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Use of palm kernel expeller and empty fruit bunches in beef cattle feed pellets in Malaysia

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Abstract

This study evaluated the effects of an oil palm by-product-based (OPB) feed pellet on beef cattle growth and feed intake. A total of 42 beef cattle were assigned to two groups and fed either the OPB or a commercial (COM) feed pellet at 1% of body weight (BW) over a 90-day trial, with *ad libitum* supply of oil palm fronds daily. Daily feed intake and monthly BW changes were recorded. Proximate analysis showed that the OPB feed pellet was isonitrogenous and isocaloric to the COM pellet. At the end of the feeding trial, a similar BW increment was observed, from 165 kg to 222 kg and 159 kg to 212 kg for OPB and COM, respectively. The average daily gain (ADG) of the OPB group was slightly higher than that of the COM group with 0.63 kg day^{-1} and 0.59 kg day^{-1}, respectively. Similarly, feed conversion ratio (FCR) in the OPB group was slightly better at 9.59 as compared to the COM group with 9.98. Additionally, meat from cattle on the OPB diet showed higher redness and yellowness values ($p < 0.05$), indicating improved meat appearance. In conclusion, the oil palm-based feed pellet provides complete nutrition for beef cattle and is comparable to commercial feed pellets in supporting growth performance.

Keywords: beef cattle, growth performance, oil palm by-products

1 Introduction

Feed is the largest single-cost item for livestock production, which accounts for 60–70 % of the total cost (Salami *et al.*, 2019). The rising prices of imported raw materials such as grain, corn, and soybean meal have had a significant impact on animal feed prices. This is particularly concerning given that Malaysia imports approximately 98 % of its grain requirements, including corn and soybean meal, primarily from countries like Argentina, Brazil, and the United States (Feed Strategy, 2022). In addition, the supply of these raw materials is limited, resulting from the competition between ruminant feed producers and poultry feed producers (Knowledge Sourcing Intelligence, 2023).

The beef cattle industry in Malaysia has a very low level of self-sufficiency compared to the non-ruminant industry, due to high feed prices, limited availability of local feed ingredients, and expensive imported raw materials (Mohd Saufi *et al.*, 2023). In Malaysia, oil palm plantations occupy approximately 17 % of the country's total land area and account for over 70 % of the national agricultural land area (Rajakal *et al.*, 2024). As of 2023, oil palm cultivation extended across 5.65 million hectares (Parveez *et al.*, 2024). During this period, the average yield of fresh fruit bunches from these plantations was documented at 15.79 tons per hectare (MPOB, 2024). This extensive land use highlights the significant role that oil palm cultivation plays in Malaysia's agricultural sector, serving as a cornerstone of the economy and a major contributor to the country's agricultural output. The substantial yield figures reflect the productivity of the sector, underlining its importance in meeting both domestic and global demand for palm oil and related products (Parveez *et al.*, 2024).

The by-products produced from oil palm plantations, as well as those generated during the processing of palm oil in mills and refineries, offer significant potential as cost-effective alternatives to the expensive imported raw materials currently used in the ruminant feed industry. These

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by-products, often abundant and underutilized, can serve as valuable resources, helping to reduce dependence on imports and lowering production costs for feed manufacturers (Kum and Zahari, 2011). The core principles of waste management focus on minimizing waste production, recycling materials, recovering energy from waste, and ultimately disposing of any remaining waste in an environmentally responsible manner (Abdullah & Sulaiman, 2013). By maximizing the efficient use of by-products generated from oil palm production, we can significantly reduce environmental pollution. This approach not only lessens the burden on waste disposal systems but also promotes the sustainable management of resources, ensuring that valuable materials and energy are recovered and reused rather than contributing to environmental degradation (Tan, 2006).

