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ORIGINAL PAPER

Potential of fermented cassava peel and leaves as maize substitutes in diets to improve the performance and meat quality of Kamang ducks

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ABSTRACT. Exploring alternative feed ingredients is essential to find an equivalent substitute for maize in Kamang duck diets, thereby reducing feed costs. Cassava waste, i.e. a mixture of fermented cassava peel and leaves (FCPL) using a novel bacterium *Citrobacter freundii* 5519, shows potential as a maize replacement. The present study evaluated its effects on the performance and meat quality of Kamang ducks. A total of 100 three-week-old male Kamang ducks were divided into 20 experimental groups and reared for five weeks. A completely randomised design (CRD) with four treatments and five replications was employed. The data were analysed using ANOVA, followed by Duncan's multiple range test (DMRT) for significant differences. Parameters under study included performance, internal organs, and meat quality. The results demonstrated that incorporating FCPL as a maize substitute at levels up to 45% significantly increased feed intake, weight gain, and carcass percentage ($P < 0.05$), while markedly reducing abdominal fat, meat fat, and cholesterol ($P < 0.05$) compared to the control group. However, no significant effects were observed on the weight of digestive organs ($P > 0.05$). Utilising FCPL as a 45% maize substitute improved performance and meat quality without negatively affecting the digestive organs of Kamang ducks.

Introduction

Male Kamang ducks are a local breed from West Sumatra, Indonesia, with meat production potential. These ducks are known for their disease resistance and low stress susceptibility (Triani et al., 2024a). Kamang ducks show higher growth rates and lower feed conversion ratios compared to other local breeds (Suhaemi et al., 2019). However, feed costs remain a significant challenge in Kamang duck farming, particularly due to the rising prices of maize – a primary ingredient in poultry diets – in Indonesia. Consequently, identifying alternative unconventional feed ingredients to replace maize is essential to reduce feed expenses.

Cassava peel and leaves are a promising alternative given their abundance in Indonesia. The country produces 14 978 310 t of cassava annually

(Ministry of Agriculture of Indonesia, 2023), with cassava peel accounting for approximately 15% of production (Umami et al., 2019) and cassava leaves accounting for about 10 t/ha (Morgan and Mingan, 2016). Cassava peel is a valuable energy source, while cassava leaves are rich in protein and beta-carotene (816 µg/g), acting as an antioxidant (Sumiati et al., 2020). In duck diets, antioxidants play a key role in inhibiting triglyceride synthesis in the liver, thereby lowering cholesterol levels (Nurrofingah et al., 2020).

However, the use of cassava peel and leaves in poultry feed is limited due to their high crude fibre and hydrogen cyanide (HCN) content. Fermentation processes can effectively reduce crude fibre and HCN levels, thereby improving the nutritional quality of cassava waste (Olurontola, 2018). *Citrobacter freundii* 5519, a novel bacterial strain isolated from cassava waste, has demonstrated high cellulase and β-glucosidase activity, making it effective in degrading HCN and crude fibre in cassava waste (Triani et al., 2024b). This study aimed to evaluate the potential of fermented cassava peel and leaves (FCPL) using a *C. freundii* 5519, as a substitute for maize in Kamang duck diets, focusing on its impact on performance and meat quality.

Material and methods

Ethical approval

This study was conducted in accordance with the guidelines for the care and use of animals and was approved by the Ethics Committee of the Faculty of Medicine, Andalas University, Indonesia (Approval No. 448/UN.16.2/EP-FK/2024).

Housing and feeding

The ducks were housed in enclosed compartments with windows and a litter floor. Each pen measured 1 m × 1 m × 0.75 m and was maintained at a temperature of 27 °C with 80% humidity. Each unit was equipped with a designated feeding and drinking area, and lighting supplied by a 25 W bulb.

The feed ingredients used in this study included fermented cassava peel and leaf flour (FCPL), maize, fish meal, maize gluten meal (CGM), limestone flour, vitamins, and minerals. A total of 100 three-week-old male Kamang ducks were housed in 20 pens, with five ducks per pen, and reared for five weeks. FCPL was prepared by fermenting cassava peel and leaves at a ratio of 80:20 for 15 days using a 3% inoculum of *C. freundii* 5519. The composition of the diets is listed in Table 1.

