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Effects of the inclusion of crude palm oil and palm kernel meal on broiler performance and chicken meat texture

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ABSTRACT

Agricultural by-products are abundantly available and cost-effective feed materials that could replace conventional feed grains for poultry production. This study aimed to evaluate the performance of broilers fed with formulations containing crude palm oil and palm kernel meal as compared to commercial feed, as well as the texture of the chicken meat produced. A total of 900 mixed-sex day-old Ross 308 broiler chicks were divided into two groups in two closed-house systems, each fed with one of two treatments: feed with crude palm oil and palm kernel meal inclusion (T1) or commercial feed (T2). The feeding trial lasted for 35 days. The results showed that T1-fed broilers had a lower feed intake than T2-fed broilers, while their weight gain was higher than that of T2-fed broilers, which resulted in a better feed conversion ratio in the T1 group of 1.32 than that of the T2 group of 1.40 over the entire period (1-35 days). The broiler performance index was above the minimum acceptable level of 270 for both groups. The fine percentage of the T1 group was significantly lower ($P<0.05$) compared to the T2 group. Meanwhile, no significant differences ($P>0.05$) were observed in the texture evaluation of raw and baked chicken meat samples between the T1 and T2 groups. This study highlighted that broiler feed formulations can use locally available feedstuffs, such as crude palm oil and palm kernel meal, as an alternative to conventional imported feed ingredients, with good overall broiler performance and chicken meat texture.

Keywords: feed conversion ratio, fines test, growth performance, meat quality, poultry

INTRODUCTION

The poultry industry has contributed greatly to the agricultural sector, especially towards protein food production. In 2023, Malaysia produced 1,545,000 metric tonnes of broiler meat and imported about 180,000 metric tonnes to meet the needs of domestic consumption (United States Department of Agriculture, 2024).

The demand for chicken meat products as high-quality and safe protein sources is expected to continuously rise with the increase in the world population and per capita income. Almost all developing countries are net importers of feed grains, i.e., the poultry industries in Africa and Asia depend on imports, which drain their foreign exchange reserves (Ravindran, 2017). Therefore, attempts to cut costs have revolved around finding cost-effective and locally available substitutes, such as agro-industrial by-products (García et al., 1999). Since the by-products are very rich in nutrients, there is a great opportunity to produce balance and adequate energy and protein levels in broilers' diet by incorporating materials at a certain percentage to get optimum productivity of the chickens.

Energy sources constitute the largest component of poultry diets, followed by plant protein sources and animal protein sources. The use of different types of oils and fats as energy sources in broiler feeds has been a growing practice (Jayalakshmi et al., 2006). Apart from that, inclusion of oils and fats also supplies dietary essential fatty acids (linoleic and linolenic acids) that cannot be synthesised by the animals, aids in the absorption of fat-soluble vitamins, and provides specific bioactive fatty acids (Sanz et al., 1999). The nutritive values of oils and fats are varied according to their chemical compositions (Wiseman et al., 1992). The oxidation degree of triglycerides from oils and fats is found to release more than double the energy compared to carbohydrates. The deposition of 1 g of energy from carbohydrates or proteins by an animal requires higher quantities of these nutrients in comparison to the deposition of 1 g of energy from oils and fats (Baiao and Lora, 2005). Considering diets with similar nutritive value, the use of different types of oils in broiler feeds has been reported to cause better performance as compared to birds fed diets without oil inclusion (Moura, 2003; Tabeidien et al., 2010).

Besides energy, proteins are also an important dietary macronutrient for animals, which plays a significant role in the process of life (Liu et al., 2015). The growth rate and feed efficiency of broilers improve with the increase in dietary proteins, and there is a wealth of information about the effects of crude proteins on the performance and body composition of chickens (Jackson et al., 1982; MacLeod, 1990; Buyse et al., 1992; Collin et al., 2003; Swennen et al., 2005; Niu et al., 2009; Miu et al., 2012). The requirements for proteins and their amino acids differ according to the age, productive state and breed of the broilers (Nutrient Requirement Council, 1994). In order to meet the requirement of protein sources in broilers' diet, a huge amount of imported feedstuffs is used to obtain maximum productivity. This has led to rising feed prices for poultry production.

The major imported conventional feed ingredients that have been used in broiler feed production are grain corn and soybean meal. Corn grain is the most commonly used material as an energy source, and soybean meal is the most common plant protein source. The price of grain corn has increased gradually year by year, from RM 642 per metric tonne in 2013 to RM 965 per metric tonne in 2023, with the highest price recorded at RM 1,334 in 2022. The price of protein meal sources such as soybean meal has also increased from RM 1,851 per metric tonne in 2013 to RM 2,447 per metric tonne in 2023 (World Bank, 2024). Given the increasing costs of these feed ingredients, there is a need to find low-cost feed ingredients as an alternative for broilers' feed production (Dorra et al., 2014).

