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Research Article

Growth Performance and Chemical Quality of Broiler Meat Fed with Fermented Palm Kernel Meal Based Ration Supplemented with Methionine and Lysine

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Abstract | This study aimed to evaluate the effects of methionine and lysine supplementation in rations containing fermented palm kernel cake on the performance and chemical quality of broiler meat. A completely randomized design (CRD) was used, consisting of five treatments with five replications each. The treatments involved different levels of methionine and lysine supplementation in fermented palm kernel cake-based rations. Treatment 0 (T0) served as the control ration (CR), containing 30% fermented palm kernel cake without the addition of methionine and lysine. T1 consisted of the CR + 0.25% lysine and 0.25% methionine, T2 was CR + 0.25% lysine and 0.5% methionine, T3 was CR + 0.5% lysine and 0.25% methionine, and T4 was CR + 0.5% lysine and 0.5% methionine. The results showed that the addition of methionine and lysine to the fermented palm kernel cake-based rations had a significant effect ($p < 0.05$) on body weight gain, feed conversion ratio, and the chemical composition of broiler meat (including moisture, ash, fat, and protein content). However, no significant effect ($p > 0.05$) was observed on feed intake. In conclusion, the supplementation of 0.5% methionine and 0.5% lysine in rations containing fermented palm kernel cake can improve broiler performance and enhance the chemical quality of the meat.

Keywords | Palm kernel meal, Methionine, Lysine, Performance, Chemical quality

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INTRODUCTION

Efforts to develop broiler farming businesses are often hampered by high feed costs because some of the ingredients still compete with human needs. Alshelmani *et al.* (2021) stated that Soybean meal and yellow corn are conventional feeds used as the main ingredients of poultry feed due to their high nutritional availability. However, corn is also needed by humans and soybean meal is also used for other livestock. The use of non-conventional feed is an alternative to reduce feed costs, such as utilizing palm kernel meal (PKM) which comes from palm oil processing by-products.

PKM has a crude protein content of 17.15% with a metabolizeable energy of 2.682 kcal/kg, but its crude fiber content is also high, reaching 16.89%, so it is a limiting factor for its use in poultry rations (Mairizal and Akmal, 2019). The high crude fiber content in PKM will cause low digestibility if used as poultry feed (Sundu and Dingle, 2003; Alshelmani *et al*., 2014). Crude fiber PKM contains 60% non-starch polysaccharides (NSP) consisting of 78% mannan, 3% arabinoxylan, 12% cellulose and 3% glucuronoxylan (Duesthorft *et al*., 1993). Mannan can bind a large amount of water so that there is an increase in digesta viscosity and reduced digesta movement (Yaophakdee *et al*., 2018). High intestinal viscosity will reduce nutrient absorption so that there is a decrease in nutrient availability for livestock (Ng *et al*., 2002). Broiler chickens do not have endogenous enzymes and cellulolytic bacteria in their digestive tract to digest non-starch polysaccharides and crude fiber (Alagawany *et al*., 2018). In order for the use of PKM as poultry feed to be optimized, mannan must be degraded into compounds that are easier to digest and absorb and one of them is through fermentation.

The processing of fermented palm kernel meal (FPKM) using molds and bacteria to reduce crude fiber content has been widely studied. Several studies have utilized *Aspergillus niger* (Abdeshahian *et al*., 2010; Ramin *et al*., 2010), *Trichoderma harzianum* (Ramin *et al*., 2010), and *Rhizopus oryzae* (Ramin *et al*., 2010; Orthman *et al*., 2013) for FPKM fermentation. Mairizal and Akmal (2019) reported that fermentation with *Bacillus cereus* increased the crude protein content of PKM from 17.15% to 21.48%, while reducing crude fiber from 16.89% to 9.89%. However, the inclusion of FPKM at a level of 30% in broiler rations has not been sufficient to optimize broiler performance. This limitation is primarily due to the low levels of essential amino acids, particularly lysine and methionine, in PKM (Yatno, 2011; Yaophakdee *et al*., 2018).

Amino acids play an important physiological role in the body (Bortoluzzi *et al*., 2018; Debnath). After absorption, amino acids will be metabolized and used to build various body tissues. Beski *et al*. (2015) stated that supplementation of synthetic amino acids in poultry feed increased feed efficiency and reduced nitrogen excretion. Kidd *et al*. (2005) showed that healthy broilers responded positively to high amino acid intake and had a positive effect on their performance. Methionine and lysine play an important role in metabolism in monogastric livestock and these amino acids play a role in increasing growth, health, and reproduction (Wu, 2013; Jankowski *et al*., 2014; Liao *et al*., 2015). The content of methionine and lysine in feed will affect the growth, performance, and carcass quality of broiler chickens (Corzo *et al*., 2005; Kidd *et al*., 2005; Zhai *et al*., 2016).