Experimental design

A completely randomised design (CRD) was employed, consisting of four treatments (T0 – 0% FCPL, T1 – 15% FCPL replacing maize, T2 – 30% FCPL replacing maize and T3 – 45% FCPL replacing maize) with five replicates. The formulated diets were standardised to contain 2800 kcal/kg of metabolizable energy and 18 crude protein content (Triani et al., 2024a). The composition of the four dietary treatments is presented in Table 1.

Table 1. Ingredient and nutrient contents of experimental diets

Ingredients, %	Treatments			
	T0	T1	T2	T3
Maize	50.00	42.50	35.00	27.50
FCPL	0.00	7.50	15.00	22.50
Rice bran	26.00	26.00	25.50	25.00
Fish meal	5.00	6.00	6.00	6.00
Maize gluten meal	17.50	15.50	14.50	13.50
Oil	0.40	1.50	3.00	4.50
Limestone flour	0.60	0.50	0.50	0.50
Premix	0.50	0.50	0.50	0.50
Total, %	100.00	100.00	100.00	100.00
Nutrient content, %				
metabolizable energy, kcal/kg	2837.90	2819.90	2822.40	2829.15
crude protein	18.01	18.24	18.34	18.44
crude fibre	5.07	5.58	6.04	6.49
crude fat	3.59	4.64	6.04	7.44
calcium	0.92	0.96	0.99	1.02
phosphorus	0.49	0.55	0.58	0.61
lysine	0.56	0.63	0.67	0.75
methionine	0.27	0.29	0.30	0.32

FCPL – fermented cassava peel and leaves; T0 – 0% FCPL (control diet), T1 – 15% FCPL substituting maize, T2 – 30% FCPL substituting maize, T3 – 45% FCPL substituting maize

Data collection and analysis

Performance

Body weight gain (BWG) was calculated by subtracting initial body weight (BW) from final body weight (FBW) recorded at the end of the experimental period. Feed intake (FI) was determined by subtracting residual feed from the amount provided each week. Feed conversion ratio (FCR) was calculated as the ratio of FI to BWG. FBW was obtained by weighing the ducks at the end of the study (8 weeks). BW and feed FI were recorded in g using an electronic scale.

Carcass weight and digestive organs

Ducks were slaughtered at 8 weeks of age, and the eviscerated carcass with the neck intact was weighed to determine carcass weight. Organ weight and abdominal fat were also measured. The relative weights of the carcass, digestive organs and abdominal fat were calculated by dividing the respective weights by the final weight and multiplying by 100%.

Meat quality

Meat fat content was measured using the Soxhlet extraction method (AOAC International, 2005). Meat cholesterol levels were determined using the enzymatic method by Roeschlau et al. (1974) and Allain et al. (1974). Fatty acid analysis involved extracting duck meat fat, esterifying fatty acids to fatty acid methyl esters (FAME), and analysing them using gas chromatography (GC), following the procedure described by Fardiaz (1989).

Statistical analysis

The results are presented as the mean values of five ducks per experimental unit. Each plot represents an experimental unit. The mathematical model used for the completely randomised design was as follows:

$$Yij = \mu + \alpha i + \varepsilon ij,$$

where: Yij – dependent variable, μ – overall mean, εij – error term, i – number of treatments (1,2,3,4) and j – number of replications (1,2,3,4,5). The normality of the data distribution was assessed using the Shapiro-Wilk test. Performance and meat quality data were analysed using ANOVA, and significant differences were further evaluated using Duncan's multiple range test (DMRT), following the method of and Torrie (1993). Differences were considered statistically significant at $P \leq 0.05$.

Results

Performance of Kamang ducks

The analysis of variance showed that increasing levels of FCPL in the diet significantly ($P < 0.05$) increased FI, BWG, FBW and carcass weight. However, no significant effect was observed on the FCR (Table 2). The inclusion of FCPL up to 45% as a substitute for maize resulted in the highest FI, BWG, FBW, and carcass weight in Kamang ducks.

