

EFFECTS OF PELLET SUPPLEMENTED WITH DIFFERENT PERCENTAGES OF OIL PALM LIPID SOURCES ON BROILER PERFORMANCE, CARCASS TRAIT AND FEED QUALITY

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ABSTRACT

This study was conducted to determine the effects of three different oil palm lipid sources originated from various extraction and refining processes on broiler performance and feed quality. Based on a completely randomised design, a total of 825 one-day old mixed sex broiler chicks (Cobb500) were randomly assigned to one of the 11 treatments with three replicates of 25 chicks per replicate. The treatments were: T1-T3: 4% crude palm oil (CPO), palm fatty acid distillates (PFAD), Malaysian Palm Oil Board-High Energy (MPOB-HIE), respectively; T4-T6: 6% CPO, PFAD, MPOB-HIE, respectively; T7-T9: 8% CPO, PFAD, MPOB-HIE, respectively; T10: control and T11: commercial feed. Addition of CPO at 4% resulted in good broiler performances in terms of weight gain, feed intake, feed conversion ratio and carcass traits compared to other treatment groups. The addition of 4%, 6% and 8% palm-based oils and fats in the broiler finisher feed met all the nutrient requirements for Cobb500 broilers and did not affect the physical quality including fines percentage (<5%) and pellet durability index (>90%). The results showed that the supplementation of oil palm lipid sources in broiler diet positively supported the growth performance and carcass traits with good chemical and physical quality of feed pellet.

Keywords: broiler performance, carcass traits, feed quality, crude palm oil, palm fatty acid distillates.

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INTRODUCTION

Oils and fats are frequently added as supplement for energy sources in a conventional broiler diet which have been in high demand throughout the year (Jayalaksi *et al.*, 2006; Ali *et al.*, 2012). Low-fat broilers chicken fed diets will be directly translated into poor growth rates, poor feathering and high mortality in the few weeks of life. Addition of oils and fats in broiler diet has been proven to give several advantages which include reducing the passage rate of the digesta through intestinal tract, improving the absorption of fat-soluble vitamins, diminishing

the pulverulence and increasing the palatability of the broiler (Peebles *et al.*, 2000; Baião and Lara, 2005; Latshaw, 2008). In addition, supplying fat sources in broiler diet will reduce the feed intake and improve the feed efficiency (Jeffri *et al.*, 2010). Moreover, during feed production, oils and fats inclusion will lower the feed dustiness and provide greasing in the pelleting process that can reduce the friction in the pelletiser.

There are a number of fat sources that are suitable and can be included in broiler ration, for instance from animal and vegetable sources as well as from the rendering industry (Sanz *et al.*, 2000). Many studies have been conducted using different types of oils and fats from animal origin (usually fats, *i.e.*, tallow, lard), vegetable origin [usually oils, *i.e.*, soyabean oil (SBO), canola/rapeseed oil, sunflower oil, linseed oil, palm oil, cottonseed oil]

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and their different percentage combinations in broiler diet (Jeffre *et al.*, 2008; Ibrahim *et al.*, 2014; Özpınar *et al.*, 2003; De Witt *et al.*, 2009; Poultry Hub, 2018). Several researchers reported that birds fed on oils and fats supplemented diet showed better broiler performance in terms of body weight gain and feed efficiency in comparison to those birds fed on unsupplemented diet (Moura, 2003; Tabeidien, 2010). Ali *et al.* (2012) stated that the use of animal fats in the feed industries is becoming less prevalent compared to vegetable fats as the effectiveness of essential fatty acids promotes consumer health issues as well as contributing to a better weight gain and feed efficiency of the broiler.

The physical quality of the feed pellet is important for a number of reasons. In addition to improving animal performance, high quality of feed pellet enables easy transportation and handling of the products without fragmentation and fines generation due to attrition stresses (Thomas and Van Der Poel, 1996; Aarseth and Prestløkken, 2003). The fineness and coarseness of ground feed ingredients play an important role in both physical properties and nutritive values of the finished feed product. The smaller particle size of the finely ground ingredients often improves the pellet quality, thereby reducing pellet breakage and the production of fines. It is also known that the form of the feed can influence the overall animal production cost as the occurrence of fine particles has a significant effect on poor feed intake and animal performance. According to Kurt (2014), improved pellet durability can be achieved by manipulating diet formulation, using raw materials with good binding capabilities, adding pellet binders and improving the manufacturing practices.

Currently, palm oil and palm kernel oil account for 34% or about one-third of the total oils and fats production, overtaking SBO (24.4%) as the most traded vegetable oil in the world (Kushairi *et al.*, 2018). Crude palm oil (CPO) and palm fatty acid distillates (PFAD) (by-products of the refining process of CPO) from oil palm industry have potential to be utilised as high energy sources in formulating animal feed. Apart from that, an innovative product of PFAD with the addition of food grade emulsifier, so-called Malaysian Palm Oil Board-High Energy (MPOB-HIE) (Osman *et al.*, 2009) has been developed to increase the digestibility in monogastric animals. The high productivity of the oil palm industry in Malaysia and other tropical countries offers a sustainable supply of oil palm lipid materials that can be used to partially replace imported feed grains, *i.e.* corn as an energy source in broiler feed formulation. In addition, oil palm lipid materials also contain essential fatty acids like linoleic acid and antioxidants such as vitamin E which can help to reduce rancidity problem in animal feed. In this study, different percentages of the three types of palm-based oils and fats; CPO,

PFAD and MPOB-HIE were used in broiler feed formulations. The purpose of the current study was to examine the influences of feeding different palm-based oils and fats sources (at certain percentages) on the broilers' performance and carcass traits as well as the chemical and physical feed qualities.