The majority of oil palm biomass such as oil palm fronds (OPF), palm kernel meal (PKM), palm oil mill effluent (POME), empty fruit bunches (EFB), and palm pressed fiber (PPF) holds significant potential for use as ingredients in compound feeds, particularly for ruminants. These by-products can be further processed into pellets, enhancing their effectiveness in livestock diets (Mohamed *et al.*, 2012). The suitability of incorporating this biomass into ruminant feed is largely attributed to its nutrient content and the composition of its fibre (Zahari *et al.*, 2003). Numerous studies have documented improvements in feed intake and overall animal performance when oil palm biomass is included in their diets, especially when optimal feed pellet formulation and processing techniques are employed. For instance, Zahari & Alimon (2005) highlighted the potential of several oil palm by-products such as OPF, PKM, and PPF as economical feed resources in Malaysia. These by-products, when properly treated (e.g., chopped, ensiled, or pelleted), were found to improve feed intake and maintain growth performance in ruminants. Similarly, Ibrahim *et al.* (2021) evaluated a diet including OPF, EFB, PKM, and palm fatty acid distillates in goat feed pellets, which recorded animal performances similar to those of traditional forages. These findings underscore the value of oil palm biomass such as OPF and EFB, as a sustainable and beneficial feed ingredient, capable of enhancing the productivity of ruminant livestock.

Efforts to increase the local production of beef cattle to reduce dependency on imports have been initiated for decades but only small reductions in import value have been achieved (Jamaludin *et al.*, 2014). Economic growth and urbanization have influenced dietary patterns in Malaysia, with a noticeable shift towards higher meat consumption. Goh *et al.* (2020) highlight that as incomes rise, Malaysians tend to consume more animal-based proteins, including beef, reflecting a broader nutrition transition. This trend further emphasizes the need to bolster domestic beef production to cater to changing consumer preferences and ensure food security.

Since 1984, Malaysia has achieved self-sufficiency concerning the domestic demand for poultry meat, consistently producing enough to satisfy local consumption. In contrast, the ruminant subsector, particularly beef production, remains underdeveloped, despite active government initiatives and involvement aimed at its improvement (Kaur, 2010). The ruminant industry in Malaysia had the lowest self-sufficiency level in 2021 with 20.2 % and 8.2 % for beef and mutton, respectively. Consequently, Malaysia heavily relies on imports to meet its demand for beef, with a large portion of the supply coming from India, predominantly in the form of buffalo meat (Khalex *et al.*, 2021). This dependency emphasizes the need for further development of and investment in the domestic ruminant industry to enhance self-sufficiency and reduce reliance on imported red meat.

Challenges in feed supply are key factors that constrain ruminant production. Currently, there is a strong focus on developing practical, cost-effective feeds tailored to different classes of ruminant species. However, the low utilisation of fibre resources and the absence of effective methods to transform local feedstuffs or agricultural by-products, such as those from oil palm, into high-quality feeds pose significant obstacles in advancing feed options for local ruminant livestock (Saminathan *et al.*, 2022). For instance, the feed pellets for beef cattle available in the market today typically incorporate only one oil palm by-product, which is the PKM. This limited approach highlights the need for more diverse and efficient feed formulations to support the growth and productivity of the ruminant sector.

Recently, the Malaysian Palm Oil Board (MPOB) has introduced an innovative formulation for beef cattle feed pellets that incorporates three key by-products from the oil palm industry. This formulation includes PKM, EFB, and crude palm oil (CPO), which together constitute approximately 80 % of the total feed composition. PKM is a source of crude protein, EFB is a source of fibre, and CPO is a source of fat and energy (Zahari *et al.*, 2012). The incorporation of EFB in this feed formulation is an innovation in the market and offers the potential to reduce raw material costs while maintaining the nutritional quality of the feed pellet. Therefore, the utilisation of oil palm by-products and their processing into high quality beef cattle feed on a commercial scale was undertaken here to evaluate the effects of these by-products on beef cattle growth.