The worldwide palm oil production reached 78 million metric tonnes in the marketing year of 2022/2023, reflecting a growth from 73 million metric tonnes in 2021/2022 (Statista, 2024). Palm oil and its derivatives play a significant role in animal nutrition and feed production. The ever-expanding oil palm cultivation in Malaysia and other tropical countries offers a sustainable supply of oil palm-based feed ingredients as an alternative to conventional feed ingredients in broiler feed formulations. CPO (Crude Palm Oil) is an oil palm product that is used as a source of energy in animal feeding (Saminathan et al., 2020). Meanwhile, PKM (Palm Kernel Meal), is a promising and affordable by-product of palm kernel oil extraction through solvent-based or mechanical processes. This can be used as a protein source in animal feed rations to reduce feed costs (Abidah and Wan Nooraida, 2017). Partial replacement of soybean meal and grain corn with PKM and CPO in formulated feed would not only greatly reduce the production cost of animal protein in Malaysia, but would also enable Malaysian livestock industries to become more competitive. Therefore, this study was conducted to evaluate the effects of CPO and PKM inclusion on broiler performances and the texture of the chicken meat produced.

MATERIALS AND METHODS

Materials

A total of 900 mixed-sex-day-old chicks Ross 308 breed, 450 males and 450 females, along with commercial broiler feed and raw materials for oil palm-based feed production such as corn, soybean meal, fishmeal, CPO, PKM and feed additives for broilers were purchased from Y&H Pet Shop in Segamat, Johor, Malaysia and Nutri Vet Livestock Sdn. Bhd. in Nilai, Negeri Sembilan, Malaysia.

Feed treatments

This study utilised two types of feed treatments. Feed for T1 was formulated using CPO, PKM, corn, soybean meal, fish meal, and feed additives. In contrast, the ingredients for T2 included plant proteins, grains, grain by-products, calcium, phosphorus, amino acids, antioxidants, mold inhibitors, vitamins, minerals, and approved antibiotics and anticoccidials, as stated on the packaging. The proportions of the feed ingredients are shown in Table 1. T1 was formulated to match T2 in terms of crude protein content (isonitrogenous) and gross energy (isocaloric).

Feed production

Broiler starter and grower feeds for T1 formulation were produced at the MPOB Animal Feed Pilot Plant, Feed Research Group, MPOB Keratong Research Station, Pahang, Malaysia. Broiler starter feed was produced in crumble form (Figure 1(a)) and fed to the broilers from day 1 until day 21, followed by broiler grower feed for utilisation from day 22 until harvesting on day 35 in 3-mm pellet form (Figure 1(b)).

Feeding trial

The feeding trial was conducted at a commercial broiler farm in Kampung Bagan, Batu Pahat, Johor, Malaysia, from December 2023 to January 2024. A total of 900 mixed-sex day-old Ross 308 chicks were used in a 35-day trial. The chicks were randomly assigned to two treatment groups and housed separately in two closed-house floor pen systems (House 1 and House 2), with 450 birds per house. Each house was divided into three replicates, comprising 150 birds per replicate (75 males and 75 females) (Figure 2). Birds in House 1 were assigned to T1, while those in House 2 received T2. Feeds were provided daily based on the Ross 308/308 FF Broiler: Performance Objectives (2022), using plastic feeders, and clean drinking water was supplied *ad libitum* via automated bell drinkers. Each house measured 37 feet in length and 10 feet in width, featuring perforated plastic flooring.

Table 1. Feed formulation of broiler starter and grower feeds

Feed Ingredients, %	Treatment	
	T1	T2
Starter feed		
Corn	53.00	-
Soybean meal	35.00	-
Oil palm products	4.00	-
Fish meal	4.00	-
Feed additives	3.00	-
Plant protein	-	NA
Grains	-	NA
Grain by-products	-	NA
Calcium	-	NA
Phosphorus	-	NA
Amino acids	-	NA
Antioxidants	-	NA
Mold inhibitors	-	NA
Vitamins	-	NA
Minerals	-	NA
Antibiotics	-	NA
Anticoccidials		NA
Grower feed		
Corn	53.00	-
Soybean meal	29.00	-
Oil palm products	10.00	-
Fish meal	5.00	-
Feed additives	3.00	-
Plant protein	-	NA
Grains	-	NA
Grain by-products	-	NA
Calcium	-	NA
Phosphorus	-	NA
Amino acids	-	NA
Antioxidants	-	NA
Mold inhibitors	-	NA
Vitamins	-	NA
Minerals	-	NA
Antibiotics	-	NA
Anticoccidials	-	NA

T1 = feeds with CPO and PKM inclusion; T2 = commercial feeds;
NA = Not available

(a)

(b)

Figure 1. T1 feed for (a) starter period in crumble form and (b) grower period in pellet form

