Research Article

Utilization of Fermented Cassava Peel-Leaf Crumble as a Commercial Feed Replacement in Broiler Diet: Effects on Broiler Performance

Mirnawati[1*], Harnentis[1], Gita Ciptaan[1], Ferawati[2], Anifah Srifani[3]

[1]Department of Animal Nutrition and Feed Technology, Faculty of Animal Science, Universitas Andalas, West Sumatra, Indonesia; [2]Department of Livestock Product Processing Technology, Faculty of Animal Science, Universitas Andalas, West Sumatra, Indonesia; [3]PMDSU Program, Graduate program of animal feed and nutrition Department, Faculty of animal Science, Universitas Andalas, West Sumatra, Indonesia.

Abstract | This study aimed to evaluate the effect of replacing commercial broiler feed with a crumble-formulated mixture of cassava peel–leaf fermented with *Rhizopus oligosporus* on the performance of broiler chickens. A total of 160 day-old broiler chicks were randomly assigned to five dietary treatments with four replications each, using a completely randomized design. The treatments consisted of varying replacement levels of commercial feed with the fermented cassava peel–leaf mixture: 0%, 25%, 50%, 75%, and 100%. Birds were housed in 20 cages measuring 80 × 80 × 60 cm, with each cage containing eight birds and equipped with feeding and drinking facilities and a 60-watt incandescent lamp for heating. Parameters measured included feed intake, body weight gain, feed conversion ratio (FCR), final body weight, carcass percentage, abdominal fat percentage, protein intake, nitrogen retention, crude fiber digestibility, and cholesterol content of thigh meat. The results showed that the replacement of commercial feed with the fermented cassava peel–leaf mixture had no significant effect ($P > 0.05$) on feed intake, body weight gain, final body weight, carcass percentage, abdominal fat percentage, protein consumption, nitrogen retention, or crude fiber digestibility. However, cholesterol content in thigh meat was significantly affected ($P < 0.01$). At the highest replacement level (100%), the broilers exhibited a feed intake of 744.00 g, body weight gain of 382.53 g, FCR of 1.94, final live weight of 1,683.25 g per bird, carcass percentage of 75.81%, abdominal fat percentage of 0.58%, protein consumption of 23.44 g per bird per day, nitrogen retention of 60.06%, crude fiber digestibility of 55.02%, and thigh meat cholesterol level of 78.7 mg per 100 g. These findings indicate that the fermented cassava peel–leaf mixture in crumble form can replace up to 100% of commercial broiler feed without negatively affecting growth performance or physiological parameters.

Keywords | Broiler, Cassava peel leaf, Commercial rations, Crumble, Fermented, *Rhizopus oligosporus*

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***Correspondence** | Mirnawati, Department of Animal Nutrition and Feed Technology, Faculty of Animal Science, Universitas Andalas, West Sumatra, Indonesia;
Email: mirnawati@ansci.unand.ac.id
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INTRODUCTION

The feed cost for poultry reaches 67 - 80% of the total production cost (Skwirzyńska *et al*., 2025). This is because some feed ingredients are still imported, such as corn, soybean meal, and fish meal, which are expensive. To reduce these costs, it is necessary to find an alternative feed that is cheaper, continuously available, non-toxic, and does not hurt the health of the poultry that consumes it, one of which can be utilized is agricultural waste in the form of cassava waste. Cassava production in West Sumatra is 141,838.0 0 tons/year, and in Padang City is 691.00 tons/year (Martadona and Leovita, 2018). With the high level of cassava production, it will produce waste in cassava peel (CP) and cassava leaves (CL), which are pretty high too.

