Aceh Journal of Animal Science (2025) 10 (3): 160-165

Aceh Journal of Animal Science

Journal homepage: www.jurnal.usk.ac.id/AJAS

Effect of Fermented Cassava Peel with *Bacillus amyloliquefaciens* in the Diet on the Performance of Indigenous Chicken

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ARTICLE INFO

Keywords:
Bacillus amyloliquefaciens
Cassava
Chicken
Performance

Received: 29 August 2025
Accepted: 23 September 2025

DOI:10.13170/ajas.10.3.48964

ABSTRACT

Feed cost is a major challenge in poultry production, prompting the need for alternative feed resources to reduce dependency on conventional ingredients. Cassava peel, an abundant agro-industrial by-product, offers potential as a feed ingredient. This study aimed to determine the effect of fermented cassava peel (FCP) flour using Bacillus amyloliquefaciens on the growth performance of indigenous chickens. A total of 100 day old chicks were allocated to five dietary treatments with four replications in a completely randomized design (CRD): Control (T0) (0% FCP), T1 (15% FCP), T2 (20% FCP), T3 (25% FCP), and T4 (30% FCP). Data on feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR) were collected over eight weeks and analyzed using one-way ANOVA followed by Duncan's Multiple Range Test at 5% significance. Results show that the inclusion of FCP up 40% had no significant effect (P>0.05) on FI, BWG, and FCR. These findings indicate that FCP flour can replace conventional feed ingredients in indigenous chicken without compromising growth performances. Further research is recommended to optimize feed formulation by balancing nutrient content and selecting effective fermenting microorganisms to fully harness the benefit of FCP in poultry production systems.

Introduction

Poultry farming plays a vital role in Indonesia's agricultural sector, serving as a key provider of animal protein. Among poultry products, chicken meat and eggs are the most widely consumed in the country, largely due to their lower cost relative to other protein sources like beef (Novra *et al.*, 2019). Moreover, Indonesia's expanding population and improved economic capacity have driven a sustained growth in the consumption of chicken meat and eggs (Sumiati *et al.*, 2025). Indonesian indigenous chickens are a promising breed that can fulfil the demand for both meat and eggs. A distinctive advantage of indigenous chicken is their adaptability to hot climates, resilience to poor feed quality, and enhanced disease resistance (Mariandayani *et al.*, 2023). However, productivity in domestic chickens remains relatively low due to slow growth rates, low egg production, and extensive management systems (Bakrie *et al.*, 2021).

The productivity of poultry is primarily influenced by an excellent feeding regimen and diet, in addition to genetic traits and environmental conditions (Yano *et al.*, 2024a). However, Abu *et al.* (2015) noted that feed costs account for 60% to 80% of the total production expenses. In developing countries, the high cost of feed is mainly due to the substantial reliance on imported feed ingredients (Sugiharto *et al.*, 2018). Thus, using alternative feed resources is advised to minimize the overall feed expenses.

Cassava peel, a by-product generated during the processing of cassava tubers, presents a promising alternative feed ingredient that can reduce the feed cost (Agustin *et al.*, 2020) and it is abundantly available in Indonesia. It was reported that Indonesia ranks as the fifth-largest cassava producer globally, with annual production reaching 14-16

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Printed ISSN 2502-9568; Electronic ISSN 2622-8734

million tons from 2018 to 2022 (Saida, 2023), generating considerable amounts of cassava peel waste, approximately 8% to 12% of the total tuber mass, which remains largely underutilized (Fitriyano *et al*., 2023). However, cassava peel is rich in fiber, which could potentially hinder the nutrient absorption. Oladimeji *et al*. (2022) reported that sun-dried cassava peel contains up to 9.4% crude fiber and 17.73% hemicellulose. Other key nutrients include 3.66% crude protein (CP), 88.58% dry matter (DM), 27.78% neutral detergent fiber (NDF). In addition, cassava peel is reported to contain antinutritional factors (ANFs) such as hydrogen cyanide (HCN) and phytate. Obasi *et al*. (2018) observed that HCN and phytate content in cassava peel are 6.25-13.29 mg/kg and 1440-2463 mg/kg, respectively.

A considerable strategy to increase nutrient digestibility and minimize ANFs is fermentation. Fermentation is a biochemical process in which complex organic compounds are metabolically converted into simpler molecules through the catalytic action of enzymes synthesized by microorganisms such as bacteria (Supriya *et al*., 2023). Among bacterial strains used in fermentation, Bacillus has a significant contribution in producing important enzymes, including protease and amylase (Crivelli *et al*., 2024), suggesting its potential for effective feed fermentation.