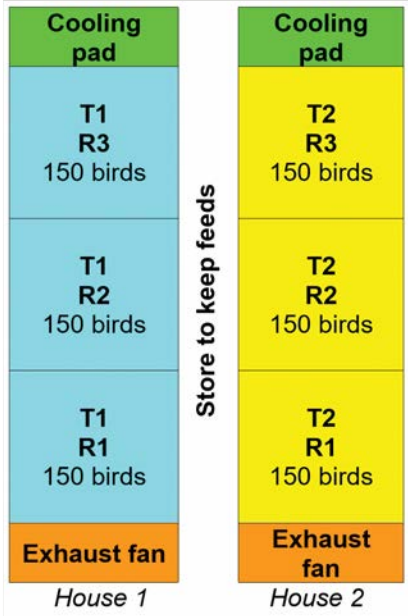

Figure 2. Experimental design for broiler feeding trial (R1: replicate 1; R2: replicate 2; R3: replicate 3)

Environmental conditions were managed using cooling pads and exhaust fans to regulate indoor temperature, and microclimatic parameters such as temperature and relative humidity were monitored daily using a digital thermo-hygrometer. The lighting regime consisted of 11 hours of natural daylight and 13 hours of artificial lighting per day.

Growth performance

The chicks were weighed in bulk upon arrival and recorded as average initial weight. Feed intake and weight gain of the broilers (15 broilers in each replication) were recorded daily and weekly, respectively, to assess the FCR (Feed Conversion Ratio) of each treatment group. The mortality of the broiler was monitored and recorded daily. Growth performance was evaluated on days 1–21 as the starter period, days 22–35 as the grower period, and days 1–35 as the whole period. Broiler Performance Index (BPI) was calculated based on their liveability, body weight, total days of trial and FCR.

$$Feed\ Conversion\ Ratio = \frac{Feed\ intake}{Weight\ gain}$$

$$Broiler\ Performance\ Index = \frac{Liveability \times Body\ weight}{Total\ days \times FCR} \times 100$$

Proximate analysis

The proximate analysis was carried out at the Analytical Laboratory, Feed Research Group, MPOB Keratong Research Station, Pahang. The experimental ration samples were analysed according to the recommended procedures of the Association of Official Analytical Chemists (AOAC, 1990) for proximate composition.

The total moisture content of the feed samples was analysed using a Moisture Analyzer (A&D, Japan). The crude fat content of the feed was determined following the ether extraction method using a SOXTHERM® machine (Gerhardt, Germany). The gross energy value of the samples was analysed using a bomb calorimeter (IKA®-WERKE, Germany). The crude protein (CP) was determined according to the Dumas method using a Dumatherm machine (Gerhardt, Germany). The total ash content was analysed by using a furnace at 600 °C for 2 hours. The crude fibre was determined using a Fibertherm system (Gerhardt, Germany) following the Van Soest method (Van Soest et al., 1991).

Fines test

The fines test for grower feeds was conducted using an American Society for Testing and Materials (ASTM) mesh sieve of 2 mm diameter. Triplicate samples of 500 g were weighed and sieved to remove the fine particles from the whole broiler grower feed pellets. Fines were calculated as the percentage of pellets remaining in the mesh sieve of the initial whole pellet weight.

Texture analysis of chicken meat

The chicken meat samples (breast part) were divided into two groups: raw and baked samples. The baked chicken meat samples were prepared by wrapping them in aluminium foil and baking them at 170 °C for 35 minutes. The texture of the raw and baked chicken meat samples was determined by using a Texture Analyzer (TA. XT21, Texture Technologies Corp., UK) with a 5 kg load cell (Figure 3). A Warner-Bratzler blade with a test speed of 5 mm/s and a post-test speed of 10 mm/s was applied to compress the samples with a distance of 28 mm penetration (Lee et al., 2022). The texture was expressed as breaking force (kg) and breaking strength (kg · cm) for the sample firmness and toughness, respectively.