The estimated CP produced is 27.3% of cassava production (Papathoti *et al*., 2021). The estimated amount of CP available in West Sumatra is 38,721,774 tons/year, and in Padang City is 188,643 tons/year. CP has a crude protein content of 8.11% (Idugboe *et al*., 2017), crude fat of 1.29%, crude fiber of 15.20%, calcium of 0.63%, and phosphorus 0.22% (Amaza, 2021). CP contains 67.97% dry matter, 4.08% crude protein, and 27.23% crude fiber (Mirzah, 2015). CP can only be used up to 7% in broiler rations (Suryana, 2016). The limited use of CP in poultry rations is due to the high crude fiber content, while poultry is limited in utilizing it. Another obstacle in using CP as poultry feed is the high content of hydrocyanic acid (HCN), which ranges from >50 ppm (Mirnawati *et al*., 2023).

Another waste from cassava production is cassava leaves. Cassava leaves contain approximately 25.46% crude protein, 8.59% crude fat, and 18.24% crude fiber, with a dry matter content of 24.79% (Abiodun et al., 2023). CL has a limiting factor as an alternative feed ingredient, namely HCN. The HCN content ranges from 550 - 620 ppm in young CL and 400 - 530 ppm in old CL (Pizarro *et al*., 2018). The use of CL in broiler rations is only 5% if 10 and 15% can reduce feed use efficiency (Aroh *et al*., 2024).

The utilization of CP and CL in poultry rations is still relatively low, so to increase its utilization, feed processing technology is needed that can improve its nutritional quality. One effort that can be made is by carrying out fermentation technology. According to Mirnawati *et al*. (2019), fermentation is when organic compounds (carbohydrates, lipids, proteins, and other organic components) undergo chemical changes in aerobic and anaerobic conditions. The action of microbe-produced enzymes accomplishes this. Therefore, fermented feeds are easier to digest and last longer without losing the nutritional value of the feed (Ciptaan *et al*., 2024a; 2024b; Devi *et al*., 2023). A study by Annisa *et al*. (2020) conducted fermentation of a mixture of cassava leaves and tofu dregs with *R. oligosporus* inoculum (10%) and a fermentation period of 3 days, which increased crude protein and a decrease in crude fiber.

The fermentation of a mixture of CP and CL in a ratio of 6:4, using *Rhizopus oligosporus*, resulted in optimal nutritional composition. The fermented product contained 20.06% crude protein, 6.5% crude fat, 9.97% crude fiber, 0.98% calcium, 0.23% available phosphorus, 2671 kcal/kg of metabolizable energy, 0.54% methionine, and 0.92% lysine. In addition, fermentation reduced hydrogen cyanide (HCN) content by 47.89 ppm (Mirnawati *et al*., 2023). The decrease in HCN from CPL fermentation is expected to result in more CPL being utilized in broiler rations. Widodo (2016) stated that feed containing HCN less than 50 ppm is not harmful to livestock, 50-100 ppm is harmful, and more than 100 ppm is very harmful to livestock.

Cassava peel leaf fermented with *R. oligosporus* (CPLF) has been tested in broiler chicken rations and can be used up to 31.8% or can replace 45% of corn use; the following results were obtained: live weight 2304 g/head, carcass percentage 78.50% and abdominal fat percentage 0.92%. This CPLF has been patented with No. Patent ID S000004821 with the following formulation of yellow corn 30.25%, CPLF 31.8%, Rice bran 5%, soybean meal 10.2%, fish meal 18%, coconut oil 4.25%, and top mix 0.5% with content of crude protein 22.00%, crude fat 8.34%, crude fiber 6.00%, calcium 1.61%, available phosphorus 0.82%, HCN 15.23 ppm, methionine 0.36%, lysine 0.70% and metabolic energy 2973.34 kcal/mg (Mirnawati *et al*., 2022b).