Methionine is an amino acid containing sulfur where the sulfur group can produce methyl groups that crutial function for various types of biological reactions in cells, especially the synthesis and metabolism of epinephrine, choline, carnitine, creatine, and muscle growth (Goulart *et al*., 2011; Fegundes *et al*., 2020). Lysine can increase carcass production and the quality of broiler chicken meat because lysine will affect the formation of chest muscles (Belloir *et al*., 2019; Lee *et al*., 2020). Dietary lysine supplementation improves the growth and performance of poultry (Barekatain *et al*., 2021; Sharma *et al*., 2018; Wen *et al*., 2017), and also increase the pH and decreases drip loss in breast meat (Berri *et al*., 2008). Lisnahan *et al*. (2017) show that the addition of amino acids methionine and lysine in feed not only increases body weight but also accelerates growth. Increasing the level of methionine and lysine in the diet can increase breast meat yield in poultry, improve meat quality (Hickling *et al*., 1990; Drażbo *et al*., 2015; Gardzielewska *et al*., 2005) and function as precursors to L-carnitine used in metabolism to facilitate fatty acid oxidation and reduce the amount of long-chain fatty acids available for fat storage as abdominal fat (Handique *et al*., 2019). L-Carnitine also plays a role in the transport of fatty acids into the mitochondria to be oxidized into energy, so that fat is used as an energy source rather than protein. Protein in the body is used more for muscle formation and will directly increase the protein content in meat. Increased fat burning through fatty acid oxidation, reduces body fat accumulation, and increase energy efficiency, subcutaneous and visceral fat reduction, and greater muscle mass gains. This study aims to determine the effect of adding methionine and lysine in fermented palm kernel cake-based rations on performance and chemical composition of broiler meat.

MATERIALS AND METHODS

Birds and Housing

The material used in this study consisted of 250 day-old chicks of the Platinum strain, produced by PT Japfa Comfeed and obtained from a poultry shop in Jambi City. The chicks were of mixed sex, with an average initial body weight of 39.58 grams, and were raised for a period of 28 days. Palm kernel meal (PKM) was sourced from PT Bukit Bintang Sawit, located in Muaro Jambi Regency, Jambi Province, Indonesia. The fermentation of PKM (FPKM) was conducted following the protocol described by Mairizal and Akmal (2019). Briefly, 0.5 kg of PKM was mixed with 2% urea, 0.05% $FeSO_4$, 0.075% $CaCO_3$, and 0.25% $MgSO_4$ as mineral sources to support bacterial growth. The mixture was then steamed for 30 minutes, allowed to cool, and subsequently inoculated with a liquid culture of Bacillus cereus V9 containing 10^6 CFU/mL, at a volume equal to 10% of the substrate weight. The inoculated substrate was placed in a plastic tray (28 × 37 × 4.5 cm), covered with another tray of the same size, and incubated at 30°C for five days. After the incubation period, the fermented product was stirred, crushed, and dried in an oven at 60°C until completely dry.

Birds were placed in 25 cages (10 broilers per cage) each with a dimension of 100 cm x 100 cm x 50 cm (L x W x H) which were equipped with feeders, drinkers and incandescent lighting for 24 hours.

Research Design

The basal rations were prepared based on recommendations from NRC (1994) and arranged based on the maintenance period, namely the starter and finisher periods. The ingredients of the ration and the nutritional content of the basal ration based on fermented palm kernel cake are shown in Table 1. This study used a Completely Randomized Design (CRD) with 5 treatments and 5 replications. The treatments were T0 = Control Ration (CR), T1 = CR + 0.25% Methionine + 0.25% Lysine, T2 = CR + 0.25% Methionine + 0.5% Lysine, T3 = CR + 0.5% Methionine + 0.25% Lysine and T4 = CR + 0.5% Methionine + 0.5% Lysine.

Table 1: Composition and nutritional content of basal ration used in the study.

Ingredient (%)	Starter (1-21days)	Finisher (22-28 days)
Corn flour (%)	36,5	41,5
Soybean meal (%)	18	14
FPKM[1] (%)	30	30
Fish flour (%)	12	12
Coconut oil (%)	3	2
Premix[2] (%)	0,5	0,5
Total	100	100
Calculated Nutrient		
Crude protein (%)	22,19	20,73
Crude fiber (%)	3,67	3,63
Crude fat (%)	6,36	4,87
Calcium (%)	1,07	1,07
Phosphorus (%)	0,65	0,64
Lysin (%)	1,14	1,06
Methionine (%)	0,42	0,41
Tryptophan (%)	0,41	0,37
ME (Kcal/kg)[3]	3163.05	30112,95

[1]Fermented Palm kernel meal. [2]Content (per kg of ration): vitamin A, 2,500 IU; vitamin D3,500 IU; vitamin E, 1.5 IU; vitamin K3, 0.4 mg; thiamine, 0.3 mg; riboflavin, 1 mg; pyridoxine, 1 mg; cyanocobalamin, 2.4 μg; vitamin C, 6 mg; niacin, 7 mg; calcium-d-pantothenate, 1 mg; manganese, 20 mg; iron, 5 mg; iodine, 0.04 mg; zinc, 20 mg; cobalt, 0.04 mg; copper, 0.6 mg; antioxidant, 2 mg; methionine, 7 mg; and lysine, 7 mg. [3]Metabolizable energy.