MATERIALS AND METHOD

Materials

The raw materials for feed production including corn, soyabean meal, rice bran, fishmeal, dicalcium phosphate, limestone, salt, choline chloride, anti-fungals, broiler vitamin and mineral premixes were purchased from local suppliers, while CPO and PFAD were obtained from Cargill Palm Oil Refinery, Gebeng, Pahang, Malaysia. The MPOB-HIE was prepared at the Energy and Protein Centre (EPC) Laboratory, MPOB Keratong, Pahang, Malaysia. Broiler starter (Table 1) and finisher (Table 2) feeds were produced at the Animal Feed Pilot Plant, MPOB Keratong, Pahang.

Method

House management and feeding trial. A total of 825 one-day old mixed sex Cobb500 chicks were purchased from LKPP-Goldkist Sdn Bhd, Paloh Hinai, Pahang and vaccinated at the hatchery with Newcastle Disease (ND) killed, Infectious Bursal Disease (IBD) and IBD Live SQ vaccines. These chicks were raised in battery cages at the Climatic Control House (CCH), MPOB Keratong, Pahang. The CCH was equipped with three rows of battery cages and each row has three-tier cages with 18 cages per tier. In this study, only the middle tiers of each row were used to place the chicks. The temperature in this house was kept constant at 24°C and relative humidity was maintained at 70%. The broiler chicks were randomly assigned to one of 11 treatments with three replicates of 25 chicks per replication based on a completely randomised design. The rations were; T1 (broiler rations with inclusion of 4% CPO), T2 (broiler rations with inclusion of 4% PFAD), T3 (broiler rations with inclusion of 4% MPOB-HIE), T4 (broiler ration with inclusion of 6% CPO), T5 (broiler rations with inclusion of 6% PFAD), T6 (broiler rations with inclusion of 6% MPOB-HIE), T7 (broiler rations with inclusion of 8% CPO), T8 (broiler rations with inclusion of 8% PFAD), T9 (broiler rations with inclusion of 8% MPOB-HIE), T10 (control, without any addition of oils and fats - negative control) and T11 (commercial feed - positive control). Water was provided *ad-libitum* throughout the experiment. Rations were formulated isocaloric and isonitrogenous and met National Research Council (NRC) recommendations (NRC, 1994).

TABLE 1. STARTER DIET COMPOSITION AND NUTRIENT LEVELS (as feed basis)

Items	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
	4% CPO	4% PFAD	4% HIE	6% CPO	6% PFAD	6% HIE	8% CPO	8% PFAD	8% HIE	Control
Ingredients (%)										
Corn	54.60	52.50	50.10	39.40	37.00	33.50	27.70	22.60	18.50	69.50
Soyabean meal	29.80	29.50	29.20	31.50	31.20	30.70	31.70	31.20	30.60	17.50
Rice bran full fat	4.90	7.30	10.00	17.60	21.20	25.20	28.60	33.60	38.90	0.00
Crude palm oil (CPO)	4.00	0.00	0.00	6.00	0.00	0.00	8.00	0.00	0.00	0.00
Palm fatty acid distillates (PFAD)	0.00	4.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00
MPOB-High Energy (MPOB-HIE)	0.00	0.00	4.00	0.00	6.00	6.00	0.00	0.00	8.00	0.00
Fishmeal	3.70	3.70	3.70	2.50	1.60	1.60	1.00	1.60	1.00	11.00
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Sodium chloride	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Choline chloride	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Amino acids	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Premix	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis										
Dry matter (%)	87.56	87.56	87.56	87.73	87.73	87.72	87.50	87.52	87.50	88.95
Crude protein (%)	21.75	21.75	21.75	21.75	21.75	21.75	21.75	21.75	21.75	21.75
Crude fat (%)	6.98	10.33	6.98	8.58	8.55	8.58	10.33	10.29	10.34	4.35
Calcium (%)	0.91	0.89	0.91	0.80	0.80	0.80	0.89	0.89	0.89	0.86
Poultry ME (cal g ⁻¹)	3 075.00	3 075.00	3 075.00	3 075.00	3 075.00	3 075.00	3 075.00	3 075.00	3 075.00	3 075.00
Lysine	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Methionine	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60

TABLE 2. FINISHER DIET COMPOSITION AND NUTRIENT LEVELS (as feed basis)

Items	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
	4% CPO	4% PFAD	4% HIE	6% CPO	6% PFAD	6% HIE	8% CPO	8% PFAD	8% HIE	Control
Ingredients (%)										
Corn	64.20	63.80	61.70	49.40	48.70	45.40	32.90	31.70	26.80	74.10
Soyabean meal	22.80	22.80	23.10	24.70	24.80	25.00	24.30	24.20	23.70	5.50
Rice bran full fat	1.20	1.70	3.90	14.40	15.20	18.70	30.00	31.30	36.70	0.00
Crude palm oil (CPO)	4.00	0.00	0.00	6.00	0.00	0.00	8.00	0.00	0.00	0.00
Palm fatty acid distillates (PFAD)	0.00	4.00	0.00	0.00	6.00	0.00	0.00	8.00	0.00	0.00
MPOB-High Energy (MPOB-HIE)	0.00	0.00	4.00	0.00	0.00	6.00	0.00	0.00	8.00	0.00
Fishmeal	4.70	4.60	4.20	2.40	2.20	1.80	1.70	1.70	1.70	17.30
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sodium chloride	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Choline chloride	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Amino acids	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated Analysis										
Dry matter (%)	87.30	87.30	87.29	87.46	87.46	87.44	87.66	87.66	87.66	88.83
Crude protein (%)	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50	19.50
Crude fat (%)	7.28	7.30	7.23	8.85	8.81	8.80	10.61	10.57	10.61	5.05
Calcium (%)	0.95	0.95	0.93	0.83	0.82	0.80	0.80	0.80	0.80	1.08
Poultry ME (cal g ⁻¹)	3 150.00	3 150.00	3 150.00	3 150.00	3 150.00	3 150.00	3 150.00	3 150.00	3 150.00	3 150.00
Lysine	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Methionine	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Growth performance. Feed intake and total weight gain of the broilers were recorded daily and weekly, respectively to assess weight gain (WG) and feed conversion ratio (FCR). The average weight of broilers, feed intake (FI) and FCR (kilogram of feed consumed per kilogram of weight gain) were calculated for each ration. Mortality was also observed and recorded daily. Growth performances were evaluated on Day 1-Day 20 as starter period and Day 21-Day 38 as finisher period.