The nutrient content of the ration containing CPLF is almost the same as the nutrient content of commercial rations with the following content: protein 22%, crude fat 5.5%, crude fiber 5%, calcium 1.1%, phosphorus 0.65%, methionine 0.51% and lysine 1.20%. The form of this commercial ration is crumble. For this reason, the ration containing CPLF was made into crumble form in this study. In addition, the crumble ration has specifications such as increasing feed consumption, easy to consume, non-dusty feed, the constituent feed ingredients are very compact and evenly mixed, and feed waste can be reduced. Furthermore, Batievskaya and Yegorov (2019) added that providing feed in crumble can better guarantee a more homogeneous mixture of feed ingredients. It is expected that the ration containing CPLF can replace commercial rations. This experiment aims to evaluate the effect of replacing commercial rations with diets containing cassava peel–leaf fermented (CPLF) with *Rhizopus oligosporus* on the performance of broilers, focusing specifically on crude fiber digestibility and nitrogen retention. The study also examines related performance parameters, including feed consumption, protein intake, body weight gain, feed conversion ratio, final body weight, carcass percentage, abdominal fat percentage, nitrogen retention, crude fiber digestibility, and thigh meat cholesterol content.

MATERIALS AND METHODS

Experimental Animals and Diet Composition

A total of 160 Cobb CP 707 broiler chicks of the mixed-sex breed from Charoen Pokphand, Indonesia, were grown in 20 wire cages measuring 80x60x50 cm per day, and each cage contains eight chickens. This study used an experimental method with a completely randomized design

(CRD), five treatments, and four replications. The treatment was the replacement of commercial rations with a mixture of cassava peel-leaf fermented (CPLF) with *R. oligosporus*, in the ratio: R1 (100% commercial ration), R2 (75% commercial ration+25% CPLF ration), R3 (50% commercial+50%CPLF ration), R4 (25% commercial ration+75%CPLF ration), R5 (100% CPLF ration). The diets were designed using an iso-protein ratio of 22% and an iso-calorie ratio of 3000 kcal/kg (Scott *et al*., 1982). The feed ingredients were fish meal, coconut oil, mineral B12, rice bran, soybean meal, yellow maize, and CPLF. Drinking water and food were given freely (ad libitum). Table 1 shows experimental and commercial rations' feed ingredient composition, nutrient content (%), and metabolic energy (kcal/kg).

Table 1: Composition (%), nutrient content (%) and metabolizable energy (kcal/kg) of the treatment ration.

Feed Ingredients*	Treatment Ration Containing CPLF
Yellow corn	30.25
CPLF	31.8
Rice bran	5
Soybean meal	10.2
Fish meal	18
Coconut oil	4.25
Top Mix (vitamin and mineral mix)	0.5
Total	100
Lysine	0.3
Nutrient Content*	
Crude protein	22.06
Crude fat	8.28
Crude fiber	5.07
Calcium	1.03
Available phosphorus	0.51
Methionine	0.51
Lysine	1.29
HCN (ppm)	15.23
ME (kcal/kg)	3000.46

Note: *CPLF: Cassava peel leaf fermented with *R. oligosporus*; **HCN:** Hydrogen Cyanide; **ME:** Metabolizable Energy.

The Procedure of Preparing CPLF

Cassava skin and leaves with a ratio of 6:4 are mashed and then sterilized with an autoclave for 15 minutes at a temperature of 121°C, then cooled after cooling, inoculated with 0.02% *R. oligosporus* inoculum, then incubated for 4 days, after which is containing cassava peel-leaf fermented (CPLF) harvested and ready to be used in broiler ration.

Ration

The composition (%), nutrient content (%), and metabolic energy (kcal/kg) of the treatment ration can be seen in Tables 1 and 2. The nutrient content (%) and metabolic energy (kcal/kg) of the commercial ration can be seen in Table 3.

Table 2: Nutrient content (%) and metabolizable energy (kcal/kg) of the commercial ration.

Nutrient Content*	Commercial Ration (%)
Crude protein	22
Crude fat	5.5
Crude fiber	5
Calcium	1.1
Available phosphorus	0.65
Methionine	0.5
Lysine	1.2
HCN (ppm)	0
ME (kcal/kg)	3000

Note: *HCN: Hydrogen Cyanide; ME: Metabolizable Energy.

