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Interactive Effects of Palm Kernel Cake Ratio and Enzyme Supplementation on Broiler Chicken Performance

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ABSTRACT

This study investigated the interactive effects of palm kernel cake (PKC) inclusion levels (10 and 20%) and enzyme supplementation (NSPase, protease, and mannanase) on the growth performance and nutrient efficiency of broiler chickens. A total of 720 male broilers were randomly assigned to four dietary treatments and 6 replicates per treatment with each treatment consisting of 30 chickens for 28 days in a completely randomized design. The parameters measured included feed intake, body weight gain, feed conversion ratio (FCR), energy and protein intake, and their respective efficiencies (Protein Efficiency Ratio (PER) and Energy Efficiency Ratio (EER)). Results showed that broilers fed diets with 10% PKC—both with and without enzyme supplementation—achieved significantly better final body weight, average daily gain (ADG), FCR, EER, and PER than those fed 20% PKC (P<0.05). Notably, enzyme supplementation improved nutrient utilization only at the 10% PKC level, while the 20% PKC inclusion led to reduced digestibility and performance, regardless of enzyme use (P<0.05). Feed, energy, and protein intake were not significantly different across treatments, indicating that variations in growth were primarily due to nutrient utilization efficiency (P>0.05). These findings suggest that a 10% PKC inclusion with or without enzymes optimizes broiler performance, while higher PKC levels may negate enzyme benefits due to increased fibre content.

Keywords: broiler performance, palm kernel cake, enzyme supplementation, nutrient efficiency

INTRODUCTION

Palm Kernel Cake (PKC), a by-product of oil extraction from *Elaeis guineensis* kernels, is gaining attention as an alternative feed for broilers due to its favorable nutrient profile and cost-effectiveness. PKC contains 14–18% crude protein (CP), 12–20% crude fibre (CF), 3–9% ether extract (EE), and essential minerals such as calcium and phosphorus (Azizi et al., 2021), making it a valuable protein and energy source in poultry and ruminant diets. Beyond its nutritional role, PKC supports gut microbiota balance, enhancing immunity and reducing digestive disorders, which are closely linked to growth and nutrient utilization (Alshelmani et al., 2017).

The use of PKC in poultry diets faces challenges mainly due to its high fiber content, which can reduce digestibility, feed intake, and growth performance. (Okukpe et al., 2019). PKC contains insoluble non-starch polysaccharides (NSPs) that hinder nutrient absorption and require careful formulation (Koranteng et al., 2022). While fibre may benefit rumen fermentation in ruminants, in poultry, it often decreases nutrient intake and digestibility (Fereira et al., 2012). Additionally, lignin and acid detergent fibre (ADF) in PKC further limit digestibility and energy availability (Pimentel et al., 2018).

Although PKC contains considerable protein, its availability is limited by anti-nutritional factors and protein binding to fibrous matrices, reducing crude protein digestibility and requiring processing or supplementation (Santos et al., 2019). Properly formulated diets, especially with enzyme inclusion, improve feed efficiency and growth performance (Olukomaiya et al., 2019). Despite its high fiber, PKC can support broiler growth when used at appropriate levels (Koranteng et al., 2022), with inclusion rates of 15–30% shown to be safe without adverse effects on carcass quality or performance (I. Wogar et al., 2012; Fafiolu et al., 2020).

The use of exogenous enzymes is a promising strategy to enhance PKC utilization, as supplementation in diets with 20% PKC has been shown to yield broiler performance comparable to control diets, particularly in ADG and FCR (Saenphoom et al., 2013), highlighting the importance of enzymes in mitigating PKC's fibre-related limitations. PKC is a promising feed ingredient to improve broiler production efficiency and sustainability. Still, its use requires precise formulation with appropriate inclusion levels and enzyme supplementation, warranting further research to determine the optimal combination.