Table 2. Effect of diets on performance of Kamang ducks at 8 weeks of age

Treatment	Feed intake, g/bird	Body weight gain, g/bird	FCR	Final body weight, g/bird	Carcass weight, %
T0	3706.20[a]	827.70[a]	4.48	1182.20[a]	57.60[a]
T1	3912.80[ab]	838.80[a]	4.66	1177.80[a]	57.70[a]
T2	3966.00[b]	853.80[a]	4.65	1200.60[a]	59.05[ab]
T3	4022.00[b]	915.80[b]	4.39	1274[b]	59.64[b]
P-value	0.045	0.009	0.383	0.016	0.037
SEM	75.12	16.87	0.13	20.62	0.53

FCPL – fermented cassava peel and leaves; T0 – 0% FCPL (control diet), T1 – 15% FCPL substituting maize, T2 – 30% FCPL substituting maize, T3 – 45% FCPL substituting maize; SEM – standard error of the mean; FCR – feed conversion ratio; [ab] – means within a row with different superscripts are significantly different at $P < 0.05$

Abdominal fat and digestive organs of Kamang ducks

The study demonstrated that the inclusion of 15, 30 and 45% FCPL as a substitute for maize in Kamang duck diets significantly reduced ($P < 0.05$) abdominal fat; however, no effect was observed on intestinal organ, including the gizzard, liver and small intestine (Table 3).

Table 3. Effect of diets on abdominal fat and internal organs in Kamang ducks at 8 weeks of age

Treatment	Abdominal fat, %	Gizzard, %	Liver, %	Small intestine, %
T0	0.69[a]	5.22	2.25	11.80
T1	0.45[b]	5.32	2.19	12.67
T2	0.46[b]	5.49	2.33	12.77
T3	0.44[b]	5.05	2.30	12.56
P-value	0.004	0.120	0.891	0.508
SEM	0.05	0.14	0.13	0.43

FCPL – fermented cassava peel and leaves; T0 – 0% FCPL (control diet), T1 – 15% FCPL substituting maize, T2 – 30% FCPL substituting maize, T3 – 45% FCPL substituting maize; SEM – standard error of the mean; [ab] – means within a row with different superscripts are significantly different at $P < 0.05$

Kamang duck meat quality

The results in Table 4 show that ducks fed a diet with 15% FCPL as a maize substitute had the lowest, significantly reduced fat content ($P < 0.05$). Feeding diets containing 30 and 45% FCPL resulted in fat content levels in animals that were not significantly different from the control, although the fat content in the diet was higher compared to the control treatment. The cholesterol content of duck meat decreased with a 45% dietary FCPL substitution, reaching 45.60 mg/100 g.

Table 4. Effect of diets on meat quality of Kamang ducks at 8 weeks of age

Treatment	Meat fat, g/100 g	Meat cholesterol, mg/100 g
T0	13.38[a]	51.43[a]
T1	6.98[b]	49.33[a]
T2	13.21[a]	48.79[a]
T3	13.52[a]	45.61[b]
P-value	0.020	0.008
SEM	1.53	1.01

FCPL – fermented cassava peel and leaves; T0 – 0% FCPL (control diet), T1 – 15% FCPL substituting maize, T2 – 30% FCPL substituting maize, T3 – 45% FCPL substituting maize; SEM – standard error of the mean; [ab] – means within a row with different superscripts are significantly different at $P < 0.05$

The fatty acid profile of Kamang duck meat is presented in Table 5 as a quantitative descriptive analysis (without analysis of variance). Increasing the proportion of FCPL in the diet tended to decrease saturated fatty acid levels while elevating unsaturated fatty acid content ($P > 0.05$). The highest levels of omega-3 and omega-6 fatty acids in the diet were obtained with a maximum inclusion of 45% FCPL replacing maize ($P > 0.05$).