Carcass quality. On Day 38, three birds from each replicate were randomly selected, weighed and slaughtered to record the data on live weight and carcass weight. The birds were then cut into parts; thigh and drumstick, breast, wing and fat. The weight of each part for each treatment diet was recorded for carcass evaluation.

Statistical Analysis

All data collected were subjected to statistical analysis with analysis of variance (ANOVA) and mean differences among treatments were analysed by Duncan's Multiple Range Test using SAS 9.1™ programmed package (SAS, 2003). Significance was set at $P < 0.05$.

Chemical Analyses

Proximate analysis. The proximate composition of both starter and grower of broiler feed samples were analysed according to the recommended procedures of Association of Official Analytical Chemist (AOAC) (AOAC, 1990). Total moisture content of the total mixed ration samples was analysed using a moisture analyser. The crude fat content of the feed was determined using the ether extraction method on a SOXTherm® machine while the gross energy value of the samples was analysed using IKA® bomb calorimeter. The crude protein was determined according to the Kjeldahl method using a Kjeltec™ machine. The samples were ashed for 2 hr in a furnace at 600°C to determine total ash content. The crude fibre was examined using the Fibertec™ 2010 system following the Van Soest method (Van Soest *et al.*, 1991).

Physical Analyses

Samples of starter and grower broiler feeds were subjected to physical analyses for feed quality determination. The analyses comprise of fines percentage and pellet durability index (PDI) following ASAE Standard S269.5 (ASAE, 2012).

Fines percentage. Fines test was conducted using a mesh sieve of 3 mm diameter (ASTM). Triplicate samples of 500 g were weighed and sieved to remove

the fines particle from the whole broiler finisher feed pellets. Fines were calculated as the percentage of pellet remained in the mesh sieve of the initial of whole pellets weight. The free fines pellets were then packed into separate bags for further analysis (PDI test).

$$\text{Fines percentage (\%)} = \frac{\text{Initial weight (W}_0\text{)} - \text{Final weight (W}_1\text{)}}{\text{Initial weight (W}_0\text{)}} \times 100\%$$

PDI. Durability was measured using a PDI tester (New Holmen, NHP100). Triplicate samples of approximately 100 g of pellets (free from fines) were weighed into the equipment and run for 60 s. The amount of the whole pellets remaining in the instrument chamber was weighed and durability was expressed as a percentage of the initial weight.

$$\text{PDI (\%)} = \frac{\text{Final weight (W}_1\text{)}}{\text{Initial weight (W}_0\text{)}} \times 100\%$$

RESULTS AND DISCUSSION

Growth Performance

Growth performance of broilers fed with different percentages of CPO, PFAD and MPOB-HIE, control and commercial diets for five weeks of feeding trial is shown in *Figure 1*. The weight of one-day old chicks upon arrival was 41.6 g. In the first two weeks of the feeding trial, broilers fed with T5 showed the highest body weight, while broilers fed with T9 possessed the lowest body weight compared to the other treatments. The weight gain of the first and second week of the feeding trial was 237.5 g and 156.9 g for T5 and T9, respectively. At Week 3, broilers fed with T4 showed the highest body weight of 808.9 g, while the lowest body weight of 591.1 g was from T11. The difference between these two treatments was 217.8 g. When entering the finisher phase (Week 4-Week 5), broilers fed with T5 grew to fetch the highest body weight compared to the other treatments, while broilers fed with T11 remained at the lowest body weight during Week 4. However, during the final week of feeding trial (Week 5), the growth trend changed where broilers fed with T1 showed the highest body weight of 2.19 kg per bird and the broilers fed with T9 had the lowest body weight of only 1.56 kg per bird. There was no mortality throughout the feeding trial recorded from T3, T4, T5 and T10 while the highest mortality was from T11 with 10.67%.

Table 3 shows individual data for all treatment diets, including the weight on arrival, WG, FI and FCR for starter (Day 21) and finisher (Day 38) periods. During starter period, the highest FI and WG of broilers fed with T4 were observed. The

results were significantly higher ($P < 0.05$) compared to T2, T6, T8, T9 and T11. However, there was no significant difference in the results ($P > 0.05$) compared to T1, T3, T5, T7 and T10. These results indicate that the broilers positively accepted the three different levels (4%, 6% and 8%) of CPO inclusion in the diet. The highest FI and WG of the broilers fed T4 also contributed to a good FCR of 1.31, while the poor FCR of 1.59 was derived from the broilers fed with T2. The T2 was also significantly different ($P < 0.05$) compared to all treatment diets, except T6, T8 and T9. This might be due to the high FI (0.89 kg) of broilers fed T2 diet but less body weight gain (0.56 kg) within three weeks of the feeding trial.