MATERIALS AND METHODS

Materials

This study used 720 male day-old broiler chicks (DOC) of the Indian River strain. The feed ingredients included corn, Palm Kernel Cake (PKC), Soybean Meal (SBM), Meat Bone Meal (MBM), oil, premix, sodium chloride (NaCl), calcium carbonate ($CaCO_3$), L-lysine-HCl, DL-methionine, and monocalcium phosphate. The enzyme cocktail used in this study consisted of: **Mannanase enzyme**, a Hemicell® HT product from Elanco Animal Health, Indiana, USA, with an enzyme activity of 106 U/kg; **NSPase enzyme**, a product of Kemin Industries (Asia) Pte. Ltd., Singapore, containing alpha-amylase (270 U/g), cellulase (2,500 U/g), xylanase (1,875 U/g), and protease (900 U/g); **Protease enzyme**, Poultrygrow 250™ from Jefo Nutrition Inc., Quebec, Canada, with an activity of 1.82 U/g. The detailed composition and nutrient content of the experimental diets are presented in Table 1.

Table 1. Composition of feed ingredients (%) and nutrient content of experimental diets

Feed Ingredients	Treatments (%)			
	P1	P2	P3	P4
Corn	55.93	49.93	55.93	49.93
Palm Kernel Cake	10.00	20.00	10.00	20.00
Soya Bean Meal	20.00	16.00	20.00	16.00
Meat Bone Meal	10.00	10.00	10.00	10.00
Soybean oil	2.00	2.00	2.00	2.00
Vitamin premix	0.03	0.03	0.03	0.03
Mineral premix	0.03	0.03	0.03	0.03
NaCl	0.06	0.06	0.06	0.06
$CaCO_3$	1.00	1.00	1.00	1.00
L-Lysine HCl	0.15	0.15	0.15	0.15
DL-Methionine	0.20	0.20	0.20	0.20
Mono-Calcium Phosphate	0.60	0.60	0.60	0.60
Total	100	100	100	100
Nutrient content	**P1**	**P2**	**P3**	**P4**
Dry matter (%)	84.28	84.73	83.28	84.73
Ether extract (%)	6.23	6.86	6.23	6.86
Crude fibre (%)	3.65	4.91	3.65	4.91
Ash (%)	10.37	10.76	10.37	10.76
Metabolizable energy (kcal/kg)	3,013	3,002	3,013	3,002
Crude protein (%)	20.99	20.66	20.99	20.66
Calcium (%)	0.82	0.84	0.82	0.84
Available Phosphorus (%)	0.50	0.52	0.50	0.50
Lysine (%)	1.11	1.05	1.11	1.05
Methionine (%)	0.49	0.49	0.49	0.49
Methionine + cystine (%)	1.03	1.08	1.19	1.08

P1: feed with 10% PKC, added enzyme cocktails (NSPase, protease, mannanase) 512 g/ton, P2: feed with 20% PKC, added enzyme cocktails (NSPase, protease, mannanase) 512 g/ton, P3: feed with 10% PKC, P4: feed with 20% PKC. Vitamin premix used vitamin A 4,500 IU, vitamin D3 1,620 IU, vitamin E 31.5 mg, vitamin K 1.35 mg, thiamine (B1) 1.35 mg, riboflavin (B2) 3.30 mg, niacin (B3) 18 mg, pantotheanic acid (B5) 5.40 mg, pyridoxine (B6) 2.10 mg, folic acid (B10) 0.69 mg, vitamin B12 0.01 mg, biotin 0.09 mg. Minerals premix used copper 4.8 mg/kg, iodine 0.38 mg/kg, iron 7.5 mg/kg, manganese 36 mg/kg, selenium 0.06 mg/kg, zinc 30 mg/kg, and cobalt 0.03 mg/kg.