Experimental Measurements

Variables observed in this study were feed intake, body weight gain, feed conversion ratio, abdominal fat and chemical composition of broiler meat. Measurement of body weight gain (BW) and feed intake was conducted weekly. BW was calculated as the difference between the final weight and the initial weight for each chicken contained in each cage unit for each week of the weighing period. Feed consumption (grams/head/week), was measured by subtracting the amount of ration given at the beginning of the week from the remaining ration at the end of the week and then divided by the number of animals. Feed conversion ratio (FCR) was calculated as the ratio between feed consumption and body weight gain for each week. While abdominal fat consists of fat surrounding the cloaca and abdominal muscles excluding fat surrounding the gizzard. Measurement of abdominal fat weight for each chicken is done by weighing the fat obtained from the fat around the gizzard and the layer attached between the abdominal muscles and intestines and calculated in grams.

Chemical Composition of Broiler Meat

The parameters observed in this study included the chemical quality of broiler meat, specifically dry matter content, crude protein content, and crude fat content. Two broiler chickens were slaughtered from each replication of each treatment group on the 35th day. The right breast muscle was collected as a sample for chemical analysis. The analyses were conducted following the standard procedures of the AOAC (2004). Dry matter content was determined using method number 934.01, crude protein content using method number 954.01, crude fat content (ether extract) using method number 920.39, and ash content using method number 942.05.

Statistical Analysis

The data were analyzed using analysis of variance (ANOVA), in accordance with the completely randomized design (CRD) employed in the study. Significant differences were considered at $P \leq 0.05$, and when significant effects were detected, mean comparisons were conducted using Duncan's Multiple Range Test (Steel and Torrie, 1995).

RESULTS AND DISCUSSION

Effect of Treatment on Performance and Abdominal Fat of Broilers

The effect of adding methionine and lysine in fermented palm kernel meal-based rations on broiler performance is shown in Table 2.

The consumption of broiler rations with the addition of methionine and lysine in FPKM-based rations did not show a significant effect ($P > 0.05$) on feed intake (Table 2). Although the addition of methionine and lysine did not substantially alter the overall nutritional composition of the basal ration, it likely improved the quality of protein consumed by better meeting the birds' amino acid requirements, particularly for methionine and lysine. The lack of impact on feed intake may be attributed to the fact that broiler ration consumption is more strongly influenced by crude fiber content and metabolizable energy levels (Azizi *et al*., 2011). In this study, the crude fiber and metabolizable energy contents of the basal ration were 3.60% and 3,163.05 kcal/kg during the starter period, and 3.63% and 3,012.95 kcal/kg during the finisher period (Table 1), which are still within the acceptable tolerance limits for broilers, as recommended by the NRC (1994).

Mateos *et al*. (2012) reported that increasing dietary fiber in poultry rations can reduce nutrient intake, while Yaophakdee *et al*. (2018) noted that high crude fiber levels may dilute the energy concentration of the feed, thereby reducing the overall nutritional availability for the birds. On the other hand, Tejeda and Kim (2021) highlighted the potential benefits of crude fiber in poultry diets, such as promoting peristalsis and stimulating the development of digestive organs. However, excessive fiber can also lead to a feeling of fullness, which may suppress feed intake.

The addition of amino acids methionine and lysine in rations based on FPKM has an effect ($P<0.05$) on increasing broiler body weight gain (Table 2). Duncan's test showed that the weight gain of T0 was not significantly different ($P>0.01$) from T1, but was lower ($P<0.01$) when compared with T2, T3 and T4. Broiler body weight gain increased in line with the increase in the concentration of added amino acids methionine and lysine (Table 2). The results of this study prove that the balance or availability of amino acids methionine and lysine is indeed needed to cover the lack of amino acids in the ration as a result of the use of FPKM. As stated by Yaophakdee *et al*. (2018) that the problems caused by the use of PKM are not only related to the physical properties of PKM but also its contribution to the overall nutrition in the ration, especially the utilization of amino acids, because PKM contains low levels of the main essential amino acids such as lysine and methionine. In line with Yatno (2011), PKM can be used as poultry feed considering the fairly high crude protein content, but it is necessary to pay attention to the availability of low essential amino acids such as methionine and lysine amino acids.

The balance of nutrients in a ration, particularly the essential amino acids methionine and lysine, plays a crucial role in influencing the weight gain of broilers. Supplementation of methionine and lysine has been shown to produce the highest weight gain, especially when included in rations based on low-quality feed ingredients (Kidd *et al*., 1997). Alagawani *et al*. (2020) stated that methionine and lysine supplementation can enhance poultry growth by meeting their nutritional requirements for energy and protein, thereby increasing body weight and accelerating growth. As shown in Table 2, the addition of 0.5% methionine and 0.5% lysine to FPKM-based rations resulted in the highest weight gain among all treatments.

Table 2: Average feed consumption, body weight gain, and feed conversion ratio of broilers.

	Treatment					P-Value
	T0	T1	T2	T3	T4	
Starter (0-21 days)						
Feed Consumption (g/head/week)	299.45 ±5.79	318.40 ±5.92	319.06 ±17.64	317.15 ±6.78	311.90 ±16.85	NS
Body Weight Gain (g/head/week)	223.37^{a} ±15.62	234.73^{ab} ±11.07	246.51^{bc} ±8.28	277.70^{c} ±17.65	265.28^{bc} ± 15.08	*
Feed Conversion Ratio	1.35^{a} ±0.09	1.36^{a} ±0.07	1.29^{ab} ±0.07	1.34^{a} ±0.04	1.18^{b} ±0.07	*
Finisher (22 – 28 days)						
Feed Consumption (g/head/week)	626.79 ±16.56	625.50 ±22.52	654.57 ±21.26	660.88 ±20.75	678.04 ±45.58	NS
Body Weight Gain (g/head/week)	343.93^{a} ±9.70	390.88^{b} ±14.25	401.14^{b} ±30.30	392.39^{b} ±29.55	406.85^{b} ±7.86	*
Feed Conversion Ratio	1.76^{a} ±0.10	1.69^{ab} ±0.09	1.64^{ab} ±0.06	1.46^{c} ±0.09	1.60^{bc} ±0.11	*

Note: Different letters indicate significant differences for the same row.* indicates significant difference at $P\leq0.05$; NS: indicates no significant differences.