Table 5. Effect of diets on fatty acids profile of Kamang duck meat, %

Fatty acids	Treatments			
	T0	T1	T2	T3
Saturated fatty acids				
lauric acid	0.73	0.04	0.03	0.06
myristic acid	1.22	0.40	0.43	0.51
palmitic acid	34.32	26.37	26.77	25.44
stearic acid	1.97	0.96	1.28	1.37
Total	38.24	27.77	28.51	27.38
Unsaturated fatty acids				
oleic acid	43.14	53.65	52.37	50.70
linoleic acid	3.43	6.77	6.26	7.39
linolenic acid	0.65	0.92	1.03	1.14
Total	47.22	61.34	59.66	59.23

FCPL – fermented cassava peel and leaves; T0 – 0% FCPL (control diet), T1 – 15% FCPL substituting maize, T2 – 30% FCPL substituting maize, T3 – 45% FCPL substituting maize

Discussion

Performance of Kamang Ducks

The high FI observed in Kamang ducks fed diets containing 30 and 45% FCPL (fermented cassava pulp leaves) substituting maize was attributed to the favourable odour of FCPL, which was preferred by the ducks.

Feed intake in T1 was not significantly different from the control because the inclusion of FCPL in the diet was relatively low. Diets containing 15% FCPL as a substitute for maize did not significantly affect feed odour, and thus did not increase feed palatability. However, increasing the replacement level of FCPL to 30 and 45% improved the feed's smell, making it more appealing to the ducks and increasing its intake.

Table 2 shows that higher levels of FCPL in the diet corresponded to increased FI compared to the control. This effect can be attributed to the improved palatability as a result of FCPL addition. Feed quality is also assessed based on its acceptability, as it directly affects FI and, consequently, poultry productivity (Edi, 2021).

The highest BWG in Kamang ducks was recorded for those fed a diet containing 45% FCPL as a maize replacement. This outcome can be attributed to the increased FI observed in treatment T3, which resulted in optimal weight gain in this study. Feed ingestion is a key determinant of nutrient intake, which has a significant impact on BWG (Zaid et al., 2023). The quality of the feed, including its nutritional composition, is a critical factor contributing to weight gain in poultry. Higher growth rates in ducks can be achieved when FI increases and nutrients providing energy, protein (amino acids), vitamins, and minerals are supplied in sufficient quantities.

The weight gain of Kamang ducks in this study ranged from 827.7 g to 915.8 g over a 5week rearing period (from 3 to 8 weeks of age). This growth performance was markedly higher than that of male Bayang ducks, whose BWG over the same age range was reported to be 521.86 g (Rafian et al., 2023).

In this study FCR of Kamang ducks was not improved compared to the control group. This is likely due to the higher crude fibre content in the diet, with levels at 5.06% in T0, 5.57% in T1, 6.03% in T2, and 6.48% in T3. Elevated crude fibre content in the diet reduces the efficiency of nutrient absorption in the digestive system of ducks. Both insoluble and soluble crude fibre can exert antinutritional effects in poultry by reducing apparent metabolizable energy (AME), starch digestibility, nitrogen retention, and utilisation of other nutrients, ultimately impairing growth performance. Additionally, high crude fibre content increases digestive viscosity, which interferes with efficient nutrient diffusion, thereby reducing its degradation and transport within the digestive tract (Sing and Woo, 2021).

The FCR of Kamang ducks in this study ranged from 4.39 to 4.66. This was consistent with findings of Zurmiati et al (2017), who reported a comparable FCR of 4.4 in a study investigating probiotics such as *Bacillus amyloliquefaciens*. However, the FCR of Kamang ducks observed in this study was lower than that reported by Sandi (2010), where male ducks reared for 10 weeks and fed diets containing cassava waste had FCRs ranging from 6.98 to 7.25.

The inclusion of 45% FCPL substituting maize in the diet resulted in the highest FBW of Kamang ducks. This outcome was due to the significantly greater BWG observed in this treatment, which directly contributed to the higher FBW. The latter is closely related to the overall BWG in ducks (Triani et al., 2024a). The average FBW recorded in this study exceeded the 1043.26 g average weight recorded for Pitalah ducks reared for 8 weeks on probiotic-supplemented diets (Zurmiati et al., 2017). It was also higher than the average FBW (728 g) of male Bayang ducks raised intensively until 8 weeks of age (Rafian et al., 2023).