For finisher period (Table 3), all CPO treatment diets (4%, 6% and 8%) showed the best performance in terms of FI and WG compared to the other two oil palm-based fats, control as well as commercial groups. In addition, broilers fed with all oils and fats treatment diets at different inclusion levels, except T9 showed significantly higher ($P < 0.05$) weight gain compared to T10 and T11. It shows that both levels (4% and 6%) with different type of fats positively influenced the weight gain of the broilers. The highest values of FI and WG from broilers fed with

T1 were 3.67 kg and 2.52 kg per bird, respectively. It is apparent from Table 1 that the lowest FI of 2.79 kg was from broilers fed with commercial diet and the result was significantly lower ($P < 0.05$) compared to all other treatments. On the other hand, broilers fed with control diet showed that the lowest WG (1.80 kg) during finisher period was significantly different ($P < 0.05$) from all treatment diets, except for T9 (1.94 kg) and T11 (1.82 kg). In terms of FCR, T1 showed the best FCR of 1.46 and in contrast to T10 with 1.94 ($P < 0.05$). This finding is in agreement with Moura (2003) and Tabeidien *et al.* (2010) who reported that bird feeds containing oils and fats diets showed better performance than bird feeds without oils and fats inclusion due to the energetic efficiency (higher energy gain and lower energy losses) with respect to those without added oils and fats (Carew and Hill, 1964; Fuller and Rendon, 1977; Nistan *et al.*, 1997). Furthermore, inclusion of oils and fats in the diet can also stimulated feed and energy consumption under heat stress condition, which in turn, increased palatability of the birds that contributed to higher feed intake and better performance (Dale and Fuller, 1979; Cherry, 1982).

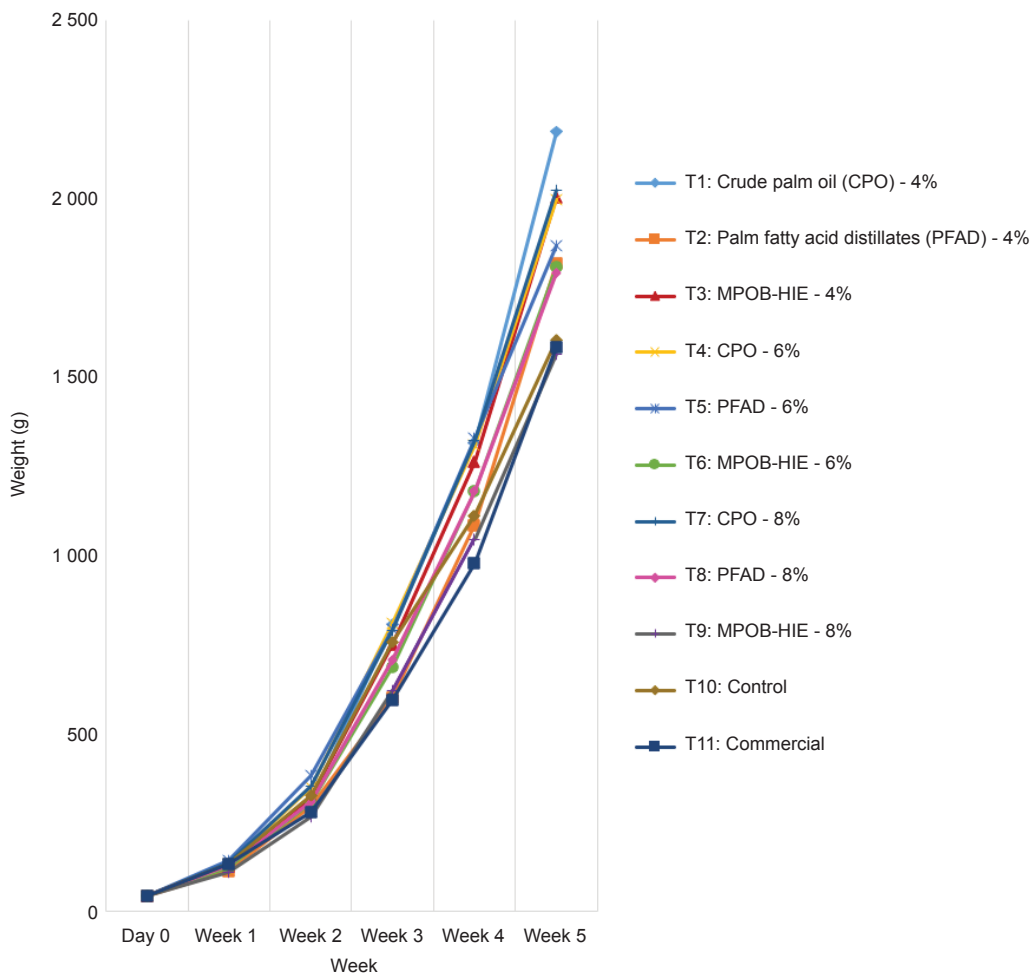


Figure 1. Growth performance of broilers fed with different levels of oil palm-based oils and fats, control and commercial diets for five weeks of feeding trial.

A similar study was conducted by comparing between control (CON), CPO and SBO at 3.5% in starter and 4% in grower feed (Wan Nooraida *et al.*, 2017). The findings were similar to the current study, with the CPO group showing the highest WG of 2.57 kg per bird. It was significantly different ($P < 0.05$) as compared to broilers fed with CON diet at 2.39 kg per bird and of SBO diet at 2.40 kg per bird. However, the best FCR of the CPO group was only 1.53, a slightly poor in conversion of feed to meat (FCR) as compared to this study (1.46). This might be due to the fact that longer feeding trial period (40 days) affected the result of FCR based on a combination of field performance results and experience conducted for Cobb500 broilers (cobb-vantress.com, 2013).

Das *et al.* (2014) carried out a similar study on the supplementation of palm oil in broilers diet at lower percentages (2.5%, 3.0% and 3.5%) and they concluded that supplementation of 3.5% palm oil resulted to a higher WG and better feed conversion compared to other levels of inclusion. The level of palm oil in their study (3.5%) was similar to this study (4%) which provided the best WG and FCR compared to other treatment groups. Ali *et al.* (2012) conducted a study on the influences of various levels (0%, 2%, 4% and 6%) of Bergafat, a palm oil derivative product, with the addition of lecithin to the performance of broilers for six weeks. They found that during the starter phase, the supplementation of Bergafat to the broilers diet significantly ($P < 0.05$) increased the WG of birds as compared to the control diet, but there was no significant ($P > 0.05$) effect during the finisher phase.