Methods

The experiment was conducted at the Research Broiler House (Closed House system) of the Faculty of Animal Science, Universitas Gadjah Mada. The study lasted for 28 days. Birds were housed in pens measuring 1.25 × 2 m, each accommodating 30 birds. The experiment followed a completely randomized design (CRD) with 4 dietary treatments and 6 replicates per treatment. The dietary treatments were as follows: **P1**: Feed containing 10% PKC with enzyme cocktail (NSPase, protease, mannanase) at 512 g/ton; **P2**: Feed containing 20% PKC with enzyme cocktail (NSPase, protease, mannanase) at 512 g/ton; **P3**: Feed containing 10% PKC without enzyme addition; **P4**: Feed containing 20% PKC without enzyme addition. In this study, the dosage and activity units of the exogenous enzyme used were determined based on the manufacturer's recommendation. Feed and water were provided ad libitum, with feeding conducted twice daily at 06:00 and 16:00 Western Indonesian Time. Feed refusals were collected weekly and summed at the end of the rearing period to calculate intake.

Parameters measured comprise: **Feed Intake (FI), which** was calculated as the difference between the amount of feed offered and the feed refused. **Body Weight Gain** was recorded at the end of the rearing period. **Feed Conversion Ratio (FCR)** was calculated by dividing FI by BWG. **Energy Intake (kcal/bird)** was calculated as the total energy consumed per bird during the experimental period. **Protein Intake (g/bird)** was calculated as the total protein consumed per bird during the experimental period. Additionally, the **Protein Efficiency Ratio (PER)** and **Energy Efficiency Ratio (EER)** were calculated using the following formulas:

PER = BWG (g) / Crude Protein Intake (g) (Golshahi et al., 2025)

EER = BWG (g) / Energy Intake (kcal) (Golshahi et al., 2025)

Data were analyzed using Analysis of Variance (ANOVA) following the Completely Randomized Design (CRD) model. If significant differences among treatments were detected, Duncan's Multiple Range Test (DMRT) was applied to compare means. All analyses were performed using RStudio (version 2025.05.1 Build 513), with the significance level set at 5%.

RESULTS AND DISCUSSION

The results of the study showed that both the inclusion levels of palm kernel cake (PKC) and supplementation with enzyme cocktails (NSPase, protease, and mannanase) had significant effects on the growth performance and nutrient efficiency of broiler chickens. Among all treatments, broilers in Treatment P1 (10% PKC + enzyme cocktails) consistently exhibited the best outcomes.

Table 2. Growth performance of broiler chickens fed diets containing different palm kernel cake (PKC) levels with or without enzyme cocktail supplementation

Parameter	Treatments				SEM	P-value
	P1	P2	P3	P4		
Feed Intake (g)	2,369.67	2,282.27	2,284.47	2,327.82	37.63	0.331
Body weight (g)	1,375.87[a]	1,124.38[b]	1,327.58[a]	1,143.21[b]	30.65	<0.001
Gain (g)	1,331.52[a]	1,079.56[b]	1,283.38[a]	1,099.12[b]	30.74	<0.001
FCR	1.73[a]	2.04[b]	1.73[a]	2.04[b]	0.05	<0.001
ADG (g)	47.55[a]	38.55[b]	45.84[a]	39.26[b]	1.10	<0.001

[ab] Different superscripts in the same row indicate significant differences (P<0.05); P1: feed contains 10% palm kernel cake + enzyme cocktails (NSPase, protease, mannanase) 512 g/ton; P2: feed contains 20% palm kernel cake + enzyme cocktails (NSPase, protease, mannanase) 512 g/ton; P3: feed contains 10% palm kernel cake; P4: feed contains 20% palm kernel cake; FCR: feed conversion ratio; ADG: average daily gain; EER: energy efficiency ratio; PER: protein efficiency ratio.

The inclusion levels of palm kernel cake (PKC) and enzyme cocktails (NSPase, protease, and mannanase) significantly influenced broiler performance. Feed intake was unaffected (P = 0.331), indicating that neither PKC level nor enzyme addition altered diet palatability (Table 2). Broilers tolerated up to 20% PKC without reduced feed consumption, suggesting acceptable diet acceptance.