2 Materials and methods

2.1 Feed pellets

Raw materials for oil palm-based feed pellet (OPB) and commercial feed pellet (COM) production were purchased from Nutri Vet Livestock Sdn. Bhd., Nilai, Malaysia. Meanwhile, OPF were obtained from Pertubuhan Peladang Negeri Johor (PPNJ) Oil Palm Plantation, Bukit Bujang, Segamat, Johor.

The OPB feed pellet was formulated using PKM, EFB, CPO, wheat pollard, soybean meal and feed additives (Table 1) to meet maintenance requirements of beef cattle, adhering to the nutrient requirements outlined by the NRC (2000). The formulation process was done by utilizing FORMAT software (WinFeed Limited, Cambridge, UK) to ensure that the OPB feed pellet was isonitrogenous and isocaloric with the COM feed pellet. The COM feed pellets were formulated using PKM, rice bran, corn and feed additives. However, the specific inclusion levels of each ingredient were not disclosed by the manufacturer.

Table 1: *Raw ingredients for palm-based feed pellet (OPB).*

Raw ingredient	*Inclusion level (% DM)*
Oil palm ingredients*	80.15
Wheat pollard	8.35
Soyabean meal	4.00
Molasses	6.00
Vitamin mineral premix	1.00
Salt	0.50

*Oil palm ingredients consist of palm kernel meal, empty fruit bunch and crude palm oil

The OPB feed pellet production was conducted at PPNJ Feedmill, Bukit Bujang, Segamat, Johor, on 13th December 2021. The feed mill was equipped with a hammer mill, four holding bins with weighers for raw material storage and weighing, a horizontal mixer with a capacity of 500 kg, a conditioner, a pelletiser with an 8 mm die, a cooler and an automatic weighing platform for feed pellet packaging. Augers and bucket elevators were used to move the raw materials from one machine to another. The operation of feed production was controlled using an automated Feedmill Control System.

PKM was pulverised to 3 mm and EFB to 5 mm using a hammer mill, then stored in respective holding bins. The raw materials and feed additives were weighed according to the developed feed pellet formulation. The weighed raw materials were transferred to the mixer and feed additives were manually added into the mixer before the ingredients were mixed for 15 minutes. The mixed materials were then transferred to the holding bin before being pelletised. The feeder frequency of the pelletiser was set at 20 Hz. The capacity of the pelletiser was 1 ton per hour. After the pelletising process, the feed pellet was cooled in the cooler machine to reduce the temperature and sieved to remove fines and feed fragments. Finally, the feed pellet was packaged into bags before being transported to the feedlot for the feeding trial.

2.2 Proximate analysis

Both OPB and COM feed pellet samples were analysed for moisture content (AOAC 930.15) was determined using an AND Moisture Analyser, crude ash (AOAC 942.05) using a Carbolite Muffle Furnace, crude protein by the Dumas method (AOAC 968.06) using a Dumatherm Analyser, crude fat (AOAC 920.39) by using a Soxtherm Extractor, and gross energy (AOAC 947.07) by using an IKA Bomb Calorimeter, following the procedures of the Association of Official Analytical Chemists (AOAC, 1990). The crude fibre content was determined using the method described by Van Soest *et al.* (1991) by using a Fibertherm system (Gerhardt, Germany).

2.3 Feeding trial and growth performance

The feeding trial was conducted at PPNJ Beef Cattle Feedlot, Bukit Bujang, Segamat, Johor, from 14th December 2021 until 28th March 2022. Forty-two (42) male Kedah-Kelantan (KK) crossbred beef cattle with an initial body weight (BW) of 162 kg were assigned to two groups, OPB and COM (21 beef cattle for each group) using a completely randomised design (CRD). The beef cattle were assigned in three replicates of 7 animals per group into six paddocks (7 $\times$ 10 meters) and had free access to water. Feed pellets were offered every morning at 1 % BW of the beef cattle. Since cattle were housed in groups, the total amount of pellets for each paddock was calculated based on the total BW of the seven animals within the group and then evenly distributed in a shared feed trough. OPF were provided ad libitum twice daily. The OPF was chopped into 2-3 cm before feeding. The beef cattle were allowed an adjustment period of 14 days, followed by the feeding trial of 90 days.