Data Collection

The parameters of this study are ration consumption (RC), body weight gain (BWG), feed conversion ratio (FCR), body weight (BW), live weight (LW), carcass percentage (CP), protein consumption (PC), nitrogen retention (NR), abdominal fat percentage (AFP), crude fiber digestibility (CFD) and cholesterol in chicken thigh meat of broiler.

Data Analysis

According to Montgomery (2019), the data were statistically analyzed using a completely randomized design analysis of variance and the DMRT (Duncan's Multiple Range Test) test to determine treatment differences.

RESULTS AND DISCUSSION

The effect of replacing commercial rations with rations containing a mixture of cassava skin and leaves fermented with *Rhizopus oligosporus* in the form of crumble is shown in Table 3. The ration consumption, body weight gain, feed conversion ratio (FCR), live weight, carcass percentage, abdominal fat percentage, protein consumption, nitrogen retention, crude fiber digestibility, and cholesterol were not significantly different (P>0.05).

Effect of Treatment on Ration Consumption (RC)

Ration consumption (RC) does not differ significantly from the actual consumption of CPLF rations in the rations treatment, according to data in Table 3. This is because the feed's energy and protein content are balanced in each

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feed treatment; adding amino acids outside of the ration will result in the same feed consumption. The balance of protein energy is very influential in feeding consumption; thus, the balance of the same energy protein in treatment feed will result in the same RC. A study by Ahiwe *et al.* (2018) explained that high consumption of rations in livestock tends to decrease, and ration consumption increases when metabolic energy (EM) levels are low.

Consumption of rations is not significantly different in this study, and the same palatability also influenced it. Christone *et al.* (2024), Mirnawati *et al.* (2022a) and Ciptaan *et al.* (2024a) stated that palatability is one of the factors that can affect RC. Palatability is influenced by the food's shape, color, taste, and texture. In this study, the rations used had the same color, taste, texture, and physical form, namely crumble, so they did not affect RC.

Table 3: Effect of replacing commercial ration with ration containing CPLF with *R. Oligosporus* on performance parameters of broilers.

Parameter	Treatment Ration				
	R1	R2	R3	R4	R5
Ration consumption (g)	754.42	753.83	753.00	750.66	744.00
Weight gain (g)	395.49	395.43	394.93	387.84	382.53
Feed Conversion Ratio	1.91	1.91	1.91	1.92	1.94
Live weight (g)	1761.00	1732.75	1727.00	1696.75	1683.25
Abdominal Fat Percentage (%)	1.24	0.71	0.75	0.85	0.58
Carcass Percentage(%)	78.85	75.93	76.56	77.78	75.81
Protein Consumption (g)	23.71	23.70	23.69	23.63	23.44
Nitrogen Retention(%)	68.39	66.12	65.11	62.17	61.06
Crude Fiber Digestibility(%)	65.68	62.84	61.44	57.84	55.02
Cholesterol (mg/100g)	186.9[a]	140.6 [bc]	115.1[cd]	87.4[de]	78.7[e]

Note: [a,b,c,d,e]Mean with different superscript letters within a row indicate a significant difference ($p<0.01$).

Effect of Treatment on Body Weight Gain (BWG)

From data Table 3, the increase in BW is not significantly different in this study was caused by the treatment ration containing CPLF, which underwent fermentation, where the fermentation product can improve the quality of the ration in terms of digestibility, resulting in an increase in BW that is the same as that of broilers given the control ration according to the opinion of Adli *et al.* (2024) that fermentation will produce a final product containing simpler compounds making the product easy to digest so that it can increase growth. Fermented products contain simpler and more easily digested compounds, thereby increasing the nutritional quality of a product (Aini *et al.*, 2023). In addition, Tachie *et al.* (2024) stated that fermented products have good content and digestibility, making them more easily absorbed. Adding 0.3% lysine resulted in no difference in BWG across treatments, meeting the broiler's amino acid requirements. This is in compliance with the recommendations of the NRC (1994), which state that the requirement for the amino acid methionine is 0.5% and lysine is 1.2% for broilers. Added by Lim *et al.* (2022), the amino acids methionine and lysine are necessary to meet the needs of very rapid broiler growth.