The observed increase in body weight with methionine and lysine supplementation is likely due to improved nutrient absorption, which enhances growth performance. According to Shen *et al*. (2015), supplementation with these amino acids supports intestinal health by promoting villi development and reducing protein oxidation in the duodenum. Similarly, Heidari and Toghyani (2018) reported that methionine supplementation improved weight gain and feed intake during the rearing period of Ross 308 broilers. Furthermore, numerous studies have highlighted the critical roles of methionine and lysine in the metabolism of monogastric animals. The consumption of these functional amino acids contributes to improved health, survival, growth, development, and reproduction (Wu, 2013; Jankowski *et al*., 2014; Wu *et al*., 2014; Liao *et al*., 2015).

FCR can be used as one of the benchmarks for success in broiler chicken farming. The addition of methionine and lysine in FPKM-based rations significantly ($P<0.01$) modulated the FCR (Table 2). Duncan's test showed that FCR in T0 treatment was higher ($P<0.01$) than T1, T2, T3 and T4. The better FCR for P3 and P4 was due to high body weight gain when the ration was supplemented with methionine and lysine. Si *et al*. (2004) stated that ideal levels of methionine and lysine would be able to increase growth and improve ration conversion. Hickling *et al.* (1990) stated that methionine and lysine increase chicken growth, thereby increasing the efficiency of feed used. Similarly, Bronstein and Lepstein (1975) reported that feed containing 19.1% crude protein then added with methionine would be able to increase the feed efficiency as a ration containing 23% crude protein. The increase in ration conversion in the P0 treatment was in line with the low body weight in the treatment, while the consumption of P0 ration with other treatment rations was not significantly different. The results of this study indicate that the addition of methionine and lysine amino acids in fermented palm kernel meal-based rations is very effective in reducing the ration conversion rate. This provides evidence that the presence of methionine and lysine amino acids is indeed needed to complement the lack of amino acids in palm kernel meal.

Table 3: Abdominal fat contents of broilers.

Treatment	Abdominal fat (g)
T0	$17.39^{a} \pm 3.29$
T1	$14.54^{ab} \pm 3.38$
T2	$12.18^{bc} \pm 2.46$
T3	$10.53^{bc} \pm 2.10$
T4	$8.33^{c} \pm 3.09$
P-Value	*

Note: Different letters indicate significant differences for the same row. * indicates significant difference at P≤0.05.

Methionine and lysine supplements in FPKM-based rations showed significant differences (P<0.05) on broiler abdominal fat (Table 3). Duncan's test showed that abdominal fat at T0 was the same (P>0.05) as T1, but higher when compared to T2, T3 and T4. While T1 was the same (P>0.05) as T2 and T3 and higher (P<0.05) than T4, but abdominal fat at T2, T3 and T4 were the same (P>0.05). The addition of methionine and lysine of 0.25% each in FPKM-based rations has not shown a significant decrease in abdominal fat. However, the addition of methionine of 0.5% with lysine of 0.25% or lysine of 0.5% with methionine of 0.25% (T2 and T3) has shown a decrease in abdominal fat when compared to without the addition of methionine and lysine (T0). The lowest decrease in abdominal fat was in the T4 treatment with methionine supplementation of 0.5% and Lysine 0.5%. The decrease in fat occurred because methionine and lysine were donors of methyl groups in the synthesis of L-carnitine, which function to transport fatty acids into the mitochondria to be oxidized into energy. Increasing the amount of methionine in the ration also increased the production of L-carnitine, which helped the chicken's body to burn fat, thereby reducing the accumulation of body fat and including abdominal fat. Methionine and lysine function as precursors of L carnitine and increase its supply which is used in metabolism which will reduce long chain fatty acids for fat storage, especially in the abdominal fat (Bayeuh, 2013; Handique *et al.*, 2019; Tufarelli *et al.*, 2020).

Effect of Treatment on Chemical Quality of Broiler Meat

The chemical quality of broiler meat, especially the fat content of the meat, is one of the reasons for people to consume broiler meat. Meat with high fat content is associated with an increased risk of heart disease and atherosclerosis (Najjar, 2023). The water, ash, fat and protein content of broiler meat supplemented with methionine and lysine in FPKM-based rations are shown in Table 4.

Table 4: Chemical quality of broiler meat.