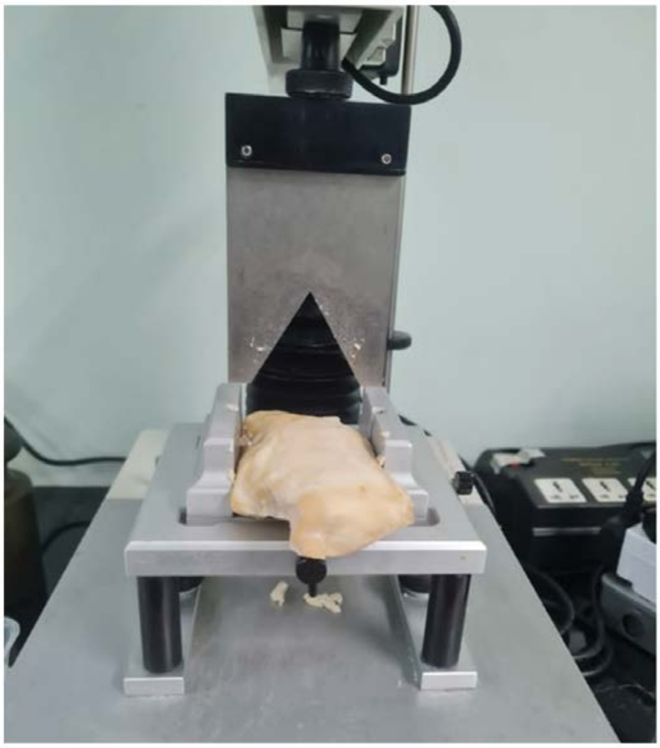

Figure 3. Texture analysis of chicken meat samples using a Texture Analyzer

Statistical analyses

All analyses were done in triplicate. The data collected were subjected to analysis of variance (ANOVA). Mean differences among treatments were analysed by Duncan's Multiple Range Test using SAS 9.1TM statistical package (SAS Institute Inc., Cary, North Carolina, USA, 2003). Statistical significance was set at $P<0.05$.

RESULTS

Proximate composition

The proximate composition of broiler starter and grower feeds for T1 and commercial feed T2 groups is tabulated in Table 2. The results show that both T1 and T2 starter feeds contained below than 13% moisture content, which is the maximum standard specification for broiler feed pellets.

Table 2. Proximate composition of broiler starter and grower feeds

Proximate Composition, %	Treatment		Standard Specification*
	T1	T2	
Starter feed			
Moisture	10.77	11.43	Max, 13
Total Ash	6.31	6.27	Max, 8
Crude Fat	6.02	7.04	Min, 5
Crude Protein	24.21	24.02	Min, 21
Crude Fibre	3.70	3.66	Max, 5
Gross Energy (cal/g)	4585	4578	Min, 2900
Grower feed			
Moisture	8.76	11.73	Max, 13
Total Ash	6.03	5.58	Max, 8
Crude Fat	7.77	8.36	Min, 5
Crude Protein	22.15	22.02	Min, 19
Crude Fibre	4.06	3.70	Max, 5
Gross Energy (cal/g)	4660	4668	Min, 3100

T1 = feeds with CPO and PKM inclusion; T2 = commercial feeds
*Source: Malaysian Standard 20:2008 (2008)

The moisture content of feed must be lower than 13% to prolong its shelf life and also to prevent bacterial and fungal growth. According to the Malaysian Standard 20:2008 (2008), the maximum level of total ash content for poultry feed is 8%. In this study, the total ash content of T1 and T2 starter feeds was in accordance with the specified level. The crude fat content of both broiler starter feeds fulfils the minimum crude fat requirement of 5% for broilers. Other than that, the crude protein content for T1 and T2 starter feeds was 24%, higher than the minimum requirement for broiler starter feed of 21%. The results of gross energy showed that T1 and T2 starter feeds meet the minimum gross energy requirement of 2900 cal/g, with values of 4585 and 4578 cal/g, respectively.

A similar trend was obtained for the proximate composition of the broiler grower feeds. T1 and T2 grower feeds fall within the standard specification, with T2 grower feed having a higher moisture content of 11.73% and T1 grower feeds having a moisture content of 8.76%. The results also indicate that T1 and T2 grower feeds did not exceed the maximum level of total ash content of 8%. Both broiler grower feeds contained crude fat above 5%, with 7.77% for the T1 feed and 8.36% for the T2 feed. Both broiler grower feeds were isonitrogenous with 22% crude protein content, and exceeding the minimum value of 19% crude protein of standard broiler grower feed. The results also showed that both treatment groups were isocaloric, with an average gross energy of 4660 cal/g.

Growth performance

Figure 4 shows the growth curves of broilers fed with T1 and T2 feeds, as well as the standard growth curve of Ross 308 broiler chicken as the benchmark of weekly weight.