Feed intake of the cattle was monitored daily by measuring the amount of feed offered and the residual feed remaining. Their BW was recorded monthly using a digital weight scale (Eziway5i, Tru-test, New Zealand) with an accuracy of 0.1 kg and a maximum capacity of 3000 kg. The amount of feed offered was adjusted every month, based on BW changes. The average daily gain (ADG) was determined by dividing the difference between the initial and final BW by the total number of days in the experiment.

2.4 Carcass composition and meat quality

At the end of the feeding trial, one animal from each group was transported to a commercial slaughterhouse. The slaughtering process was carried out following the Halal procedures specified in MS 1500:2009 (Malaysian Standard, 2009). The dressed weight of the carcasses was recorded after removing the skin, head, internal organs, and internal fats. The carcasses were divided into two halves (right and left) and the left carcasses were weighed again before being transported to Feed Research Group (FRG), MPOB Keratong Research Station, Pahang. After being refrigerated in a cold room at 4 °C for 24 h, the weight of the cold carcasses was recorded. The carcasses were further dissected into meat, bone, and fat and the data were used to determine carcass composition based on the left side of the cold carcass weight.

A representative meat sample from the Longissimus dorsi muscle of the left half-carcass was collected from each slaughtered animal for meat quality evaluation. For each treatment group, meat quality traits were measured in triplicate using samples from the same animal. The meat colour of the raw muscle samples was measured at room temperature using a Konica Minolta Chroma Meter (CR-400 Chroma Meter, Osaka, Japan) at three points on the cut surface of each meat sample. Colour measurements were recorded in terms of luminosity (L^*), index of red (a^*) and index of yellow (b^*).

Natural drip loss and cooking loss were assessed following Honikel (1998). Three ~20 g slices from each raw meat sample were sealed in polyethylene bags and stored at 4 °C. After 20 h, samples were re-weighed to calculate drip loss as the weight difference. Another three slices were weighed, sealed in plastic bags, and cooked in a water bath at 80 °C for 1 h. Samples were then cooled under running water for 30 min, blotted dry, and re-weighed. Cooking loss was determined as the weight difference before and after cooking.

Meat texture was analysed using a TA.XT-plus Texture Analyser (Stable Micro System, Surrey, UK) with a Warner-Bratzler shear device. Three samples were sheared longitudinally, parallel to the muscle fibres. The blade was applied perpendicular to the fibres at 4.0 mm s^{-1} to measure Warner–Bratzler shear force (WBSF), indicating meat tenderness by the force required to cut through the muscle.

2.5 Statistical analysis

Statistical analysis was performed on data relating to growth performance and feed intake parameters using a t-test (SAS Inst., 2013) to compare means at the 0.05 significance level.

3 Results

3.1 Composition of feed pellets and cattle growth performance

The proximate values of OPB and COM feed pellets are shown in Table 2.

Table 2: *Proximate analysis of oil palm-based beef cattle (OPB) and commercial (COM) feed pellets.*

Proximate analysis	*OPB*	*COM*
Moisture content, % DM	7.35	10.38
Crude ash, % DM	3.73	4.74
Crude fat, % DM	8.10	4.17
Crude protein, % DM	17.30	17.11
Crude fibre, % DM	14.40	14.68
Gross energy, kJ g^{-1}	19.95	18.62

Note: OPB – oil palm-based beef cattle feed pellet; COM – commercial pellet; DM – dry matter.

Table 3: *Growth performance of beef cattle fed with different feed pellets.*

Parameters	*OPB*	*COM*	*SEM*	*p-value*
Initial BW, kg	165.5	159.1	2.91	0.28
Final BW, kg	222.1	212.1	3.73	0.18
Tot. weight gain, kg	56.7	53.1	2.11	0.40
Av. daily gain, g day^{-1}	590	630	0.02	0.41
FCR	9.56	10.0	0.49	0.69

Note: Data show means of three statistical replicates per group. BW - body weight; Av. - average; OPB – oil palm-based beef cattle feed pellet; COM – commercial pellet; FCR – feed conversion ratio: kg feed per kg BW gain.