Treatment	Dry matter (%)	Ash (%)	Crude protein (%)	Crude fat (%)
T0	$23.38^{a}\pm0.35$	$1.14^{a}\pm0.02$	$18.55^{a}\pm0.14$	$3.65^{a} \pm 0.20$
T1	$22.62^{ab}\pm0.76$	$1.15^{a} \pm0.01$	$18.65^{ab}\pm0.10$	$3.40^{ab} \pm 0.19$
T2	$22.10^{ab}\pm0.48$	$1.16^{ab}\pm0.01$	$19.23^{b}\pm0.12$	$3.20^{b} \pm 0.18$
T3	$21.82^{ab}\pm0.52$	$1.18^{ab}\pm0.02$	$19.60^{bc}\pm0.14$	$3.05^{bc} \pm 0.12$
T4	$21.62^{b}\pm0.32$	$1.19^{b}\pm0.02$	$19.98^{c}\pm 0.16$	$2.82^{c} \pm 0.15$
P-Value	*	*	*	*

Note: Different letters indicate significant differences for the same row. * indicates significant difference at P≤0.05.

Broiler meat dry matter was affected (P<0.05) by methionine and lysine supplementation in FPKM-based rations. Duncan's test showed that T0 was not significantly different (P>0.05) from T1, T2 and T3, but dry matter in T4 was higher (P<0.05) than T0. While dry matter T4 was not different (P>0.05) from T1, T2, and T3. The decrease in meat dry matter in T4 was in line with the decrease in meat fat content. Previous studies reported that an increase in meat dry matter was in line with an increase in crude fat (Namroud *et al.*, 2010; Maghfuri *et al.*, 2014). Methionine and lysine play a role in fat metabolism and increased fat metabolism can reduce abdominal fat accumulation. High levels of lysine in the diet will increase energy expenditure to store protein and maintain muscle mass so that less energy is stored in the form of fat deposits (Lesson *et al.*, 1995).

Supplementation of methionine and lysine in FPKM-based rations significantly affected (P<0.05) the ash content of broiler meat. Duncan's test showed that the ash content of T0 was lower (P<0.05) when compared to T4, but did not differ (P>0.05) from T1, T2, and T3. The ash content of T2 did not differ (P>0.05) from T3 and T4. Ash content is a determining factor in the nutritional content related to the mineral content of chicken meat. The results showed that the addition of 0.5% methionine and 0.5%

lysine could increase the mineral content of broiler meat, as indicated by higher ash content. In this study, the ash content ranged from 1.14% to 1.19%, which falls within the normal range for raw broiler meat. This is consistent with the findings of Bogosavljević-Bošković *et al.* (2010), who reported that the ash content of raw broiler meat typically ranges from 0.7% to 3.6%.

Supplementation of methionine and lysine in FPKM-based rations showed a significant effect (P<0.05) on the crude protein content of broiler meat. Duncan's test showed that the protein content in T0 was lower than T2, T3 and T4, but was not significantly different (P>-.05) from T1. The addition of methionine and lysine each as much as 0.25% in FPKM-based rations did not show any effect on the protein content of meat. Increasing the provision of Methionine and Lysine to 0.5% each showed an increase in the protein content of meat. The increase in the protein content of meat was due to the availability of methionine and lysine which were sufficient for protein synthesis to occur. Methionine plays a role in muscle protein synthesis, supports more muscle growth, and helps reduce the accumulation of body fat. Lysine supports collagen formation and increases muscle protein synthesis, contributing to the formation of stronger and more muscle tissue. Both work together to increase the amount of protein in broiler meat, which ultimately improves meat quality with more muscle and less fat. According to Handique *et al.* (2019), methionine is needed for protein synthesis because methionine is the initiator of protein synthesis and lysine is needed to optimize breast muscle growth. Rations that are deficient in protein, especially in essential amino acids such as methionine and lysine, will affect the formation of meat and its chemical composition. Rations T0 without the addition of amino acids lysine and methionine are thought to be deficient in these essential amino acids so that meat protein will also be reduced. According to Bogosavljević-Bošković *et al.* (2010) the main factors that affect the chemical composition and quality of broiler meat are the use of raw materials and their chemical composition, as well as the protein and energy content of the ration. Rations that are deficient in protein, especially in essential amino acids such as methionine and lysine, will affect the formation of meat and its chemical composition.

The addition of methionine and lysine in FPKM-based rations showed a significant effect (P<0.05) on the crude fat content of broiler meat. Duncan's test showed that T0 had a higher (P<0.01) crude fat content in meat compared to T2, T3 and T4, but was not significantly different (P>0.05) from T1. The addition of methionine and lysine of 0.25% each did not significantly affect fat metabolism so that the fat content of meat in treatment T1 did not differ (P>0.05) from T0. The high crude fat content of meat in T0 when compared to treatments T1, T2, T3 and T4 is caused by an imbalance of amino acids, especially the amino acids methionine and lysine, so that they cannot be used for protein synthesis. The limiting amino acid in broiler rations is methionine followed by lysine (Smith, 2001). Imbalance and deficiency of amino acids can cause decreased secretion of thyroxine hormone resulting in higher fat accumulation (Namroud *et al*., 2010). A decrease in carcass fat content is associated with an increase in lysine content in the diet, thereby increasing energy expenditure (Leeson *et al*., 1995). Lysine and methionine affect carcass and breast meat composition and can increase protein content and reduce excessive fat in broiler carcasses. has been shown to have specific effects on carcass composition and breast meat yield, increase protein content, and reduce excess fat accumulation in carcasses (Handique *et al*., 2019).