Bacillus amyloliquefaciens is one Bacillus strains that is proven effective in feed fermentation. Lee *et al.* (2022) reported that *Bacillus amyloliquefaciens* showed the best degradation rate for feather and keratinase activity compared to Bacillus subtilis var. natto N21 and B. subtilis CU14 in broiler chicken. In addition, Imsya *et al*. (2023) also reported that *Bacillus amyloliquefaciens* produced significantly lower hemicellulose and cellulose content compared to *Lactobacillus plantarum* up to 10.24% and 9.65%, respectively, in blood meal. Moreover, *Bacillus amyloliquefaciens* is effective in improving growth, digestion, and immunity in goats (Lee *et al*., 2025) as well as the growth of fish (Ponomareva *et al*., 2024).

Despite the abundant availability of cassava peel and its potential as an alternative feed ingredient, its high fiber content and presence of ANFs limit its direct use in poultry diets. Fermentation using *Bacillus amyloliquefaciens* offers a promising strategy to enhance the nutritional quality of cassava peel by reducing fiber and ANFs while improving nutrient availability. Du *et al*. (2023) observed that *Bacillus amyloliquefaciens* could regulate the abundance of intestinal beneficial bacteria, such as *Lactobacillus sp*, while reducing pathogenic bacteria. In turn, the beneficial bacteria produce enzymes that help break down the ANFs and fiber.

Although several studies have highlighted the efficacy of *Bacillus amyloliquefaciens* in improving feed digestibility and animal performance in various livestock species, limited research has been conducted in its application in the diet of indigenous chickens. Therefore, this study aims to determine the effect of fermented cassava peel with *Bacillus amyloliquefaciens* on the performance of indigenous chickens. Its application is expected to optimize feed utilization, reduce cassava processing waste and production costs, and support the sustainability of local poultry farming systems.

Materials and Methods

Time and place of the study

The research was completed from September to March 2024 at the Faculty of Animal Science, Universitas Andalas, Indonesia (latitude -0.9087° S and longitude 100.4550° E). Daily temperatures range from 25-32°C, with humidity levels ranging 64-91%. The chicken rearing was conducted at the poultry farm, while fermented cassava peel were produced at Laboratory of Feed Technology. Animal feed nutrient analysis was conducted at the Laboratory of Non-ruminant nutrition while bacterial preparation and production were conducted at the Laboratory of Ruminant Nutrition.

Cassava peel processing

Cassava peels obtained from the cassava chip production industry were first cleaned to remove any attached impurities, followed by chopping. Subsequently, the peels were dried under direct sunlight for 9 hours. Once dried, the cassava peels were ground to obtain cassava peel flour.

Microbial inoculants

The isolation, purification, and identification of *Bacillus amyloliquefaciens* was conducted based on the modified method of Ying *et al*. (2022). Nutrient agar and distilled water (aquades) were boiled until clear, then transferred into a test tube (5 ml, filling ¼ of the tube). The tube was sealed with cotton sterilized with alcohol and covered with aluminum foil. It was sterilized using an autoclave at 121°C for 15 minutes. After sterilization, the tube was tilted at a 20° angle. Next, *Bacillus amyloliquefaciens* was inoculated into the tube using a sterile loop. The culture was incubated at 40°C for 24 hours.

In this study, the inoculum of *Bacillus amyloliquefaciens* was prepared using 100 grams of rice bran as the substrate. The rice bran was sterilized using an autoclave at 121°C and 1 atm pressure for

15 minutes, then cooled to room temperature (24°C). Subsequently, 10 ml of sterile distilled water was added to a petri dish containing bacterial culture and gently agitated to release the microbes from the medium. The resulting suspension was transferred into an erlenmeyer flask containing 240 ml of sterile distilled water. The sterile rice bran was then mixed with 200 ml of *Bacillus amyloliquefaciens* suspension. The mixture was incubated for 24 hours, followed by drying in an oven at 40°C to obtain a powdered form, which was used as the inoculum.

Production of fermented cassava peel (FCP)

The substrate used in this study was 1 kg of cassava peel, which was autoclaved at 121°C and 15 psi for minutes, with water autoclaved separately. After sterilization, the cassava peel was then inoculated with *Bacillus amyloliquefaciens* at a concentration of 3% of the substrate weight based on modified method of Lee *et al.* (2022). The mixture was thoroughly stirred to ensure even distribution of the inoculum, and then levelled before being incubated for 4 days. After the fermentation period, the mixture was dried in an oven at 60°C for 18-24 hours, resulting in the fermented cassava peel (FCP) product.

Bird and housing

A total of 100 mixed-sex day old chicks (DOC) of CP 808 strain was purchased from a commercial poultry shop in Padang city. This experiment was carried out using a completely randomized design consisting 5 treatment groups with 4 replicates each, and 5 chickens per replicate

The treatments were differentiated by the amount of FCP flour, inoculated with *Bacillus amyloliquefaciens*. The treatments were as follows: Control (T0) (0% FCP), T1 (15% FCP), T2 (20% FCP), T3 (25% FCP), and T4 (30% FCP). The ration used in this study was a commercial feed mixed with corn, soybean meal (SBM), fish meal, coconut oil, and FCP flour inoculated with *Bacillus amyloliquefaciens*. The composition of the experimental diet and its nutritional content are shown in Table 1.