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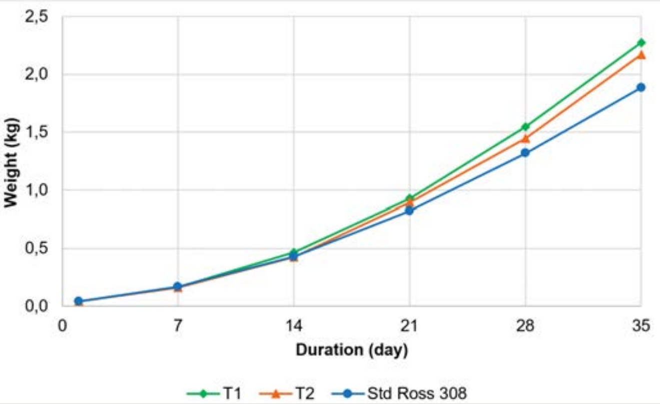
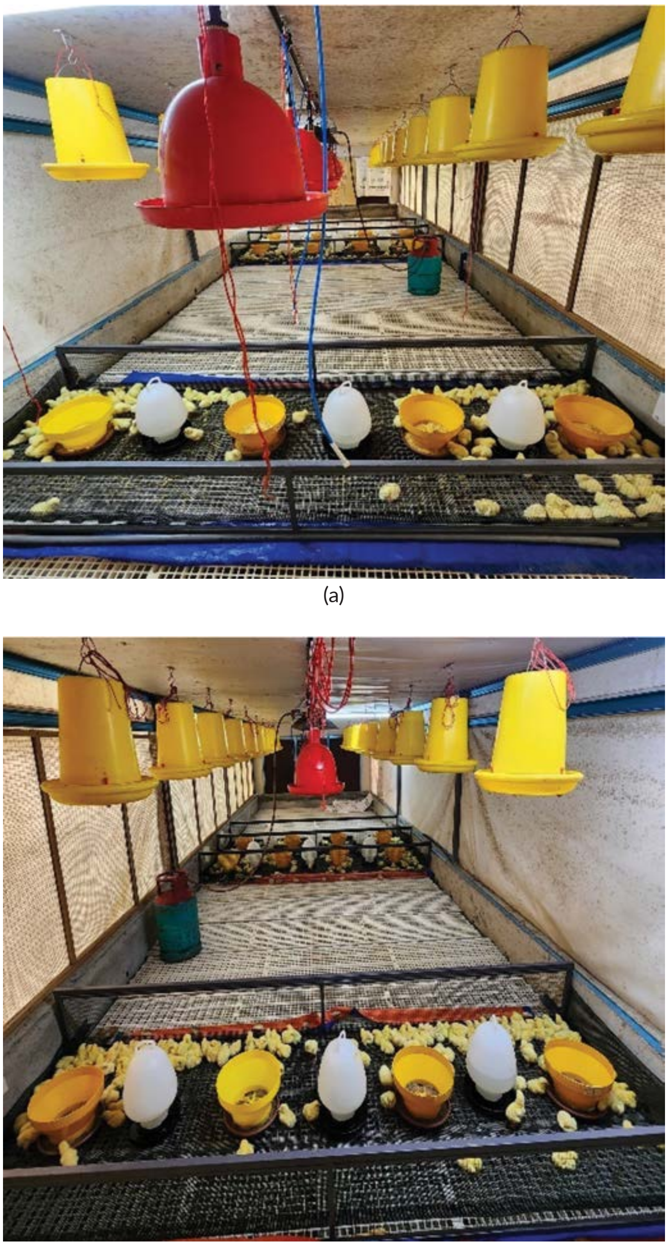


Figure 4. Growth curves of broilers fed with T1 and T2 for 35 35-day feeding trial

The initial mean weight of day-old chicks was 0.043 kg. During day 7 of the feeding trial, broilers in both T1 and T2 groups showed a comparable body weight to the standard Ross 308, with an average of 0.16 kg. T1-fed broilers showed superior weight starting from day 14 with 0.46 kg, while T2-fed broilers showed slightly lower weight than the standard Ross 308 weight of 0.42 and 0.43 kg, respectively. During day 21 of the feeding trial, T1-fed broilers continued to show a similar trend, reaching a weight of 0.93 kg. Meanwhile, T2-fed broilers started to have better weight with 0.89 kg compared to the standard Ross 308 of 0.82 kg. During the grower period on days 28 and 35, a similar trend was observed. T1-fed broilers again showed higher weight with 1.55 and 2.27 kg on days 28 and 35, respectively, as compared to the T2 group with 1.45 and 2.17 kg on days 28 and 35, respectively. Both groups had a higher weight than that of the standard Ross 308 growth curve in this grower period. Figures 5 and 6 show the broiler feed houses on days 1 and 35, respectively.

Figures 7 and 8 illustrate the number of mortalities based on replication and mortality rates, as well as the liveability of broilers fed with T1 and T2 feeds throughout the 35-day feeding trial, respectively. A total of ten broilers, which account for 2.22% of the broilers in the T1 group, did not survive. Among them, there were 6 mortalities in replicate 1 (R1), 3 mortalities in replicate 2 (R2), and 1 mortality in replicate 3 (R3), all of which occurred in House 1. Meanwhile, in House 2, T2-fed broilers showed a higher total mortality of 14 birds, equivalent to 3.11%. R1 showed the highest mortality of 8 birds, followed by R3 with 4 mortalities and R2 with 2 mortalities. These reflect a slightly higher liveability rate of T1-fed broilers, with 97.78% as compared to T2-fed broilers, with 96.89%. Most of the broilers died during the starter period from days 8 to 21 in both houses, with a consistent pattern where R1 from each house recorded the highest mortality compared to the other replicates.



(a)

(b)

Figure 5. Feeding trial on day 1 (a) T1-feed house (b) T2-feed house

(a)

(b)

Figure 6. Feeding trial on day 35 (a) T1-feed house (b) T2-feed house

This might be attributed to the location and function of the cooling pads installed at the rear of the houses adjacent to R3, which serve to lower the houses' temperature and efficiently eliminate ammonia at the back of the houses.