CONCLUSIONS AND RECOMMENDATIONS

Fermented palm kernel meal (FPKM) can be utilized as a component in broiler rations. However, a major limitation in its use is the deficiency of essential amino acids, particularly methionine and lysine. Supplementation with these amino acids is essential to address this nutritional shortfall. The inclusion of 0.5% methionine and 0.5% lysine in FPKM-based rations has been shown to enhance broiler growth performance and improve the chemical quality of broiler meat.

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NOVELTY STATEMENTS

This study found the best level of methionine and lysine addition in fermented palm kernel meal-based rations that can increase body weight gain and physical quality of broiler meat.

AUTHOR'S CONTRIBUTIONS

Mairizal: Conceptualization, laboratory work, data collection and analysis and writing the manuscript, revising the manuscript. Akmal and Fahmida: formal analysis, laboratory work. data collection. Filawati: animal husbandry, data collection, editing and revising the manuscript. Teja Gusli Ananda: animal husbandry, data analysis and writing the manuscript. All authors have read, reviewed and approved the final manuscript.

Conflict of Interest

The authors declares that there is no conflict of interests regarding the publication of this article.

REFERENCES

Abdeshahian PN, Noraini S, Hamid AA, Yusoff WMW (2010). Utilization of palm kernel cake for production of β-mannanase by *Aspergillus niger* FTCC 5003 in solid subtrate fermentation using an aerated column bioreactor. J. Ind. Microbiol Biotechnol., 37:103-109. https://doi.org/10.1007/s10295-009-0658-0

Alshelmani IM, Loh TC, Foo HL, Lau WH, Sazili AQ (2014). Biodegradation of palm kernel cake by cellulolytic and hemicellulolytic bacterial cultures through solid state fermentation. Sci. W. J., 2014: Page:1-8. https://doi.org/10.1155/2014/729852

Alshelmani IM, Abdalla EA, Kaka U, Basit AM (2021). Nontraditional Feedstuffs as an Alternative in Poultry Feed. Adv. In Poult. Nut. R., Page:1-14. http://dx.doi.org/10.5772/intechopen.95946

Alagawany M, Elnesr SS, Farag MR, Tiwari R, Yatoo MI, Karthik K, Michalak I, Dhama K (2020). Nutritional significance of amino acids, vitamins and minerals as nutraceuticals in poultry production and health - a comprehensive review. Vet. Q., 41(1):1-29. https://doi.org/10.1080/01652176.2020.1857887

Alagawany M, Elnesr SS, Farag MR (2018). The role of exogenous enzymes in promoting growth and improving nutrient digestibility in poultry. Iran J. Vet. Res., 19(3):157–164. https://doi.org/10.22099/ijvr.2018.4932

AOAC (2004). Official Methods of Analysis of the Association of Official Analytical Chemists, 18th ed. Washington DC. USA. 2004.

Azizi B, Ghorbanali S, Ahmad K, Fakhradin A (2011). Effects of dietary energy and protein dilution and time of feed replacement from starter to grower on broiler chickens performance. J. Cent. Euro. Agr., 12:44-52. https://doi.org/10.5513/JCEA01/12.1.879

Barekatain R, Romero LF, Sorbara JOB, Cowieson AJ (2021). Balanced nutrient density for broiler chickens using a range of digestible lysine-to-metabolizable energy ratios and nutrient density: Growth performance, nutrient utilization and apparent metabolizable energy. Anim. Nutr., 7: 430–439.

Belloir P, Lessire M, Lambert W, Corrent E, Berri C, Tesseraud S (2019). Changes in body composition and meat quality in response to dietary amino acid provision in finishing broilers. Animal, 13(5):1094–1102. https://doi.org/10.1017/S1751731118002306

Berri C, Besnard J, Relandeau C (2008). Increasing dietary lysine increases final pH and decreases drip loss of broiler breast meat. Poult. Sci., Volume 87, Issue 3; 480-484, https://doi.org/10.3382/ps.2007-00226

Beski SS, Swick RA, Iji PA (2015). Specialized protein products in broiler chicken nutrition: A review. Anim. Nutr., 1(2):47–53.

Bogosavljević-Bošković S, Pavlovski Z, Petrović MD, Dosković V, Rakonjac S (2010). Broiler meat quality: Proteins and lipids of muscle tissue. Afr. J. Biotechnol., 9(54):9177–9182. https://www.ajol.info/index.php/ajb/article/view/125762

Bornstein S, Lipstein B (1975). The replacement of some of the soybean meal by the first limiting amino acids in practical broiler diets: 1. The value of special supplementation of chick diets with methionine and lysine. Br. Poult. Sci., 16: 177-188. https://doi.org/10.1080/00071667508416175

Bortoluzzi C, Rochell SJ, Applegate TJ (2018). Threonine, arginine, and glutamine: Influences on intestinal physiology, immunology, and microbiology in broilers. Poult. Sci., 0:1–9. https://doi.org/10.3382/ps/pex394

Bouyeh M (2013). Effects of excess dietary lysine and methionine on performance and economical efficiency of broiler chicks. Ann. Bio. Res., 4 (5): 241-246.