Body weight gain (BWG) in treatments R1, R2, R3, R4, and R5 is because nitrogen retention is not significantly different. The higher the nitrogen retained, the higher the resulting body weight gain. This complies with the opinion of Musigwa *et al.* (2020), who stated that higher nitrogen retention results in more BWG. Mirnawati *et al.* (2020) and Mirnawati *et al.* (2023) stated that a significant relationship exists between nitrogen retention and BWG, so that positive nitrogen retention indicates that livestock protein needs are met, ultimately increasing BWG.

Effect of Treatment on Feed Conversion Ratio (FCR)

In treatments R1, R2, R3, R4, and R5, the difference in FC was also due to the comparison of the amount of ration consumed and the weight gain that resulted from balancing the two treatments; high consumption was also associated with high WG, and low consumption was associated with low WG (Table 3). Ration conversion, on the other hand, compares weight growth to ration consumption. This supports the assertion made by Aini *et al.* (2023) that the ratio of RC to weight increase over a specific period is known as feed conversion. The higher the RC, the more rations are needed for feed conversion.

The average ration conversion obtained during the study is between 1.94. This result is also almost the same as that obtained from the research of Ciptaan *et al.* (2021), with an FC of 1.97. Mirnawati *et al.* (2022a) stated that a low FC indicates good efficiency in the use of rations because the more efficiently the livestock consumes rations for their growth.

Effect of Treatment on Live Weight (LW)

From Table 3, it can be seen that the more commercial rations are replaced with CPLF, the slight decrease in LW is shown, but statistically, it does not show a difference or is non-significant. No differences in LW in this study were

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due to the use of fermented products with high digestibility so that up to 100% replacement can still match the live weight of broilers receiving commercial rations. This complies with the opinion of Mirnawati *et al*. (2022a) that fermented products contain simpler and more easily digested compounds, thereby increasing the nutritional quality of a product. In addition, Tachie *et al*. (2024) stated that fermented products have good content and digestibility, making them more easily absorbed.

The nitrogen retention in this study also contributed to the variation in LW; however, it was not substantially different. The increased nitrogen retention resulted from a larger nitrogen content in the diet than in the excreta, which affected both live WG and BWG. This is corroborated by the finding by Na *et al*. (2018) that there is a correlation between livestock's body weight gain and the quantity of nitrogen they retain. Nitrogen retention is related to protein consumption in the ration; if protein consumption is high, it will also result in high NR, so LW will increase and vice versa. Ciptaan *et al*. (2021) found that high NR was caused by the protein content consumed being higher than the protein excreted through feces and urine.

The difference in LW in this study was because the consumption of rations and the resulting BWG were also insignificant. The same consumption of rations and BWG will produce relatively the same live weight. According to Mirnawati *et al*. (2020), the live weight of broilers is influenced by RC and BWG. Mirnawati *et al*. (2022a) also added that the live weight produced is determined by the amount of ration consumed; the more rations consumed, the more the live weight produced will increase.

The difference in LW in this study was also affected by the content of methionine and lysine amino acids that complied with the needs of broiler chickens. The standard requirement for methionine in broiler rations is 0.50%, and lysine is 1.20% (NRC, 1994). In this treatment ration, methionine is sufficient, but lysine is not sufficient. Therefore, adding 0.30% lysine to the ration can meet the need for 1.20%. Methionine is an essential amino acid, so it must continue to be available in the ration in sufficient quantities (Ghazagi *et al*., 2024).