Table 3 shows the overall broiler performance for the starter, grower, and whole periods of the T1 and T2 groups. During the starter period (days 1–21), T2-fed broilers consumed a significantly higher (P<0.05) amount of feed, with 1.06 kg of feed per bird as compared to T1-fed broilers with 1.05 kg of feed per bird.

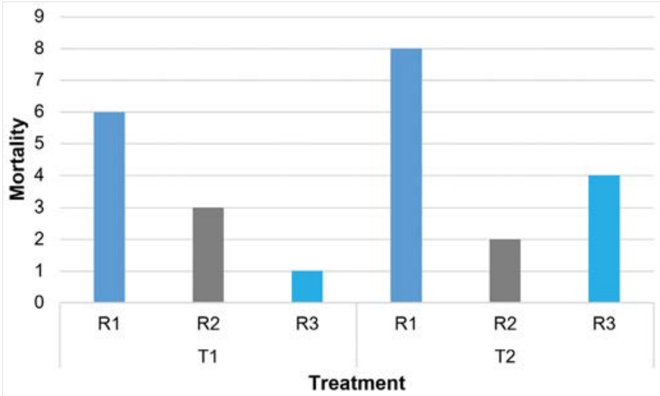


Figure 7. Mortality number of broilers fed with T1 and T2 feeds based on replication (R1 = replicate 1; R2 = replicate 2; R3 = replicate 3)

However, despite a lower feed intake, T1-fed broilers showed a higher weight gain of 0.89 kg than that of T2-fed broilers, with 0.85 kg on day 21. This led to a better FCR value in the starter period for T1-fed broilers at 1.18 compared to T2-fed broilers with a FCR value of 1.25. During the grower period (days 22–35), T1-fed broilers consistently consumed lower feed intake and produced a higher average weight gain than T2-fed broilers, which resulted in a significantly better (P<0.05) FCR in the former of 1.42 compared to the FCR in the latter of 1.53.

The whole period (days 1–35) of broiler performance followed the same pattern as the starter and grower periods. The average feed intake of T1-fed broilers (2.94 kg) was lower than that of T2-fed broilers (2.98 kg), while the average weight gain of T1-fed broilers was higher (2.23 kg) than that of T2-fed broilers (2.13 kg). On day 35, the T1-fed broilers again had a better FCR value of 1.32 than that of the T2-fed broilers at 1.40. Despite the given results, no significant differences (P>0.05) were seen in these three parameters over the whole period. The broiler performance index (BPI) was calculated based on the weight gain, liveability, days of feeding and the FCR value obtained. In this study, the BPI was above the minimum acceptable level of 270 for both groups, with a higher level reported for the T1-fed broilers (490.14) as compared to the T2-fed broilers (436.48). This implies that the entire group performed well, with a low overall mortality rate, a high body weight gain, and an acceptable FCR value throughout the feeding trial.

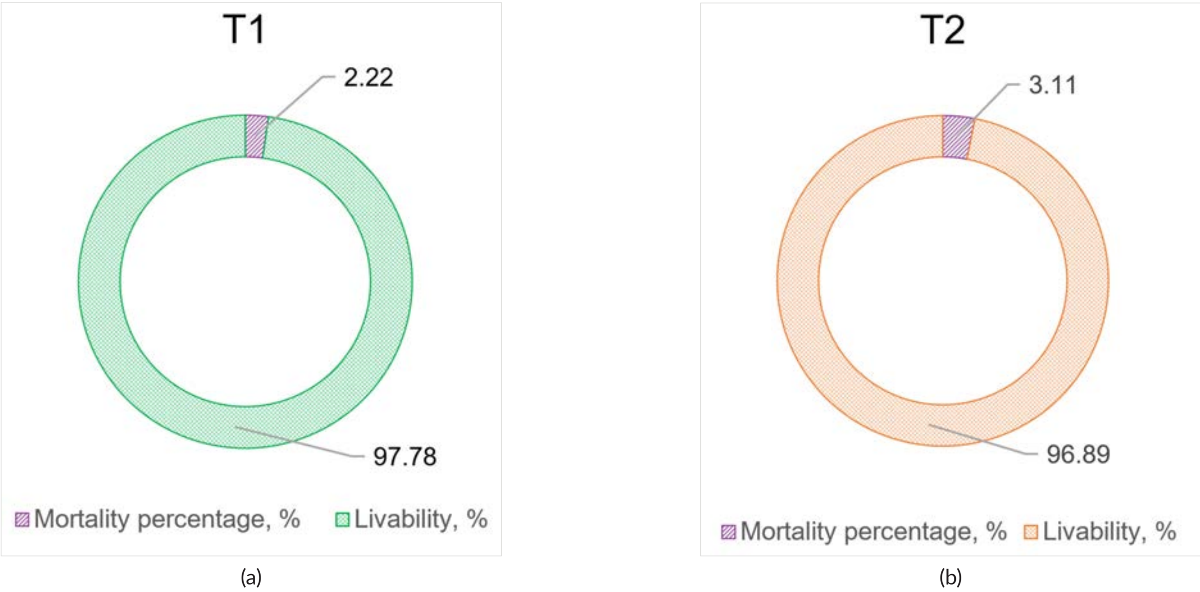


Figure 8. Mortality and livability of broilers fed with (a) T1 and (b) T2 feeds throughout the 35-day feeding trial