Corzo A, Kidd MT, Burnham DJ, Branton SL, Gonzalez-Esquerra R, Miller ER (2005). Dietary aminio acid density effects on growth and carcass of broi-lers differing in strain cross and sex. J. Appl. Poult. Res., 14: 1–9. https://doi.org/10.1093/japr/14.1.1

Drażbo A, Kozłowski K, Chwastowska-Siwiecka I, Sobczak A, Kwiatkowski P, Lemme A (2015). Effect of different dietary levels of DL-methionine and the calcium salt of DL-2-hydroxy-4-[methyl] butanoic acid on the growth performance, carcass field and meat quality of broiler chickens. Eur. Poult. Sci., 79. https://doi.org/10.1399/eps.2015.114

Dusterhoft EM, Bonte AW, Voragen AGJ (1993). Solubilisation of non-starch polysaccharides from oil seed meals by polysacharide degrading enzymes. J. Sci. Food Agric., 63: 211-220. https://doi.org/10.1002/jsfa.2740630207

Fagundes NS, Milfort MC, Williams SM, Da Costa MJ, Fuller AL, Menten JF, Rekaya R, Aggrey SE (2020). Dietary methionine level alters growth, digestibility, and gene expression of amino acid transporters in meat-type chickens. Poult. Sci., 99(1):67–75. https://doi.org/10.3382/ps/pez588

Gardzielewska J, Jakubowska M, Majewska T, Jankowski J, Kozłowski K, Pudyszak K, Paszko B (2005). The quality of meat of turkey-cocks receiving DL-methionine supplemented feeding. Vet. Zootechnika, 29 (51): 73-76.

Goulart CC, Costa FGP, Silva JHV, Souza JG, Rodrigues VP, Oliveira CFS (2011). Requirements of digestible methionine + cystine for broiler chickens at 1 to 42 days of age. R Bras. Zootec., 40(4):797–803. https://doi.org/10.1590/S1516-35982011000400013

Guoyao W (2013). Functional amino acids in nutrition and health. Amino Acids, 45: 407–411. https://doi.org/10.1007/s00726-013-1500-6

Handique B, Saikia G, Dowarah R, Saikia BN, Tamuly S (2019). Effect of supplementation of synthetic lysine and methionine on serum biochemical profile, carcass characteristics and meat composition in broiler chicken. Indian J. Anim. Nutr., 36 (1): 40-46. https://dx.doi.org/10.5958/2231-6744.2019.00007.0

Handique B, Yengkhom R, Maurya LK (2019). Lysine and methionine supplementation in commercial broiler chicken: A review., J. Ent. Zool. Stud., 7(3): 193-196.

Heidari S, Toghyani M (2018). Effect of stocking density and methionine levels on growth performance and immunity of broiler chicks. Iran. J. Appl. Anim. Sci., 8(3):483–489.

Hickling D, Geuenter W, Jackson ME (1990). The effects of dietary methionine and lysine on broiler chicken performance and breast meat yield. Can. J. Anim. Sci., 70: 673-678. https://doi.org/10.4141/cjas90-079

Jankowski J, Kubińska M, Zduńczyk Z (2014). Nutritional and immunomodulatory function of methionine in poultry diets–a review. Ann. Anim. Sci., 14: 17–32. https://doi.org/10.2478/aoas-2013-0081

Kidd MT, Kerr BJ, Anthony NB (1997). Dietary Interactions between lysine and threonine in broilers. Poult. Sci., 76: 608-614 https://doi.org/10.1093/ps/76.4.608

Kidd MT, Corzo A, Hochler D, Miller ER, Dozier WA (2005). Broiler responsiveness (Ross x 708) to diets varying in amino acid density. Poult. Sci., 84: 1389–1396. https://doi.org/10.1093/ps/84.9.1389

Lee CH, Ai-Lian AS, Loh TC, Rahim RA (2020). Effects of lysine and methionine in a low crude protein diet on the growth performance and gene expression of immunity genes in broilers. Poult. Sci., 99(6): 2916-2925. https://doi.org/10.1016/j.psj.2020.03.013

Lesson S, Diaz G, Summers JD (1995). Poultry Metabolic Disorder and Mycotoxin. University Books, Guelph, Ontario, Canada

Liao SF, Wang T, Regmi N (2015). Lysine nutrition in swine and the related monogastric animals: muscle protein biosynthesis and beyond. Springer plus 4: 147–158. https://doi.org/10.1186/s40064-015-0927-5

Lisnahan CV, Wihandoyo, Zuprizal Harimurti S (2017). Effect of addition of methionine and lysine into diets based on cafeteria standards on the growth performance of native chickens at starter phase. Int. J. Poult. Sci., 16: 506-510. https://doi.org/10.3923/ijps.2017.506.510

Maghfuri M, Sudarman A, Mutia R (2014). Effects of amino aAcid supplementation on nutritional values and L-carnitin of broiler meat. Anim. Prod., 16(1):31-38.

Mairizal, Marlida Y, Mirzah, Fahmida M (2018). Isolation and characterization of mannanase-producing *Bacillus cereus* isolated from the hindgut of termites. Pak. J. Nutr., 17: 116-123. https://doi.org/10.3923/pjn.2018.116.123

Mairizal, Akmal (2019). Evaluasi Nutrisi dari Peningkatan Kualitas Bungkil Inti Sawit yang Difermentasi dengan *Bacillus cereus* V9 dalam Pemanfaatannya sebagai Pakan Ternak Unggas. Laporan Penelitian.LPPM Universitas Jambi.