On the first day, sugar water was provided to restore the chickens' energy, the floor was lined with newspaper, and a heat lamp was turned on. At 4 days old, the chickens were weighed, leg-banded for identification, and randomly assigned to 20 units of raised cages, each measuring 85 x 70 x 30 cm, with 5 chickens per cage. The cages were equipped with a feeding tray, drinking container, and a 60-watt incandescent bulb for heat and lighting. A black plastic sheet was placed under the cages to collect the chickens' feces. The chickens were also vaccinated against Newcastle Disease using ocular drops at 4 days old.

Data Collection and analysis

The data collected includes feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR). FI was determined by calculating the difference between the total amount of feed provided and the remaining feed. BWG was measured by weighing the animals every week and subtracting the weight from the previous week. The FCR was calculated by dividing the total FI over the 8-week period by the BWG during the same 8-week period. All data obtained were analyzed statistically using Analysis of Variance (ANOVA) according to the Completely Randomized Design (CRD) pattern. If there are significant differences between treatments, further analysis will be conducted using Duncan's Multiple Range Test (DMRT).

Table 1. Composition and nutritional content of basal diet

Feedstuff	Ration (%)				
	T0	T1	T2	T3	T4
Commercial feed	32.00	32.00	32.00	32.00	32.00
Corn	36.50	31.50	28.00	25.25	20.50
SBM	6.00	5.50	5.50	5.50	5.25
Fish meal	9.00	9.00	9.00	9.00	9.00
Coconut oil	1.00	1.00	1.50	1.75	2.00
Rice bran	15.00	5.50	3.50	1.00	0.75
FCP flour	0.00	15.00	20.00	25.00	30.00
Top mix	0.50	0.50	0.50	0.50	0.50
Total	100	100	100	100	100
Chemical composition (%)					
Crude protein (CP)	18.15	18.04	18.06	18.08	18.07
Crude fat	4.92	4.37	4.71	4.80	4.96
Crude fiber	5.16	5.81	6.14	6.42	6.90
Calcium (Ca)	0.78	0.90	0.93	0.97	0.99
Phosphorus (P)	0.49	0.47	0.47	0.46	0.46
Metabolizable energy (ME) (Kcal/kg)	2914.60	2903.86	2905.53	2902.30	2864.15

Source: Based on the analysis result in the laboratory of non-ruminant nutrition, Faculty of Animal Science, Universitas Andalas, Indonesia

Results

Feed intake

The average FI of indigenous chicken for each treatment during the experiment is presented in Table 2.

Table 2. Effect of fermented cassava peel (FCP) on FI of indigenous chicken

Treatment	FI (g/bird/week)
T0	231.889 ± 12.692
T1	242.131 ± 13.271
T2	236.859 ± 13.316
T3	235.803 ± 13.074
T4	230.619 ± 14.607
P-value	P >0.05

Note: Non-significant at P > 0.05. Control (T0) (0% FCP), T1 (15% FCP), T2 (20% FCP), T3 (25% FCP), and T4 (30% FCP).

Table 2 shows that the average FI of indigenous chicken raised during the study ranged between 230.619 to 242.131 g/bird/week. The analysis of variance indicated that the inclusion of FCP with *Bacillus amyloliquefaciens* up to a level of 30% in the diet had no significant effect (P>0.05) on the FI of indigenous chicken.

Body weight gain

The average BWG of indigenous chicken for each treatment during the study is presented in Table 3.

Table 3. Effect of fermented cassava peel (FCP) on BWG of indigenous chicken

Treatment	BWG (g/bird/week)
T0	76.811 ± 5.922
T1	78.797 ± 7.760
T2	75.519 ± 3.318
T3	75.513 ± 3.395
T4	73.627 ± 2.494
P-value	P >0.05

Note: Non-significant at P > 0.05. Control (T0) (0% FCP), T1 (15% FCP), T2 (20% FCP), T3 (25% FCP), and T4 (30% FCP).

Table 3 shows that BWG of indigenous chicken ranged between 73.627 to 78.797 g/bird/week. The ANOVA indicated that the inclusion of FCP with *Bacillus amyloliquefaciens* up to a level of 30% in the diet had no significant effect (P>0.05) on the BWG of indigenous chicken.

Feed conversion ratio

The FCR values of indigenous chicken for each treatment during the study are presented in Table 4.