Table 3 presents the growth performance of beef cattle fed with the two types of pellets. The initial BW of the cattle showed no significant differences between the treatment groups ($p > 0.05$), implying that the animals were uniformly distributed by weight. By the end of the feeding trial, both groups exhibited a similar BW increase, with the OPB group increasing from 165.5 kg to 222.1 kg, and the COM group increasing from 159.1 kg to 212.1 kg. The ADG of the OPB group was slightly higher than that of the COM group with 630 g day^{-1} as compared to 590 g day^{-1}, respectively ($p = 0.41$). The feed conversion ratio (FCR) for beef cattle in the OPB group was slightly better with 9.59 as compared to the COM group with 9.98 ($p = 0.69$).

Table 4 shows the feed intake of beef cattle fed with the two different feed pellets. There were no differences ($p > 0.05$) observed for pellet dry matter intake (DMI), OPF

DMI and total DMI. The DMI (% BW) ranged from 3.04–3.06, which is within the requirement for beef cattle.

Table 4: *Feed intake of beef cattle fed with different feed pellets.*

Parameters	*OPB*	*COM*	*SEM*	*p-value*
Pellet DMI, kg day^{-1}	1.96	1.97	0.025	0.85
OPF DMI, kg day^{-1}	4.58	4.26	0.081	0.08
Total DMI, kg day^{-1}	6.54	6.24	0.094	0.07
DMI, % BW	3.04	3.06	0.052	0.89

Note: Data show means of three statistical replicates per group. OPB – oil palm-based beef cattle feed pellet; COM – commercial pellet; DMI – dry matter intake; OPF – oil palm fronds.

3.2 Carcass composition and meat quality

Characteristics of slaughtered animals and their carcass composition are shown in Table 5. Beef cattle fed with the OPB pellet had slightly higher values of meat and fat percentages with 71.7 % and 9.6 %, respectively, as compared to beef cattle fed with the COM feed pellet. Table 6 presents the meat quality results for beef cattle fed with different feed pellets. The meat from the OPB group showed higher redness (a*) and yellowness (b*) values compared to the meat from the COM group, suggesting a noticeable difference in meat colour.

Table 5: *Slaughter characteristics and carcass composition of beef cattle fed OPB and COM diets*

Parameters	*OPB*	*COM*
Slaughter characteristics		
Slaughter weight, kg	220.0	200.0
Dressed carcass weight (whole), kg	103.5	98.5
Dressing percentage, %	47.1	49.3
Dressed carcass weight (left side), kg	46.0	56.3
Cold carcass weight (left side), kg	44.7	54.8
Carcass composition (% of cold carcass weight)		
Meat	71.73	69.62
Bone	18.69	22.15
Fat	9.59	8.23

Note: Data represent one animal randomly selected from each group of 21 animals. OPB – oil palm-based beef cattle feed pellet; COM – commercial pellet. The data are descriptive only and were not statistically analysed due to the lack of replication.

4 Discussion

Conducting proximate analysis helps feed manufacturers to understand the nutritional composition of feed formulations and ensures the quality and nutritional adequacy of feed pellets in livestock production. In this study, both feed pellets had a total moisture content below 13 %, which is considered optimal for preventing mold growth, as storage fungi typically proliferate at moisture levels above 13–15 % (Ungureanu *et al*., 2018). Mold growth not only poses a risk to the health of animals consuming the feed but can also degrade the quality of the pellets during storage.