Table 3. Broiler performance for starter (days 1–21), grower (days 22–35) and whole (days 1–35) periods

Broiler performance	T1	T2	*P* - value
Weight at arrival (kg)	0.043	0.043	ND
Starter period			
Average feed intake days 1–21 (kg)	1.05[b]	1.06[a]	<0.05
Average weight gain days 1–21 (kg)	0.89	0.85	0.24
FCR starter period	1.18	1.25	0.18
Grower period			
Average feed intake days 22–35 (kg)	1.87	1.91	0.26
Average weight gain days 22–35 (kg)	1.32	1.25	0.05
FCR grower period	1.42[b]	1.53[a]	<0.05
Whole period			
Average feed intake days 1–35 (kg)	2.92	2.97	0.16
Average weight gain days 1–35 (kg)	2.23	2.13	0.06
FCR whole period	1.32	1.40	0.06
Broiler Performance Index	471.96	421.17	ND

[ab] Means in the same row without common letter are different at $P < 0.05$.
T1 = feeds with CPO and PKM inclusion; T2 = commercial feeds; FCR = feed conversion ratio; ND = not determined.

Fines test

Table 4 presents the physical qualities of broiler grower feed pellets. The feed pellets were analysed in a fines test. T1 broiler grower feed pellets (1.03%) had a significantly lower (*P*<0.05) fines percentage than T2 broiler grower feed pellets (8.30%). A lower fines percentage is preferred as it reflects good quality of the feed pellets. Lower fines percentages can be obtained by adjusting manufacturing procedures such as diet formulas, particle sizes, and production rates, which result in thermomechanical changes in nutrients, such as starch gelatinization to improve binding pellet properties (Vakili et al., 2015). T2 has a higher fines percentage due to the various actions during several storage and transport processes before reaching the end user, including rubbing against surfaces or impacts, which can cause abrasion.

Table 4. Fines test of broiler grower feed samples

Physical Analysis	T1	T2	*P* - value
Fines, %	1.03[b]	8.30[a]	<0.05

[ab] Means in the same row without a common letter are different at *P*<0.05

T1 = feeds with CPO and PKM inclusion; T2 = commercial feeds

Texture of chicken meat

Table 5 shows the texture analysis of two types of chicken meat samples: raw and baked, from the T1 and T2 groups. The chicken meat samples were analysed in terms of firmness and toughness using the instrumental method. The firmness of raw chicken meat from the T1 group (7.07 kg) was higher than that from the T2 group (6.29 kg). The baked chicken meat from T1 was also firmer than that from the T2 sample, with 4.95 and 4.61 kg, respectively. The toughness analyses of chicken meat from T1 (raw and baked samples) were higher (25.29 and 24.14 kg · sec, respectively) than those of chicken meat from T2 (19.45 and 18.86 kg · sec, respectively). The firmness and toughness of baked chicken meat are normally reduced as the meat is subjected to heat. No significant differences (*P*>0.05) were observed between T1 and T2 chicken meat for both raw and baked samples.

Table 5. Texture analysis on raw and baked chicken meat samples from T1 and T2 groups

Parameter	T1	T2	*P* - value
Raw samples			
Firmness (kg)	7.07	6.29	0.24
Toughness (kg · sec)	25.29	19.45	0.11
Baked samples			
Firmness (kg)	4.95	4.61	0.50
Toughness (kg · sec)	24.14	18.86	0.08

T1 = feeds with CPO and PKM inclusion; T2 = commercial feeds

DISCUSSION

Proximate composition

Feed formulation development is the process of combining various feed components in the proportions required to supply the appropriate quantity of nutrients at a specific stage of growth (Ahiwe et al., 2018). Knowledge of feed composition, as well as nutritional requirements, is critical for feed formulation. In this study, both T1 and T2 broiler starter and grower feeds met the nutritional levels specified by the Malaysian Standard 20:2008 (2008) for poultry feed. They also had the same amount of calories and nitrogen. Energy and protein are the second most critical feed ingredients, after water, and are required for health, development, and productivity. Broiler rations should be formulated to provide an adequate combination of energy, protein and amino acids, minerals, vitamins, as well as essential fatty acids for optimal development and performance (Olugbenga et al., 2015).

Growth performance

Studies on utilisation of CPO or PKM to partially substitute grain corn or soybean meal have been conducted by many researchers (Panja et al., 1995; Ezieshi and Olomu, 2004; Onuh et al., 2010; Abdulla et al., 2016; Catolico and Ampode, 2019; Anyanwu et al., 2020; Martínez et al., 2020; Sampath et al., 2020; Sudharsan et al., 2022). However, studies on the combination of both CPO and PKM in a broiler diet are limited.