Effect of Treatment on Carcass Percentage (CP)

This study's carcass percentage (CP) variation resulted from a considerably varied final LW (Table 3). The carcass percentage is calculated by dividing the carcass weight by the live weight and multiplying the result by 100%. This supports the finding of Londok *et al*. (2017) that carcass output and LW are strongly correlated; as live weight rises, so will carcass production, and the same live weight will yield the same carcass weight. The proportion of body components or the percentage of carcass produced was the same. There is a belief that a high percentage of carcasses will follow a high live weight and carcass weight, or vice versa. According to Mirnawati *et al*. (2022a), the comparatively identical carcass weight was also caused by the ration's quality and the amount of feed that was consumed.

The amount of abdominal fat (AF) in this study was the cause of the variation in the percentage of carcasses, which was likewise not much different. According to Setyaningrum *et al*. (2022), the percentage of carcasses produced is significantly influenced by the weight of the AF; a higher AF results in a lower percentage of carcasses. Low levels of AF and an abundance of meat are characteristics of a good carcass.

The difference in CP in this study was due to the balanced content of methionine and lysine amino acids, where these amino acids are complementary or feed supplement groups that are added to feed ingredients to complete the nutritional content according to livestock needs. Methionine is an essential amino acid, so it must remain available in the ration in sufficient quantities. This is in accord with the opinion of Ghazagi *et al*. (2024), which states that methionine is an essential substance for poultry, and the formation of broiler chicken meat is greatly influenced by methionine in the ration. Lysine is an amino acid needed for broiler growth. This is under Mousa *et al*. (2023), who stated that the amino acid lysine is necessary to meet the needs of very rapid broiler growth. Methionine and lysine greatly affect carcass weight, so the percentage of carcass produced will be the same, too.

Effect of Treatment on Abdominal Fat Percentage (AFP)

The difference in the amount of AFP in this study resulted from the treatment ration's energy content being roughly the same (Table 3), which meant that energy consumption and the percentage of AFP generated were also the same. This is consistent with Chuang *et al*. (2020) assertion that energy intake directly impacts the buildup of AFP in broiler chickens.

The percentage of abdominal fat in this study was not a significant difference (P>0.05). This shows that there was no accumulation of energy in the body of broiler chickens. However, there was a difference in fat content in the ration (8.28% vs 5.5%); the fat content of this ration is still within the tolerance limit of fat requirements for poultry (Nwe *et al*., 2007). The difference in abdominal fat in this study was also due to the energy of each treatment ration being the same (3000 kcal/kg). According to Na *et al*. (2019), energy, which results from the metabolism of nutrients

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that enter the chicken's body exceeding the level of needs the body itself requires for both basic life and production, is the cause of the accumulation of fat in the chicken's body, including abdominal fat.

Age also affects the proportion of AFP in broilers. Broilers are still growing at 5-6 weeks, which means that the body is still using the resources it has ingested for growth and that little fat has developed. The opinion of Wei *et al.* (2024), who claimed that fat tissue in hens starts to build quickly at the age of 6-7 weeks and subsequently continues to accumulate more quickly, supports this assertion.

In this study, the percentage of AFP generated varied from 0.58% to 1.24%. At 35 days of age, the percentage of AFP varied from 0.73% to 3.78%, according to Salam *et al.* (2013) and Carmona *et al.* (2017). The quality of the carcass of broiler chickens improves with a reduced percentage of AFP. This is consistent with the findings of Luo *et al.* (2022), who claimed that the carcass quality of broilers will be impacted by their high or low percentage of AFP. Broiler fattening conditions are generally better, as seen by the low amount of AFP obtained.

Effect of Treatment on Protein Consumption

The ration's protein content was 22%, and metabolic energy was 3000 kcal/kg, respectively, which resulted in a negligible change in protein consumption across treatments R1, R2, R3, R4, and R5 (Table 3). This is consistent with the statement of Mirnawati *et al.* (2022a), who stated that the consumption of the same ration indicates that the metabolic energy provided is the same in the same ration; in other words, rations that have duplicate protein content cause protein consumption to be the same.