Another study reported by Firman *et al.* (2008) on comparing palm oil with other fat sources (*i.e.* SBO, yellow grease, poultry fat, tallow and lard) in broilers ration concluded that differences in the metabolisable energy (ME) values between these oils and fats sources do not translate into the differences in performance of broilers due to several reasons. One of these is the improvement in utilisation of other dietary components is equally improved regardless of the types of oils and fats being added indicating that the net energy available to the broilers was similar (Leeson and Atteh, 1995; Firman *et al.*, 2008). For instance, if two fats with different ME content are included in a diet at the same percentage, the difference in ME content of the complete ration would be very small leading to no difference in broilers performance was observed. They also suggested that the oils and fats sources used in broilers formulation should be selected based on price to reduce the cost of broilers production. The same finding was reported by Ibrahim *et al.* (2014) using different oils and fats sources; SBO, palm oil, fatty acids, distilled fatty acids and fry fat in starter, grower and finisher diets containing inclusion levels of 2%, 3% and 4%, respectively.

Carcass Quality

The highest broilers live weight was from T1, but the value was not significantly different ($P > 0.05$) compared to 6% of all treatment diets (T4, T5 and T6) and T7 (Table 4). CPO inclusion in broilers diet regardless of their levels (T1, T4 and T7) gave significantly higher ($P < 0.05$) carcass weight compared to other type of fats (PFAD and HIE), control and commercial feed, except for T5 and T6. For carcass part analysis, the highest thigh and drumstick were 0.76 kg from T1 and T4, while the lowest was 0.56 kg of T11. For the breast part, T7 has the highest weight of 0.71 kg, while T10 has the lowest breast weight of 0.38 kg, which is about half the weight of T7. T4 showed the highest wing weight of 0.19 kg, followed by 0.18 kg for T2, T3, T7; 0.17 kg of T1, T5 and T6; 0.16 kg of T8 and T9; and the lowest weight of 0.13 kg were from T10 and T11. Except for T10 and T11, the difference in the results of wing part among all the treatment diets was not significant ($P > 0.05$). In terms of fat deposition, the highest was from broilers fed T10 with 0.22 kg, while the lowest was from broilers fed T9 with 0.05 kg.

In the present study, the breast weight was higher compared to that of treatment group without oils and fats supplementation group which is in agreement with the findings of Das *et al.* (2014) and Nayebpor *et al.* (2007). No significant difference ($P > 0.05$) was observed in the wing part among the different fats at 3% inclusion level, with an average of 120 g on Day 50 (Firman, 2008), and it was slightly lower compared to the yield reported in this study with an average of 160 g -190 g of wings on Day 38. However, fat deposition result was found to contradict Bobadoye (2006) who reported that fat accumulation increased with increasing levels of oil. Poorghasemi *et al.* (2013) conducted a similar study using different fat sources (tallow, canola oil and sunflower oil) at 4% of inclusion level, and their combination (2% tallow and 2% canola oil) resulted in a significant weight gain in the breast of 557 g ($P < 0.05$) compared to single fat source group.

Chemical Analyses

Proximate analysis. The proximate composition of the broiler starter feed with different treatments is tabulated in Table 5. The results showed that the moisture content of T2 (14.33%) and T5 (13.16%) was higher than 13% compared with the other treatments with an average of 11%. However, the moisture content is within the good specifications of animal feed. The moisture content of the feed must be lower than 13% to prolong its shelf-life and prevent the growth of mold. According to the Malaysian Standards (2008), the maximum level of total ash content of poultry is up to 8%. In this study, the total ash content of all treatments was in compliance with the specified

TABLE 3. WEIGHT ON ARRIVAL, WEIGHT GAIN, FEED INTAKE AND FEED CONVERSION RATIO (FCR) OF BROILER FED WITH DIFFERENT TREATMENTS FOR STARTER (Day 21) AND FINISHER (Day 38) PERIODS

Items	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
	4% CPO	4% PFAD	4% HIE	6% CPO	6% PFAD	6% HIE	8% CPO	8% PFAD	8% HIE	CONT	COM
Weight (g) on arrival, Day 0	41.60	41.60	41.60	41.60	41.60	41.60	41.60	41.60	41.60	41.60	41.60
Weight gain (kg), Day 21	0.76 ^{abc}	0.56 ^{de}	0.71 ^{abc}	0.77 ^a	0.75 ^{ab}	0.65 ^{cd}	0.75 ^{abc}	0.66 ^{bc}	0.58 ^{de}	0.72 ^{abc}	0.55 ^e
Feed intake (kg), Day 21	1.01 ^a	0.89 ^d	0.98 ^{ab}	1.01 ^a	1.00 ^{ab}	0.97 ^b	0.99 ^{ab}	0.93 ^c	0.89 ^d	0.97 ^b	0.76 ^e
FCR, Day 21	1.33 ^b	1.59 ^a	1.38 ^b	1.31 ^b	1.33 ^b	1.49 ^{ab}	1.32 ^b	1.41 ^{ab}	1.53 ^{ab}	1.35 ^b	1.38 ^b
Weight gain (kg), Day 38	2.52 ^a	2.15 ^a	2.22 ^a	2.34 ^a	2.29 ^a	2.20 ^b	2.36 ^a	2.13 ^{ab}	1.94 ^{bc}	1.80 ^c	1.82 ^c
Feed intake (kg), Day 38	3.67 ^a	3.44 ^{abc}	3.53 ^{ab}	3.58 ^a	3.50 ^{ab}	3.36 ^{bc}	3.57 ^{ab}	3.28 ^c	2.90 ^d	3.50 ^{ab}	2.79 ^e
FCR, Day 38	1.46 ^b	1.60 ^b	1.59 ^b	1.53 ^b	1.53 ^b	1.53 ^b	1.51 ^b	1.54 ^b	1.49 ^b	1.94 ^a	1.53 ^b

Note: CPO – crude palm oil, PFAD – palm fatty acid distillates, HIE – high energy, CONT – control, COM – commercial.