Table 4. Effect of fermented cassava peel (FCP) on FCR of indigenous chicken

Treatment	FCR
T0	3.025 ± 0.144
T1	3.092 ± 0.309
T2	3.137 ± 0.116
T3	3.126 ± 0.200
T4	3.131 ± 0.132
P-value	P >0.05

Note: Non-significant at P > 0.05. Control (T0) (0% FCP), T1 (15% FCP), T2 (20% FCP), T3 (25% FCP), and T4 (30% FCP).

Table 4 shows that the FCR for indigenous chicken across all treatments ranged from 3.025 to 3.137. Based on the statistical analysis, this study indicates that the inclusion of FCP with *Bacillus amyloliquefaciens* up to 30% in the diet has no significant effect (P>0.05) on the FCR of indigenous chicken.

Discussion

In this study, fermented cassava peel (FCP) flour is expected to significantly improve chickens' FI, BWG, and FCR. However, the result of the study showed that FCP flour up to 30% exhibits similar FI, BWG, and FCR. These findings contrast with those of Animashahun *et al.* (2024), who reported significant improvements in broiler performance when fed cassava peel-leaf mix fermented with *Aspergillus niger*. This suggests that *Aspergillus niger* may be more effective in the fermentation process than *Bacillus amyloliquefaciens*. Although no direct comparison between these two microorganisms was made in the present study, *Aspergillus niger* is widely regarded as one of the most influential and commonly used microorganisms in feed ingredient fermentation aimed at enhancing poultry performance (Yano *et al.*, 2024b; Akhirini *et al.*, 2024; Irawan *et al.*, 2022).

Interestingly, Abu *et al.* (2015) reported significant improvements in broiler performance, specifically higher final body weight and lower FCR using 10% cassava peel-leaf mix without any fermentation, while FI remained similar. These contrasting results may be attributed to differences in dietary protein levels. In the present study, although the birds were fed fermented feed ingredients, the protein content was approximately 18% throughout the experiment. In contrast, the previous study by Abu *et al.* (2015) provided higher protein levels around 22% during the starter phase and 19% during the grower phase. According to Zardadzaei *et al.* (2023), protein plays a crucial role in supporting the growth performance of poultry. In addition, protein is essential for optimal bone development, as it enhances the stability of mineral deposition in bone tissue (Widodo *et al*., 2012).

Ezeoke *et al.* (2022) reported that laying hens fed diets containing 20% fermented cassava peel meal showed similar hen day production, but experienced reduced final body weight, and increased FCR. In contrast, the present study demonstrates better tolerance to higher inclusion levels of FCP, suggesting that growing chickens may handle this feed ingredient more effectively than laying hens. This difference may be attributed to the distinct physiological requirements between laying and growing chickens, which influence how feed ingredients are utilized. As noted by Yaung *et al*., (2024), the characteristics of feed ingredients are closely related to FI, weight gain, and feed utilization efficiency. A higher FI generally reflects greater feed palatability, suggesting that increased consumption should result in greater weight gain and improved efficiency. Additionally, the FI can be assessed through FCR, where a lower FCR indicates greater efficiency in converting feed into body weight. It was reported that the standard range of FCR for indigenous chicken is 2.8-3.8 (Waithaka *et al*., 2022), suggesting that FCR in this study is within the normal range.

Furthermore, antinutritional factors (ANFs) present in the CFP flour are likely the cause of insignificant findings. Oladimeji *et al.* (2021) reported that sun-dried cassava peels contained the highest cyanide, tannin, saponin, and oxalate, compared to other processed cassava peels, with concentrations of 20.63 mg/100 g, 86.97 mg/100 g. 3.83 mg/100 g, 9.13 mg/100 g, respectively. The presence of ANFs quickly decreases nutrient absorption and digestion, which in turn negatively affects poultry growth performance (Li *et al*., 2014). Unfortunately, the ANF's content was not measured in this study, leaving the exact cause unclear.

Overall, the findings of this study highlight the complexity of utilizing FCP as an alternative feed ingredient, where its effectiveness is strongly influenced by the type of fermenting microorganisms, dietary protein levels, the physiological stage of the chickens, and ANFs content. Although no significant improvements in growth performance were observed, the birds' ability to tolerate up to 30% FCP inclusion demonstrates its promising applicability.

Conclusions

The inclusion of FCP meal with *Bacillus amyloliquefaciens* up to 30% in indigenous chicken diets had no significant effect on FI, BWG, and FCR, indicating that FCP can be used as an alternative feed ingredient without compromising growth performance. This approach offers an environmentally friendly solution to reduce reliance on conventional feed ingredients and minimize cassava processing waste. Further research is recommended to optimize feed formulation by balancing nutrient content and selecting effective fermenting microorganisms to fully harness the benefit of FCP in poultry production systems.

Acknowledgments

The authors would like to thank the Faculty of Animal Science, University of Andalas, for supporting research facilities.

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