The average protein consumption obtained in this study was 23.45g/head/week to 23.84g/head/week. This is consistent with the opinion of Zhang *et al.* (2023) that providing crude fiber above 7% in the ration will cause decreased growth due to low intake, which causes nutrients to be lost along with the excreta. High crude fiber causes the rate of digestion to increase, causing the digestibility value of other nutrients to decrease and resulting in decreased ration consumption, which indirectly affects protein consumption. In this study, the crude fiber content was 5.07%, so ration and protein consumption were high. Protein consumption did not differ since it was impacted by ration consumption, which did not differ significantly ($P>0.05$). This supports the assertion made by Mirnawati *et al.* (2022a) that a high protein intake will follow a high ration intake.

Effect of Treatment on Nitrogen Retention (NR)

The difference in NR in treatments R1, R2, R3, R4, and R5 was not significant (Table 3) because CPLF underwent fermentation where the fermentation product had good quality, as seen from the high amino acids so that 100% replacement could match the NR of commercial rations. This complies with the opinion of Omar *et al.* (2021), who stated that all fermented products contain simpler and easier-to-digest compounds, increasing their nutritional value. In addition, according to Mirnawati *et al.* (2022a), fermented products contain simpler and easier-to-digest compounds, thereby increasing the nutritional quality of a product. Adding 0.3 grams of lysine amino acid to the ration composition can match the lysine content in commercial rations. If amino acids are met, it can increase the biological quality of the protein so that there is an increase in nitrogen retention in the broiler's body. This complies with the opinion of Toghyani *et al.* (2020), who stated that protein digestibility in the ration can affect the level of nitrogen retained.

A livestock's excreta has less nitrogen, the more nitrogen it can keep in its body (Strifle *et al.*, 2023). Fermentation may be the cause of this. Fermentation transforms complicated substances into simpler ones and can enhance the quality of nutrients by converting protein into amino acids, substances that the whole digestive tract can absorb more readily.

The form of feed can also influence high nitrogen retention values. Crumble feed can increase the NR in broiler feed. This complies with the opinion of Pope *et al.* (2020), who stated that the conditioning process in crumble or pellet feed manufacturing can cause short-chain fatty acids to evaporate and denature proteins. This allows crude protein in the ration to have a greater opportunity to be utilized, and crude protein in the ration is one of the factors that influences nitrogen retention. Strifler *et al.* (2023) stated that crude protein in the ration is a factor that influences nitrogen retention. This means that the more crude protein in the ration is utilized, the higher the nitrogen retention obtained will be, and vice versa.

Effect of Treatment on Crude Fiber Digestibility

As exhbited in Table 3, the difference in the digestibility of crude fiber in R1, R2, R3, R4, and R5 is due to the use of fermented products, where fermented products have good quality and are easy to digest from the original ingredients. Setiarto and Widhyastuti (2016) stated that fermented products are highly digestible because fermentation changes complex proteins, crude fibers, and fats into simple ones. The digestibility of crude fiber decreases with increasing crude fiber content. According to Mirnawati *et al.* (2017), the digestibility of crude fiber is influenced by the amount of crude fiber in the feed; the higher the amount of crude fiber, the less digestible the crude fiber is because of the poultry's limited ability to digest it. Additionally, the amount of crude fiber in feed, the make-up of crude fiber preparations, and the activity of microorganisms all affect digestion (Pujiawati *et al.*, 2021; Tejeda and Kim, 2021; Bortoluzzi *et al.*, 2023).

The crumble feed shape has an impact on the high digestion of crude fiber as well. Crumble-shaped rations have the same shape as crumbs, which are larger than mash-shaped feed and smaller than pellet-shaped feed, so crumble-shaped feed has a higher density than mash-shaped feed. This is compliant with the opinion of Massquetto *et al.* (2018) and Idan *et al.* (2023), who said that crumble-shaped feed is a pellet that is chopped into crumbs so that it is suitable for use as broiler feed in the starter to finisher period. Rations in the form of crumbles are compact and firm, making it difficult for animals to break them down back into their constituent parts. This makes the meal easier for them to digest.