^{abcde} Means in the same column with different superscripts are significantly different (P<0.05).

TABLE 4. CARCASS ANALYSIS OF BROILER CHICKEN ON DAY 38

Treatment	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
	4% CPO	4% PFAD	4% HIE	6% CPO	6% PFAD	6% HIE	8% CPO	8% PFAD	8% HIE	CONT	COM
Live weight (kg)	2.52 ^a	2.19 ^{cd}	2.26 ^{bcd}	2.47 ^a	2.41 ^{ab}	2.36 ^{abc}	2.51 ^a	2.21 ^{cd}	2.10 ^d	1.89 ^e	1.86 ^e
Carcass weight (kg)	2.35 ^a	2.05 ^{cd}	2.08 ^{bcd}	2.30 ^b	2.23 ^{ab}	2.20 ^{abc}	2.28 ^a	2.01 ^{cd}	1.93 ^d	1.74 ^e	1.75 ^e
Carcass parts											
Thigh and drumstick (kg)	0.76 ^a	0.73 ^{ab}	0.69 ^{abc}	0.76 ^a	0.72 ^{ab}	0.72 ^{ab}	0.74 ^a	0.64 ^{bcd}	0.62 ^{cd}	0.57 ^d	0.56 ^d
Breast (kg)	0.70 ^{ab}	0.59 ^{bc}	0.61 ^{abc}	0.66 ^{ab}	0.68 ^{ab}	0.65 ^{abc}	0.71 ^a	0.59 ^{bc}	0.55 ^{cd}	0.38 ^e	0.49 ^d
Wing (kg)	0.17 ^a	0.18 ^a	0.18 ^a	0.19 ^a	0.17 ^a	0.17 ^a	0.18 ^a	0.16 ^{ab}	0.16 ^{ab}	0.13 ^b	0.13 ^b
Fat (kg)	0.21 ^{ab}	0.13 ^d	0.15 ^{bcd}	0.20 ^{abc}	0.13 ^{cd}	0.07 ^{de}	0.08 ^{de}	0.10 ^{de}	0.05 ^e	0.22 ^a	0.11 ^{de}

Note: CPO – crude palm oil, PFAD – palm fatty acid distillates, HIE – high energy, CONT – control, COM – commercial.

^{abcd} Means in the same column with different superscripts are significantly different (P<0.05).

levels, except that T7 was slightly higher than the specification (8.08%). For crude fat content, the value increased with increased percentage of fat (CPO, PFAD and HIE) in the feed rations. The highest crude fat content was from T9 (11.82%), while T10 and T11 gave lower values than the specified value of at least 5%, with 3.01% and 4.16%, respectively. Based on Table 1, the calculated crude protein (CP) percent for starter diet was 21.75%. However, there was variation in CP% for starter diet in proximate analysis but all treatment diets still met the nutrient requirements, except for T6 and T9 which showed slightly lower than the requirements with 19.09% and 17.46%, respectively. T6 and T9 also contained crude fibre content that was slightly higher than the maximum 5% of the feed ration. The starter and finisher diets of fat levels ranging from 4% to 8% were formulated to be isocaloric with T10 and T11 at 3075 cal g⁻¹ and 3150 cal g⁻¹, respectively by manipulating the percentage of other macro ingredients such as corn, soyabean meal, rice bran full fat and fishmeal as shown in Tables 1 and 2. The total energy results showed that the lowest value of T11 was 3738 cal g⁻¹ compared to the other treatment groups with values ranging from 3804-4221 cal g⁻¹.

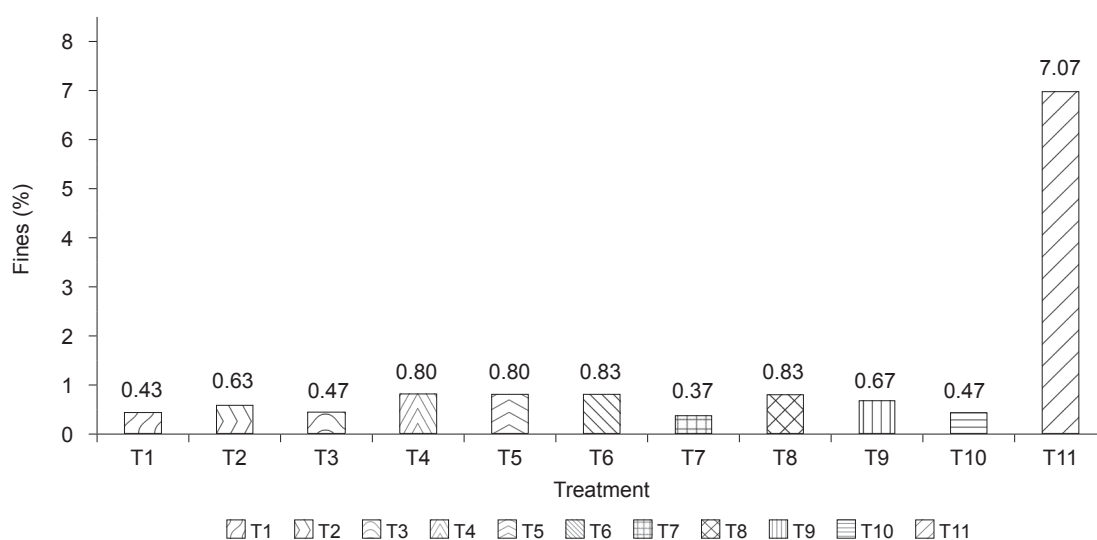
Proximate composition of the broiler finisher feed in Table 6 demonstrates that the highest moisture content was 13.82% of T10, which was higher than the standard specification, while the lowest was 8.95% of the T3 group. Other treatment groups showed an average moisture content of 11%. The results also indicated that none of the treatment groups had a total ash content of more than 8% and the highest was 7.36% from T11. The crude fat content in the broiler finisher feed was similar to that of the broiler starter feed, with results ranging