Final body weight differed markedly among treatments (P < 0.001). Birds in P1 (10% PKC + enzymes) and P3 (10% PKC without enzymes) achieved the highest weights (1,375.87 g and 1,327.58 g), surpassing those in P2 and P4 (20% PKC with/without enzymes; 1,124.38 g and 1,143.21 g). Notably, P1 exceeded P2 by 22.36%, while P3 outperformed P4 by 16.13%. These findings indicate that moderate PKC inclusion (10%) promotes optimal growth, whereas higher levels (20%) compromise performance despite enzyme addition. The likely cause is elevated dietary fibre, which reduces digestibility and nutrient absorption.

Weight gain and average daily gain (ADG) followed similar trends (P < 0.001). P1 and P3 yielded superior gains (1,331.52 g and 1,283.38 g; ADG 47.55 g/day and 45.84 g/day), while P2 and P4 produced lower results (1,079.56 g and 1,099.12 g; ADG 38.55 g/day and 39.26 g/day). Relative to the 20% PKC groups, P1 improved gain by 23.34% compared to P2, and P3 exceeded P4 by 16.76%. These outcomes confirm that broilers benefit most from 10% PKC inclusion, with enzyme supplementation enhancing growth only within this lower-fiber range.

Feed conversion ratio (FCR) also improved significantly at lower PKC levels (P < 0.001). Both P1 and P3 had the most efficient values (1.73), about 18% better than P2 and P4 (2.04). This suggests that enzymes were unable to offset the adverse effects of high PKC inclusion on nutrient utilization. The limited efficacy may relate to the inability of enzymes to fully degrade complex non-starch polysaccharides (NSPs) present in high-fibre PKC diets.

Although PKC offers several nutritional advantages, its use in poultry diets also presents specific challenges. The high fibre content of PKC can limit feed digestibility, thus requiring careful formulation to prevent reduced feed intake and growth performance (Okukpe et al., 2019). Moreover, the presence of insoluble NSPs in PKC has been associated with impaired nutrient absorption, necessitating feed adjustments to mitigate these effects (Koranteng et al., 2022). Pangesti et al. emphasized the positive role of protease enzymes in enhancing amino acid digestibility in PKC-based diets. Even at low inclusion levels (0.01% to 0.08%), protease supplementation improved the digestibility of essential amino acids such as lysine and threonine, thereby enhancing overall protein efficiency in poultry diets (Pangesti et al., 2023). These findings align with those of Abdollahi et al., who observed improved FCR and nutrient utilization following enzyme supplementation in PKC-based diets (Abdollahi et al., 2016).

Enzyme inclusion also impacts intestinal health in broilers. Okukpe et al. reported that xylanase supplementation in PKC diets promoted beneficial changes in gut microbiota, resulting in enhanced bird health (Okukpe et al., 2019). Such modulation of the gastrointestinal microbiome is crucial for nutrient absorption and immune function, ultimately contributing to better growth performance. Furthermore, Koranteng et al. investigated the effects of varying PKC inclusion levels (with and without enzymes) on broiler growth performance. They found that enzyme supplementation at 10% PKC significantly improved FCR compared to unsupplemented diets. However, higher inclusion levels (e.g., 20%) had detrimental effects on FCR, emphasizing the need for precise formulation strategies when combining PKC and enzymes in broiler diets (Koranteng et al., 2022).

Table 3. Nutrient intake and utilization efficiency of broiler chickens under different dietary treatments with varied palm kernel cake (PKC) inclusion and enzyme supplementation

Parameter	Treatments				SEM	P-value
	P1	P2	P3	P4		
Energy intake (kcal)	7139.82	6851.37	6883.10	6988.11	113.09	0.295
Protein intake (g)	497.39	471.52	479.51	480.93	7.82	0.157
EER	18.66[a]	15.78[b]	18.67[a]	15.73[b]	0.46	<0.001
PER	2.68[a]	2.29[b]	2.67[a]	2.29[b]	0.07	<0.001

[ab] Different superscripts in the same row indicate significant differences (P<0.05); P1: feed contains 10% palm kernel cake + cocktail enzyme (NSPase, protease, mannanase) 512 g/ton; P2: feed contains 20% palm kernel cake + cocktail enzyme (NSPase, protease, mannanase) 512 g/ton; P3: feed contains 10% palm kernel cake; P4: feed contains 20% palm kernel cake; FCR: feed conversion ratio; ADG: average daily gain; EER: energy efficiency ratio; PER: protein efficiency ratio.

