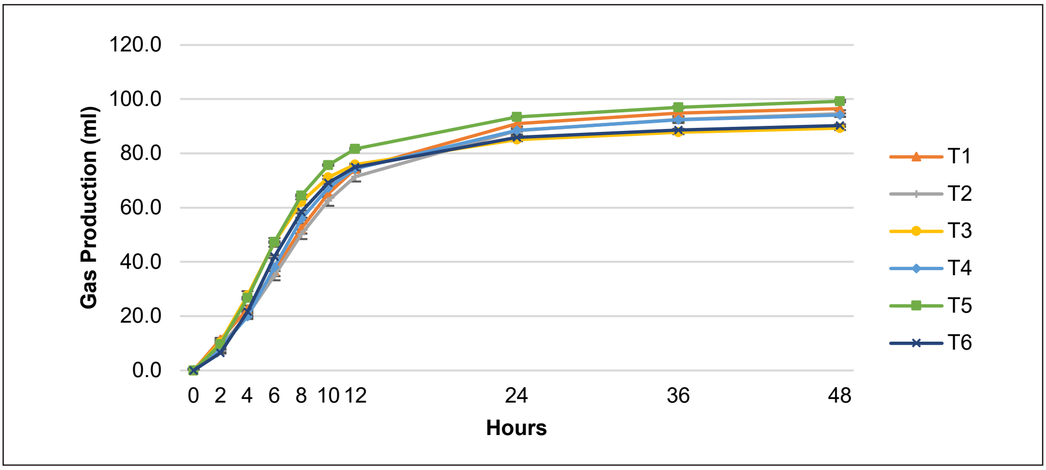

Figure 1. In vitro rumen gas production according to different treatment groups

total VFA (64.29 mM) and propionic acid (25.34 mM), suggesting favourable fermentation. Total VFA reflects rumen activity and energy availability, whereas propionate supports gluconeogenesis and reduces methane (Bergman, 1990; Ungerfeld, 2020). Lower VFA in T3 and T6 indicates reduced fermentability at higher fibre levels, emphasizing the importance of optimizing PKE–EFB ratios for efficient energy supply.

CONCLUSION

Incorporating PKE and EFB in beef cattle feed enhances nutritional value and rumen fermentation. The 65% PKE + 10% EFB (T5) diet showed superior gas production,

Table 2
Effect of PKE and EFB in cattle feed on in vitro *rumen fermentation and VFA profile*

Treatment	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Rumen Fermentation						
pH	6.67 ± 0.02	6.72 ± 0.01	6.74 ± 0.02	6.76 ± 0.01	6.79 ± 0.01	6.81 ± 0.02
*iv*DMD (%)	52.60 ± 4.19	50.95 ± 2.52	53.73 ± 2.13	53.91 ± 3.71	55.11 ± 2.67	58.40 ± 1.56
*iv*OMD (%)	68.23 ± 1.39	65.78 ± 1.07	65.64 ± 0.90	66.54 ± 1.54	69.45 ± 1.23	68.64 ± 0.27
VFA profile						
Acetic	15.01 ± 0.96 ^{a}	10.84 ± 0.32 ^{e}	11.09 ± 0.70 ^{d}	11.55 ± 0.18 ^{c}	12.54 ± 0.30 ^{b}	10.27 ± 0.27 ^{d}
Propionic	25.34 ± 0.66 ^{a}	19.52 ± 0.55 ^{b}	15.81 ± 1.16 ^{e}	18.90 ± 0.36 ^{c}	19.48 ± 0.44 ^{b}	17.07 ± 0.30 ^{d}
Iso-Butyric	1.46 ± 0.08 ^{a}	0.74 ± 0.03 ^{d}	0.74 ± 0.03 ^{d}	0.82 ± 0.01 ^{b}	0.77 ± 0.02 ^{c}	0.79 ± 0.02 ^{c}
Butyric	18.27 ± 0.77 ^{a}	14.55 ± 0.27 ^{b}	11.93 ± 1.06 ^{c}	12.55 ± 0.21 ^{c}	11.64 ± 0.18 ^{d}	12.61 ± 0.31 ^{c}
Iso-Valeric	1.26 ± 0.08 ^{a}	0.66 ± 0.02 ^{c}	0.64 ± 0.05 ^{c}	0.73 ± 0.01 ^{b}	0.69 ± 0.02 ^{c}	0.67 ± 0.03 ^{c}
Valeric	1.79 ± 0.03 ^{a}	1.32 ± 0.03 ^{b}	1.11 ± 0.10 ^{c}	1.29 ± 0.01 ^{b}	1.33 ± 0.03 ^{b}	1.24 ± 0.03 ^{b}
Caproic	0.14 ± 0.01	0.12 ± 0.02	0.13 ± 0.01	0.10 ± 0.01	0.12 ± 0.01	0.13 ± 0.01
Total VFA	64.29 ± 2.57 ^{a}	47.73 ± 0.31 ^{b}	42.11 ± 3.09 ^{b}	45.40 ± 0.75 ^{b}	46.57 ± 0.98 ^{b}	42.78 ± 0.89 ^{b}

Note. T1 = 70% PKE, 5% EFB; T2 = 70% PKE, 10% EFB; T3 = 70% PKE, 15% EFB; T4 = 65% PKE, 5% EFB; T5 = 65% PKE, 10% EFB; T6 = 65% PKE, 15% EFB. Means (± standard error) in the same row with different superscripts indicate statistically significant difference at $p<0.05$

digestibility, and good VFA profile balance. This approach supports sustainable feeding by reducing reliance on conventional feeds, lowering costs, and repurposing palm-based by-products.

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