from 3.99% to 12.80%. The crude protein content of all treatment groups was between 17.77% and 21.95%, and the protein content of T4 was slightly lower than the minimum specified value of 19%. All broiler finisher feeds showed a crude fibre content of less than 5%, except for T9 of 6.01%. The results also showed that the gross energy of all treatment groups was higher than 3100 cal g⁻¹, the highest was from T9 (4303 cal g⁻¹), while the lowest was 3750 cal g⁻¹ from T11.

As can be seen from the results obtained, broilers have different feed requirements in terms of protein and energy during different stages of their growth. Young broilers have a high protein requirement for the development of muscles, feathers and other body organs (Ayed *et al.*, 2015). As the broilers grow, their energy needs for fattening up will increase, while their protein requirements will decrease. Therefore, broilers require a higher protein content in the starter ration than in the finisher ration.

Physical Quality

Good pellet quality is defined as the ability to withstand mechanical handling such as bagging and transportation without breaking up, and to reach feeders without generating a high proportion of fines. The fines percentage of broiler finisher pellet is shown in Figure 2. Based on the chart, the fines percentage for almost all treatment groups is less than 1% (ranging between 0.37% and 0.83%), which is lower than the specified fines level (5%), except for T11 at 7.07%. According to Goh (2015), the cause of fines in the finished pellet feed is due to poor cooking starch and low level of available gelling agent required for good intra-particles bonding.



Note: T1: Crude palm oil (CPO) - 4%; T2: Palm fatty acid distillates (PFAD) - 4%; T3: Malaysian Palm Oil Board-High Energy (MPOB-HIE) - 4%; T4: CPO - 6%; T5: PFAD - 6%; T6: MPOB-HIE - 6%; T7: CPO - 8%; T8: PFAD - 8%; T9: MPOB-HIE - 8%; T10: Control; T11: Commercial.

Figure 2. Fines percentages of broiler finisher pellet for all treatments.

TABLE 5. PROXIMATE COMPOSITION OF BROILER STARTER FEED WITH DIFFERENT TREATMENTS

Proximate analysis	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Standard specification*
	4% CPO	4% PFAD	4% HIE	6% CPO	6% PFAD	6% HIE	8% CPO	8% PFAD	8% HIE	CONT	COM	
Moisture	11.64 ± 0.11	14.33 ± 0.19	11.07 ± 0.10	10.51 ± 0.13	13.16 ± 0.06	10.12 ± 0.11	10.21 ± 0.08	12.43 ± 0.06	10.45 ± 0.19	12.14 ± 0.13	11.80 ± 0.12	Max, 13
Total ash	7.76 ± 0.07	6.51 ± 0.12	6.94 ± 0.03	7.49 ± 0.01	6.70 ± 0.01	6.93 ± 0.01	8.08 ± 1.28	7.55 ± 0.03	7.40 ± 0.04	6.79 ± 0.06	7.64 ± 0.18	Max, 8
Crude fat	6.05 ± 0.01	6.72 ± 0.01	5.86 ± 0.01	7.90 ± 0.01	8.25 ± 0.01	9.17 ± 0.01	9.17 ± 0.01	10.62 ± 0.01	11.82 ± 0.01	3.01 ± 0.01	4.16 ± 0.01	Min, 5
Crude protein	25.90 ± 0.06	20.66 ± 0.08	23.20 ± 0.13	25.27 ± 0.09	24.02 ± 0.14	19.09 ± 0.04	26.06 ± 0.04	26.70 ± 0.13	17.46 ± 0.03	23.58 ± 0.05	22.59 ± 0.27	Min, 21
Crude fibre	2.98 ± 0.18	3.42 ± 0.16	3.20 ± 0.29	3.36 ± 0.33	3.94 ± 0.19	5.30 ± 0.21	3.79 ± 0.11	4.38 ± 0.12	5.42 ± 0.27	1.70 ± 0.15	3.35 ± 0.06	Max, 5
Gross energy (cal g ⁻¹)	3 997 ± 1.5	3 851 ± 20.4	4 021 ± 3.8	4 094 ± 20.6	4 041 ± 14.0	4 149 ± 8.74	4 216 ± 11.9	4 164 ± 8.89	4 221 ± 11.5	3 804 ± 22.61	3 738 ± 7.09	Min, 2900

Note: CPO – crude palm oil, PFAD – palm fatty acid distillates, HIE – high energy, CONT – control, COM – commercial.