Mateos GJ, Moreno J, Serrano EM, Lazaro R (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. J. App. Poult. Res., 21. 156-174. 10. https://dx.doi.org/10.3382/japr.2011-00477

Najjar RS (2023). The impacts of animal-based diets in cardiovascular disease development: A Cellular and Physiological Overview. J. Cardiovasc Dev. Dis., 10(7):282. https://doi.org/10.3382/japr.2011-00477

Namroud NF, Shivazad M, Zaghari M, Shahneh Z (2010). Effect of glycine to low protein diets on performance, thyroid function and fat deposition in chickens. South Afr. J. Anim. Sci. 40(3):238- 244.

Ng W, Lim H, Lim S, Ibrahim C (2002). Nutritive value of palm kernel meal pretreated with enzyme or fermented with Trichoderma koningii (*Oudemans*) as a dietary ingredient for red hybrid Tilapia (*Oreochromis sp.*) Aquac. Res., 33, pp.1199-1207 https://doi.org/10.1046/j.1365-2109.2002.00757.x

NRC (1994). Nutrient Requirements of Poultry. 9th Edn., National Academy Press, Washington, DC., USA.

Orthman MF, Kalil MS, Sahri M (2013). Solid state fermentation of palm kernel cake (PKC) by newly isolated *Rhizopus oryzae* ME01. Asian J. Exp. Biol. Sci., 4:84-88.

Ramin M, Alimon AR, Ivan M (2010). Effects of fungal treatment on the *in vitro* digestion of palm kernel cake. Livestock. Res. Rural Dev., 22 (4). http://www.lrrd.org/lrrd22/4/rami22082.html

Barbara JR (2009). The relationship between dietary energy density and energy intake. Physiol. Behav., 97(5):609-15. https://doi.org/10.1016/j.physbeh.2009.03.011

Sharma NK,Choct M, Toghyani M, Laurenson YC, Girish CK, Swick RA (2018). Dietary energy, digestible lysine, and available phosphorus levels affect growth performance, carcass traits, and amino acid digestibility of broilers. Poult. Sci., 97, 1189–1198. https://doi.org/10.3382/ps/pex405

Shen YB, Ferket P, Park I, Malheiros RD, Kim SW (2015). Effects of feed grade L-methionine on intestinal redox status, intestinal development, and growth performance of young chickens compared with conventional DL-methionine. J. Anim. Sci., 93:2977–2986. https://doi.org/10.2527/jas.2015-8898

Si J, Kersey JH, Fritts CA, Waldroup PW (2004). An evaluation of the interaction of lysine and methionine in diets for growing broilers. Int. J. Poult. Sci., 3: 51-60. https://doi.org/10.3923/ijps.2004.51.60

Smith AJ (2001). Poultry. The tropical agriculturalist series (CTA). Rev. Edn., Macimillan Education Ltd., Oxford. London.

Steel RGD, Torrie JH (1995). Prinsip dan Prosedur Statistika: Suatu Pendekatan Biometrik. Penerjemah Bambang S. Edisi ke-2. Jakarta: PT. Gramedia Pustaka Utama.

Sundu B. and Dingle J (2003). Use of enzyme to improve the nutritional value of palm kernel meal and copra meal. Proceedings of Queensland Poultry Science Symposium Australia. Vol: 11(14)1-15

Tejeda TO, Kim KW (2021). Role of dietary fiber inpPoultry nutrition. Animals (Basel), 11(2):461. https://doi.org/10.3390/ani11020461

Tufarelli VH, Mehrzad-Gilmalek H, Bouyeh M, Qotbi A, Amouei H, Seidavi A, Paz E, Laudadio V (2020). Effect of different levels of l-carnitine and excess lysine-methionine on broiler performance, carcass characteristics, blood constituents, immunity and triiodothyronine hormone. Agriculture, 10:1-8. https://doi.org/10.3390/agriculture10040138

Wen ZG, Rasolofomanana TJ, Tang J, Jiang Y, Xie M, Yang PL Hou SS (2017). Effects of dietary energy and lysine levels on growth performance and carcass yields of Pekin ducks from hatch to 21 days of age. Poult. Sci., 96: 3361–3366. https://doi.org/10.3382/ps/pex122

Wu G (2013). Functional amino acids in nutrition and health. Amino Acids 45:407–411. https://doi.org/10.1007/s00726-013-1500-6

Wu G, Bazer FW, Dai Z, Li D, Wang J, Wu Z (2014). Amino acid nutrition in animals: protein synthesis and beyond. Annu. Rev. Anim. Bio. Sci., 2: 387–417. https://doi.org/10.1146/annurev-animal-022513-114113

Yatno (2011). Fractionation and Physico-Chemical Characteristics of Palm Kernel Meal. Agrinak, 10:11-16.

Yaophakdee N, Ruangpanit Y, Attamangkune S (2018). Effects of palm kernel meal level on live performance and gut morphology of broilers, Agric. Nat. Res., 52 (1):75-78.

Zhai W, Peebles ED, Schilling MW, Mercier Y (2016). Effects of dietary lysine and methionine supplementation on Ross 708 male broilers from 21 to 42 d of age (I): growth performance, meat yield, and cost effectiveness. J. Appl. Poult. Res., 25:197–211. https://doi.org/10.3382/japr/pfw002