The results of the proximate analysis show that OPB feed pellet formulation using oil palm by-products as the main ingredients produced a complete nutrient feed for beef cattle which is comparable to the commercial feed in terms of crude protein, crude fibre and gross energy content. Crude protein and gross energy are key components in feed formulations to meet livestock requirements. Crude protein directly supports growth, muscle development, milk production, and overall productivity. However, crude protein is also one of the most expensive components in animal feed, making it a significant factor in the overall cost of feed production (Vakili *et al*., 2015). The OPB feed formulation aimed to achieve a similar level of crude protein as the COM pellet (isonitrogenous) with 17.3 % and 17.11 %, respectively, and isocaloric to the COM feed pellet with a gross energy value of 19.95 kJ g^{-1} and 18.62 kJ g^{-1}, respectively. The crude fat content was higher in the OPB pellet than in the COM pellet, as the recommended total fat content for feedlot diets is 8.0 % (Vasconcelos & Galyean, 2007). A higher fat content can improve palatability and enhance overall performance, such as improving weight gain or feed efficiency in beef cattle (Cho *et al*., 2024).

Cattle producers usually use the ADG to control the feed allocated to the animals, ensuring that the target weight can be reached within the desired timeframe (Nugi & Danbaro, 2018). In this study, both groups recorded comparable ADG data to Kedah-Kelantan beef cattle in Malaysia, ranging between 0.12–0.53 kg day^{-1} with locally available feedstuff on grazing lands and some concentrate supplementation with PKM and salt licks (Islam *et al*., 2021).

Another study has shown that no significant effects of PKM inclusion on ADG and FCR of crossbred cattle as compared to no PKM inclusion into the diet (de Melo Lisboa *et al*., 2021). Similarly, Yusoff *et al*. (1987) reported that ADG of cattle fed with 100 % PKM was not significantly different to ADG of cattle fed with a 50:50 ratio of PKM and sago pith. Another study by Santos *et al*. (2019) showed that Holstein × Zebu crossbred cows fed with a diet including PKM had better ADG and FCR than non-PKM groups. This was due to the higher DMI by the supplemented animals.

Among the factors that influence feed intake in animals are diet composition, feed availability, and palatability (Yusuf *et al*., 2014). Although Abubakr *et al*. (2013)

described that oil palm by-products such as PKM are often regarded as unpalatable, our current study showed that incorporating these ingredients into the diet did not affect feed intake. This suggests that offering the product in a pelleted form may have successfully mitigated palatability issues. Similarly, Wong & Wan Zahari (1997) stated that DMI remained constant in cattle fed with either 100 % PKM or a diet combining PKM and cocoa pod husks. Other studies have also shown improvements in feed intake through various processing techniques for incorporating agricultural by-products (Leng, 1990; Abubakr *et al.*, 2013; Karimizadeh *et al.*, 2017).

In terms of carcass and meat quality, Santana Filho *et al.* (2016) found that replacing soybean meal with oil palm by-products in bulls' diets maintained the meat quality including water holding capacity and texture parameters, which was also reported by Andrae *et al.* (2001). Another study by Rodrigues *et al.* (2021) found that feeding cattle a diet containing oil palm by-products significantly increased the yellowness of the meat when compared to the group fed a control diet. In certain markets, such as parts of South Africa, a segment of consumers, particularly those with higher education levels, prefer beef with yellow fat, associating it with natural feeding practices and perceived health benefits (Mare *et al.*, 2013). Similarly, Phoemchalard & Uriyapongson (2015) reported that cattle fed with CPO had a higher redness index of the meat as compared to non-CPO fed cattle. This might be attributed to the vitamin E content, which is associated with higher myoglobin levels in the meat (Faustman *et al.*, 2010).

5 Conclusion

The oil palm-based feed pellet provides a complete nutrient profile, fulfilling all essential nutritional needs for beef cattle. Its effectiveness in promoting beef cattle growth performance is equivalent to that of commercial feed pellets. The findings indicate that incorporating oil palm by-products in feed pellets can be used as alternative feed formulation approach that is not compromising beef cattle performance.

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Conflict of interest

The authors declare that they have no conflict of interest.

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