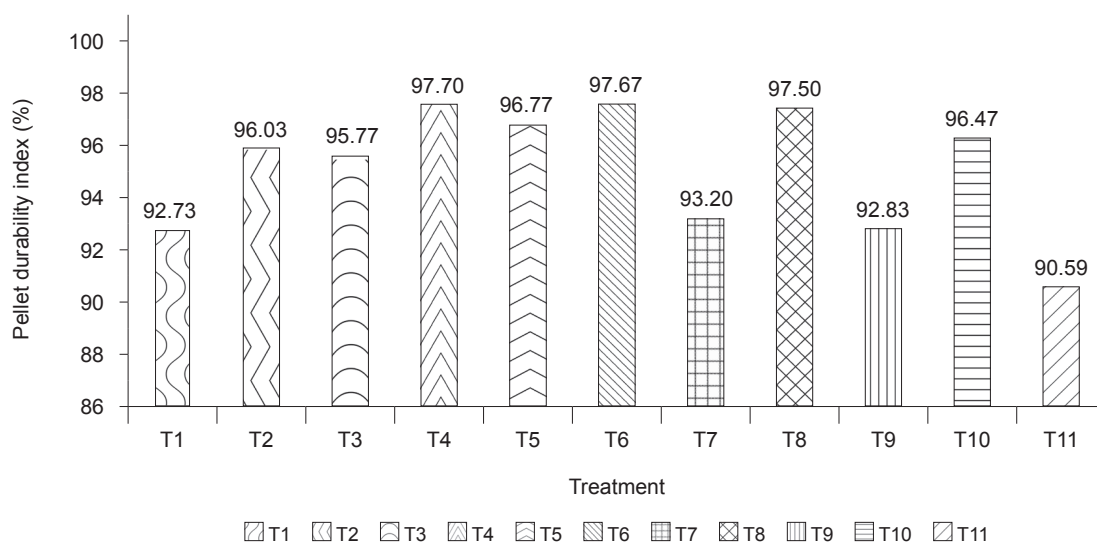
*Malaysian Standard MS 20:2008 Poultry Feeds – Specification (Fourth revision).

TABLE 6. PROXIMATE COMPOSITION OF BROILER FINISHER FEED WITH DIFFERENT TREATMENTS

Proximate analysis	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	Standard specification*
	4% CPO	4% PFAD	4% HIE	6% CPO	6% PFAD	6% HIE	8% CPO	8% PFAD	8% HIE	CONT	COM	
Moisture	12.06 ± 0.11	11.44 ± 0.21	8.95 ± 0.10	11.10 ± 0.15	10.64 ± 0.37	11.40 ± 0.31	11.69 ± 0.19	10.23 ± 0.31	9.48 ± 0.25	13.82 ± 0.23	11.26 ± 0.14	Max, 13
Total ash	5.85 ± 0.06	5.83 ± 0.08	5.53 ± 0.04	5.75 ± 0.08	5.96 ± 0.10	5.71 ± 0.06	6.83 ± 0.04	6.41 ± 0.03	7.16 ± 0.09	3.38 ± 0.03	7.36 ± 0.05	Max, 8
Crude fat	7.31 ± 0.01	6.21 ± 0.01	6.89 ± 0.01	9.64 ± 0.01	8.63 ± 0.01	9.95 ± 0.01	12.21 ± 0.01	12.65 ± 0.01	12.80 ± 0.01	4.32 ± 0.01	3.99 ± 0.01	Min, 5
Crude protein	18.84 ± 0.23	19.10 ± 0.11	18.50 ± 0.06	17.77 ± 0.10	18.99 ± 0.13	18.73 ± 0.02	20.60 ± 0.13	19.85 ± 0.04	20.26 ± 0.15	21.06 ± 0.11	21.95 ± 0.24	Min, 19
Crude fibre	2.05 ± 0.07	2.15 ± 0.05	1.83 ± 0.07	3.44 ± 0.19	3.61 ± 0.07	4.06 ± 0.12	4.85 ± 0.14	4.70 ± 0.30	6.01 ± 0.11	4.05 ± 0.54	2.48 ± 0.07	Max, 5
Gross energy (cal g ⁻¹)	3 909 ± 16.6	3 907 ± 12.5	4 062 ± 14.8	4 086 ± 23.5	4 096 ± 14.5	4 062 ± 10.0	4 185 ± 6.0	4 231 ± 11.4	4 303 ± 25.5	3 738 ± 11.7	3 750 ± 8.1	Min, 3100

Note: CPO – crude palm oil, PFAD – palm fatty acid distillates, HIE – high energy, CONT – control, COM – commercial.

*Malaysian Standard MS 20:2008 Poultry Feeds – Specification (Fourth revision).



Note: T1: Crude palm oil (CPO) - 4%; T2: Palm fatty acid distillates (PFAD) - 4%; T3: Malaysian Palm Oil Board-High Energy (MPOB-HIE) - 4%; T4: CPO - 6%; T5: PFAD - 6%; T6: MPOB-HIE - 6%; T7: CPO - 8%; T8: PFAD - 8%; T9: MPOB-HIE - 8%; T10: Control; T11: Commercial.

Figure 3. Pellet durability index of broiler finisher pellet for all treatments.

All broiler finisher feed pellets also showed good PDI values, which were higher than the recommended PDI level of 90% (Figure 3). As compared to other treatment groups, T4 showed the highest PDI value of 97.70%, while the lowest PDI value was 90.59% from T11. There is a clear correlation between fines percentage and PDI, for instance in T11, higher fines percentage has resulted in a lower PDI value. Carre *et al.* (2005) reported that by lowering the formation of fines, higher PDI value could also reduce the feed wastage and provide larger particles selection by the birds. Pellet durability is thought to be inversely related to particle size (Angulo *et al.*, 1996), based on the fact that smaller particles have more contact points with each other because of their larger surface area per unit volume (Behnke, 2001).

Figure 3 also shows that the PDI values in all fat treatment groups (CPO, PFAD and HIE) increased with the increase of oil or fat inclusion in the ration up to 6%. However, the values decreased with the 8% inclusion of fat. This finding is in line with Kurt (2014) who reported that the PDI can be vastly improved by adding 2%-5% of fat either at the pelletiser or downstream of the cooler.

CONCLUSION

Based on the above findings, it can be concluded that supplementation of 4% CPO level in the diet of broilers resulted in good broilers' performance in terms of weight gain, feed intake and FCR as well as carcass weight compared to those of other treatment groups. Addition of palm-based oils and fats ranging

from 4% to 8% in the broiler finisher feed met all the nutrient requirements for Cobb500 broiler and did not affect the physical quality including the fines percentage (<5%) and PDI (>90%).

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