The dietary inclusion of 45% FCPL replacing maize also resulted in the highest carcass weight in Kamang ducks. This result was attributed to the significantly greater BW achieved in ducks fed this diet. Carcass weight is closely linked to BW, as higher weight gain is directly proportional to carcass yield when feed quality is adequate. The findings of this study indicate that CPL is an effective and safe substitute for maize in Kamang duck diets, supporting the inclusion of up to 45% FCPL to achieve higher carcass weights.

This result aligns with the findings of Ramadhan et al. (2019), who reported that carcass weight was strongly influenced by both live weight and feed quality. The high carcass weight in Kamang ducks observed in this study was also attributed to the higher lysine and methionine content in FCPL (Table 1). These amino acids enhance protein synthesis, leading to better muscle formation in Kamang ducks. Wu et al. (2021) similarly reported that rations with higher amino acid content (lysine and methionine) promoted meat production while reducing fat deposition, thereby improving carcass component parameters and minimising inedible offal.

The carcass percentage recorded in this study was higher than that of male Tegal ducks raised for 8 weeks, whose carcass weight percentage was 52.96% (Ramadhan et al., 2019). Moreover, the results are comparable to those of Saragih (2020), who reported that carcass percentages obtained in Bayang ducks at 6 weeks of age, supplemented dietary probiotics (*Bacillus amyloliquefaciens*), ranged from 58.99% to 61.50%.

Abdominal fat and digestive organs in Kamang ducks

The decrease in abdominal fat observed in ducks fed diets containing 15, 30, and 45% FCPL instead of maize can be attributed to the presence of saponins in cassava leaves, which inhibit lipogenesis, thereby reducing fat deposits in ducks. Saponins are known to suppress lipogenesis in poultry, significantly lowering blood triglyceride concentrations. This, in turn, limits the availability of blood triglycerides for transport and deposition in the abdominal region (Fouad and El-Senousey, 2014). The abdominal fat content reported in this study is consistent with findings by Ramadhan et al. (2019) in male Tegal ducks, who reported abdominal fat content ranging from 0.13 to 0.72%. The current study indicates that including fermented cassava waste flour in Kamang duck rations, replacing up to 45% of maize, can improve carcass quality by reducing abdominal fat.

The mass and strength of the gizzard are influenced by the size, quality, and quantity of feed (Kusmayadi et al., 2019). A high fibre content in the feed enlarges the gizzard, as the organ is stimulated to work more actively and digest fibre both mechanically and enzymatically. In the present study, although the FCPL-containing diet had a higher fibre content, it remained within the tolerance limits for Kamang ducks, and thus, no significant increase in gizzard activity was observed. The average gizzard percentage in this study was lower than the 5.37–6.17% reported by Sandi (2010) for male ducks fed FCPL-supplemented diets. However, the result obtained in the present study was slightly higher than the 4.55% observed in hybrid ducks. These findings indicate that replacing maize with up to 45% FCPL in the diet is safe for the gizzard health in Kamang ducks.

The inclusion of FCPL in the Kamang duck diet did not affect liver activity or liver mass, as FCPL is both safe and toxin-free. The fermentation process effectively removed cyanide from the cassava peel and leaves. The liver is an internal organ responsible for detoxifying toxins; an increase in its mass is generally considered a positive indicator of higher metabolic and detoxification activity (Hanim et al., 2023).

Cassava waste containing cyanide compounds is toxic to ducks. However, previous studies demonstrated that fermentation of cassava waste using *Citrobacter freundii* strain 55-19 could significantly reduce its cyanide content (Triani et al., 2024b), making it safe to use as feed ingredient to replace up to 45% of maize in Kamang duck rations. Sandi (2010) reported an increase in liver size in mice fed rations containing cyanide, with liver cells showing higher activity in response to elevated thiocyanate concentrations as part of the detoxification process.