Sampath et al. (2020) conducted a similar study on the supplementation of palm oil and soybean oil at 1.3% in the diet of Ross 308 cross-bred chicks. In the study, they found that the palm oil-supplemented group had significantly higher (*P*<0.05) body weight gain than the soybean oil treatment and control groups. The feed intake from the study was similar to the current study; however, better findings were observed in terms of body weight gain and FCR in the current study at day 35. This might be due to the difference in the chemical compositions, i.e., crude protein and metabolisable energy levels, of the experimental diets. Abdulla et al. (2016) also concluded that the inclusion of palm oil up to 6% could be used as an alternative to soybean and linseed oils to improve growth performance in broiler chickens. However, the study conducted by Sudharsan et al. (2022) contradicted the current study. The inclusion of up to 4.5% palm oil in the feed formulation resulted in lower body weight gain and FCR as compared to the current study, which had only 1.34 kg of body weight gain and 2.62 FCR. Nonetheless, it was shown that replacing palm oil with rapeseed oil at different ratios resulted in higher body weight gain and FCR with comparable feed consumption over the finisher period. Rapeseed oil-containing diets that have higher saturated and unsaturated fatty acid ratios may improve broiler body weight gain and FCR, as they require higher concentrations of bile salts and pancreatic lipase for fat digestion and absorption (Burlikowska et al., 2010).

On the other hand, Onuh et al. (2010) found that broilers fed PKM performed better than those fed without PKM inclusion diet, which was consistent with our current findings. However, the average daily feed consumption was significantly higher (*P*<0.05) in the broiler-fed PKM diet in their study, which contradicted our findings. Another study on the inclusion of PKM at 5, 10, and 15% was carried out by Martínez et al. (2020). They found that while the diet groups did not affect feed intake, the body weight gain was significantly higher (*P*<0.05) by about 5–10% of PKM, with significantly better FCR values (*P*<0.05) than those of the control group diet (without PKM inclusion). Similar research was also conducted by Anyanwu et al. (2020), except that they included a higher percentage of PKM (35–45%). The results showed that body weight increase was significantly lower (*P*<0.05) in all treatment groups compared to the group that did not receive PKM. According to Abdelrahman et al. (2019), the use of PKM is very common in diets of ruminant animals to give volume to the diet and to substitute the high-priced dietary ingredients. However, in non-ruminant diets, it should be limited, especially in poultry diets, due to the high fibre content (Chen et al., 2018), which can affect the absorption and proper use of nutrients and cause a negative effect on weight gain and organ growth (Kalmendal et al., 2011). Therefore, the inclusion of enzyme supplementation at higher levels of PKM in the diet can be considered.

Both dietary nutrient content and feed intake have an impact on broiler growth, with high-quality feed pellets providing the best feed intake (Vakilli et al., 2015). According to the Ross 308/308 FF Broiler: Performance Objectives (2022), a 10% rise in fines (1 mm) can result in a 40 g drop in body weight after 35 days. This highlights the need to reduce fine particle levels. This was demonstrated in this study when T1-fed broilers gained more body weight than T2-fed broilers due to a lower fine percentage of the T1 feed. Pellet quality can be deteriorated by improper delivery, elevation, or handling. Diet formulation and feed manufacturing practices, such as grinding and conditioning, may also impact the quality of feed pellets (Kenny and Rollins, 2007).

Texture of chicken meat

The instrumental method is an important step in determining the sensory qualities of commercial meat products (Paredes et al., 2022), using mechanical tests such as Warner Bratzler shear blades to simulate the force required to cut through the meat during the first bite. Meat texture and tenderness are crucial factors for consumers to consider when evaluating the acceptability of cooked meat, as variations in tenderness can significantly impact a consumer’s decision to repurchase (Bindon and Jones, 2001; Čurlej et al., 2013). In the current study, the firmness and toughness of the baked chicken meat samples were lower than those of the raw chicken meat samples. Bertola et al. (1994) found that cook time and temperature, along with the heat-induced denaturation of meat proteins, influence the texture of meat. Connective tissue and myofibrillar components largely influence tenderness, as heating induces chemical changes in muscle fibres and connective tissues. Overall, no significant differences (*P*>0.05) were observed between T1 and T2 chicken meat for both raw and baked samples, indicating that the chicken meat texture from the T1 group was equivalent to that from the T2 group.

CONCLUSION

Incorporation of CPO and PKM into the T1 broiler feed formulations resulted in better weight gain, FCR, and BPI when compared to the T2 commercial broiler feed. Furthermore, the texture of the chicken meat produced from broiler feeds containing oil palm-based ingredients was found to be equivalent to that of the chicken meat produced using T2 feeds. The feed industry should therefore consider the partial substitution of imported grain corn and soybean meal in broiler rations with CPO and PKM as sources of energy and protein, respectively.

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