The average digestibility of crude fiber obtained in this study was 65.68% to 55.02%. Crude fiber digestibility depends on the crude fiber in the feed. High crude fiber content will lead to low digestibility due to poultry's limitations in digesting crude fiber. Since poultry lacks the enzyme cellulase in their digestive tracts, they cannot eat high cellulose feeds (Srifani *et al.*, 2023).

Effect of Treatment on Cholesterol in Chicken Thig Meat

The findings of the analysis of variance indicate that the cholesterol content of broiler thigh meat is significantly impacted (P<0.01) by the addition of a mixture of cassava peel leaf fermented (CPLF) in the diet (Table 3). The results of the analysis showed that R1 was significantly different (P<0.05) from R2, R3, R4 and R5. Treatment R2 was not significantly different (P>0.05) from R3 but significantly different (P<0.05) from R4 and R5. Treatment R3 was not significantly different (P>0.05) from R4 but significantly different (P<0.05) from R5. At the same time, Treatment R4 was not significantly different (P>0.05) from R5. In other words, there was a tendency for cholesterol to decrease broiler thigh meat with the increasing replacement of commercial rations with rations containing CPLF. The lowest cholesterol content of broiler thigh meat was obtained when using CPLF at a level of 40% in the ration, along with the increase in carotenoid content. The decrease in cholesterol in broiler thigh meat in the R5 treatment (40%) was due to CPLF containing β-carotene (133.26 mg/100g). Carotenoids can suppress cholesterol synthesis by inhibiting the activity of the HMG-CoA reductase enzyme in the formation of mevalonate in the cholesterol biosynthesis process (Csernus *et al.*, 2020). Wang *et al.* (2023) stated that the ability of β-carotene to lower cholesterol is related to the enzyme hydroxy methyl glutaryl-CoA. This enzyme functions in the formation of mevalonic in cholesterol biosynthesis.

Carotenoids also act as antioxidants in reducing oxidative stress, which can indirectly contribute to reducing cholesterol synthesis in the body, where carotenoids act as antioxidants that protect cell membranes from oxidative damage, which can reduce the risk of increased cholesterol due to oxidative stress (Sun *et al.*, 2018; Hidayat *et al.*, 2023).

CONCLUSIONS AND RECOMMENDATIONS

The study concluded that the addition of 0.3% lysine to a crumble-formulated blend of cassava peel and cassava leaves fermented with *Rhizopus oligosporus* can fully replace commercial broiler rations without negatively affecting performance. This conclusion is supported by the observed performance metrics, including a feed intake of 744.00 g, body weight gain of 382.53 g, feed conversion ratio of 1.94, final live weight of 1,683.25 g per bird, carcass yield of 75.81%, abdominal fat percentage of 0.58%, protein intake of 23.44 g per bird per week, nitrogen retention of 61.06%, crude fiber digestibility of 55.02%, and thigh meat cholesterol level of 78.7 mg per 100 g. These findings suggest that the fermented cassava-based ration, supplemented with lysine, is a viable and sustainable alternative to conventional broiler feeds.

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NOVELITY STATEMENT

This study introduces a novel use of fermented cassava peel–leaf blends with lysine supplementation as a complete substitute for commercial broiler feed, offering a cost-effective and sustainable alternative without compromising broiler performance or meat quality.

AUTHOR'S CONTRIBUTIONS

Mirnawati: designed the research concept, conducted experiments, and analyzed data.
Harnentis, Gita Ciptaan and Ferawati: composed and wrote the script.
Anifah Srifani: did the work in the laboratory and visualized the data.

Conflict of Interest

All authors declare that there is no conflict of interest.

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