The results of the current study indicated that feeding a diet with up to 45% of maize replaced with FCPL was tolerated by Kamang ducks, as it did not affect small intestine function. The consistency in diet quality across treatments resulted in similar small intestine lengths. In addition to age, factors such as feed form, and its nutritional content also influence the digestive tract in ducks (Fandi et al., 2019). The average percentage of small intestine length in male

Kamang ducks at 8 weeks in this study ranged from 11.79 to 12.76%, and it was higher than that reported by Budiarta et al. (2023) in male Bali ducks at 8 weeks of age (9.55 to 11.80%). The observed differences likely stem from genetic variation between Kamang ducks and Bali ducks.

Quality of Kamang duck meat

FCPL contains more easily digestible fibre, which binds fat in the intestines and reduces its absorption, thereby decreasing the fat content in Kamang duck meat. Increasing crude fibre content in the diet can reduce fat deposition in the liver and body of ducks (Abouelezz et al., 2022). Fibre forms a gel in the digestive tract, which binds bile acids and lipids, limiting fat absorption by the intestinal mucosa. Additionally, this fibre can suppress fat accumulation by regulating short-chain fatty acid (SCFA) levels and inducing the adenosine monophosphate-activated protein kinase (AMPK) pathway. This pathway subsequently stimulates the expression of lipid catabolic genes (*CPT-1* and *PPARα*) while downregulating lipid anabolic targets such as *FAS, ACC*, and *SREBP-1c*, ultimately suppressing lipogenesis (Zhou et al., 2023).

Dietary FCPL, which consists of cassava leaves, contains bioactive compounds such as tannins, flavonoids, and saponins. These substances are known to exert hypolipidemic effects, reducing fat levels in the blood and tissue. Moreover, they inhibit fat synthesis by suppressing the activity of lipogenic enzymes such as acetyl-CoA carboxylase (ACC) and fatty acid synthase (FAS). Reduced accumulation of acetyl-CoA, coupled with increased fat oxidation, can reduce fat deposition in tissues, including the liver (Batchuluun et al., 2022).

The decrease in cholesterol levels in duck meat is attributed to the inclusion of FCPL, which increases the content of omega-3 fatty acids and other unsaturated fatty acids in duck meat (Table 5). Unsaturated fatty acids inhibit the activity of HMG-CoA reductase, an important enzyme in cholesterol biosynthesis, thereby reducing cholesterol production in meat. Compounds that inhibit HMG-CoA reductase play a crucial role in lowering the rate of cholesterol synthesis (Samizo and Kaneko, 2023).

The increase in polyunsaturated fatty acids (PUFAs), particularly linolenic acid (omega-3) and linoleic acid (omega-6), in meat from ducks fed FCPL contributes to lowering cholesterol levels by limiting the availability of fatty acids for triglyceride synthesis. Omega-3 fatty acids achieve this effect by inhibiting the activity of phosphatidic acid phosphohydrolase (PAP) and diacylglycerol transferase (DGAT). This suppression decreases plasma triglyceride production and helps control triglyceride accumulation in the liver of ducks (Sumiati et al., 2020).

The highest levels of omega-3 and omega-6 fatty acids were observed in ducks fed a diet containing 45% FCPL as a maize substitute. The increase in unsaturated fatty acids may be attributed to the higher antioxidant content in FCPL, derived from cassava skin and leaves. Cassava leaves, in particular, are rich in antioxidants, such as β-carotene, which help protect omega-3 fatty acids from oxidation (Nurrofingah et al., 2020) and increase their proportion in duck meat tissue.

Conclusions

Fermented cassava peel and leaves (FCPL) using *Citrobacter freundii* 5519 can replace up to 45% of maize in the diet of male Kamang ducks aged 3 to 8 weeks. This substitution improves performance parameters, including feed intake, weight gain, and carcass percentage, without negatively affecting internal organ function. Furthermore, the inclusion of FCPL improves meat quality by reducing fat and cholesterol content while increasing the proportion of unsaturated fatty acids, particularly omega-3 and omega-6.

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Conflict of interest

The Authors declare that there is no conflict of interest.

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