Nutrient intake did not differ significantly across treatments. Energy intake (P = 0.295) ranged from 6,851.37 kcal (P2) to 7,139.82 kcal (P1), and protein intake (P = 0.157) from 471.52 g (P2) to 497.39 g (P1) (Table 3). Thus, performance variations were primarily due to nutrient utilization efficiency rather than intake.

Energy Efficiency Ratio (EER) was markedly higher in P1 and P3 (18.66 and 18.67) compared to P2 and P4 (15.78 and 15.73), representing an 18% advantage. Protein Efficiency Ratio (PER) showed a similar pattern: 2.68 and 2.67 in P1 and P3 versus 2.29 in both high-PKC groups. These results emphasize that 10% PKC allows more efficient nutrient conversion, while excessive inclusion diminishes macronutrient utilization. Enzyme addition could not sufficiently counteract the negative impact of excessive dietary fiber on digestibility.

Previous studies have established that dietary energy composition plays a crucial role in influencing broiler EER. Liu et al. reported that high-energy-density diets result in lower feed conversion ratios (FCR), thereby improving overall energy efficiency (Liu et al., 2019). This finding implies that feed formulation strategies that optimize energy content can significantly affect both growth performance and feed efficiency. Furthermore, Chen et al. demonstrated that energy restriction strategies in broiler diets can enhance EER by promoting more efficient energy usage, contributing to improved FCR and weight gain (Chen et al., 2012). Additionally, dietary supplementation with feed additives has been shown to positively affect EER. Wickramasuriya et al. found that incorporating emulsifiers and enzymes into low-energy diets improved growth rates and feed efficiency, suggesting an alternative approach to maximizing EER without increasing total energy intake (Wickramasuriya et al., 2022).

Numerous studies have emphasized the importance of dietary protein concentration as a key determinant of PER in broilers. Liu et al. demonstrated that increasing protein levels in broiler diets significantly enhanced growth performance, suggesting that protein intake has a stronger impact on weight gain compared to carbohydrates or fats (Liu et al., 2017). These findings are supported by Liu et al., who found that optimizing dietary protein levels can improve both weight gain and FCR (Liu et al., 2019).

The source and digestibility of protein also play critical roles in determining PER. Mahardhika et al. explored the incorporation of legume-based proteins and enzyme supplementation in broiler diets and found that these combinations could achieve growth performance comparable to standard high-protein diets (Mahardhika et al., 2023). This highlights the significance of protein quality and digestibility in influencing PER.

Furthermore, Attia et al. reported that specific feed formulations can alter protein digestibility and nutrient absorption, thereby affecting overall feed efficiency and broiler growth (Attia et al., 2015). Thus, focusing on protein quality—not merely quantity—may lead to more effective protein utilization and improved performance in broiler production.

CONCLUSION

Based on the results of this study, it can be concluded that broiler diets containing 10% palm kernel cake (PKC) yielded the best growth performance and highest nutrient efficiency, regardless of enzyme supplementation. Enzyme addition showed a significant positive effect only at lower inclusion levels of PKC and was insufficient to counteract the negative effects associated with higher PKC inclusion (20%). The similarity in feed, energy, and protein intake across treatments indicates that performance differences were primarily driven by the efficiency of nutrient utilization rather than the quantity of intake. High levels of PKC inclusion tend to reduce broiler production performance, irrespective of enzyme supplementation, likely due to the high crude fibre, mannan, and other antinutritional compounds in PKC that interfere with nutrient absorption.

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