

Effect of Banana Peel Powder as a Feed Ingredient on the Growth Performance, Intestinal Morphology, Carcass Yield, and Meat Quality of Broiler Chickens

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Abstract

This study investigated the effects of banana peel powder (BPP) on the growth performance, intestinal morphology, carcass yield, and meat quality of broilers. A total of 126 one-day-old chicks were randomly assigned to three dietary treatments: control (BPP0, corn–soybean basal diet), BPP7 (7% banana peel), and BPP10 (10% banana peel), with three replicates of 14 birds each, and reared for 35 days. The survival rate was not significantly different among the groups ($P > 0.05$), although BPP10 showed the highest value (96.97%). The inclusion of 7% and 10% BPP in the diets did not significantly affect the initial weight, average daily gain, feed intake, or feed conversion ratio ($P > 0.05$). However, broilers fed the 10% BPP diet showed numerically higher final weight and weight gain values, with both parameters reaching statistical significance ($P = 0.05$). No statistically significant differences were observed in the villus height, crypt depth, or villus height to crypt depth ratio. The carcass traits were not influenced by diet ($P > 0.05$). However, several meat quality traits were significantly affected ($P < 0.05$). In the thigh meat, yellowness (b^*) decreased in BPP7 and BPP10. In the breast meat, lightness (L^*) increased and yellowness (b^*) decreased with banana peel inclusion ($P < 0.05$). In conclusion, the inclusion of 10% banana peel powder tended to enhance growth and altered the meat color without adverse effects on the FCR or carcass yield, supporting its potential as a sustainable feed ingredient in broiler production.

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Keywords

Banana peel powder, broiler, growth performance, carcass, by-products

Introduction

As the cost of feed represents a major expense in poultry production, the use of alternative feed resources, such as by-products from agro-industries, has become a desirable option. Fruit peels are a major waste from fruit processing plants, which if not properly handled, will become a hazard to the environment (Dias *et al.*, 2020). To minimize production waste, these by-products could be reused as a natural, cost-effective source of energy, such as fiber in poultry feed (Juskiewicz *et al.*, 2015; Adekeye *et al.*, 2021). Additionally, active compounds in diets containing fruit peels have been shown to have a significant impact on regulating gut microbial activity, thereby influencing the structure and physiological function of the intestine and improving the health of broiler chickens (Vlaicu *et al.*, 2020).

Bananas (*Musa* spp.) are a popular fruit worldwide. The banana peel is the outer covering and a by-product of household consumption and banana processing industries. It accounts for 30–50% (depending on the banana variety) of the total fruit weight. Banana peels contain 6–9% crude protein and 20–30% NDF (neutral detergent fiber) on a dry matter basis (Emaga *et al.*, 2011), and the lignin content increases during ripening (from 7 to 15% DM). In a study by Fas *et al.* (2015) in Nigeria, feeding broiler chickens a diet containing 10% banana peel had no adverse effects on their production performance. Abel *et al.* (2015), who replaced corn with banana peel at 10%, 20%, and 30%, observed statistically significant differences in daily weight gain, daily feed intake, and slaughter weight, with the 10% inclusion level yielding positive results. Yitbarek (2019) also concluded that a 10% inclusion of banana peel improved the feed efficiency and the quality of meat and eggs, but warned that exceeding this level could impair growth rates. Conversely, Haryanto *et al.* (2016) found no significant differences in the feed conversion ratio (FCR), total cholesterol, or LDL levels with banana peel powder supplementation, though HDL and triglyceride concentrations were significantly altered. Using banana peel

powder (BPP) as a substitute feed may contribute to enhancing the sustainability of the livestock production chain and improving meat output (Sánchez-Muros *et al.*, 2014).

Vietnam's banana sector is seeing impressive growth, with a cultivated area of over 161,000 ha, which produced nearly 3 million tonnes in 2024 (EastFruit, 2025). The peel, which makes up 18–30% of the entire fruit, is the primary by-product of bananas (González-Montelongo *et al.*, 2010). This means that the amount of banana peel by-products is very large when considering the total annual production, with hundreds of thousands of tons of banana peels being discarded. Although the potential of banana by-products has been demonstrated in numerous international studies covering aspects such as growth, blood parameters, and feed efficiency, research on the use of banana peel powder in broiler diets in Vietnam remains very limited. There is a particular lack of in-depth evaluations of its effects on the growth performance, carcass characteristics, meat quality, and intestinal morphology of chickens. This represents a significant research issue that needs to be addressed to facilitate the effective application of this abundant by-product in practical production.

Materials and Methods

Experimental design

A total of 126 one-day-old Ross 308 broiler chickens from a reputable hatchery were used in this experiment. The birds were sexed, leg-banded, and randomly allocated into three dietary treatments in a completely randomized design. Each treatment consisted of three replicates, with 14 birds per replicate (1:1 male-to-female ratio), totaling 42 birds per treatment. The dietary treatments were: (1) a control group (BPP0) fed a corn-soybean basal diet with no banana peel powder; (2) treatment 1 (BPP7) fed the basal diet supplemented with 7% banana peel powder; and (3) treatment 2 (BPP10) fed the basal diet supplemented with 10% banana peel powder.

Banana peels, sourced from the Nafoods Company (Nghe An province), were freeze-dried

for three days and subsequently ground into a powder (1-2mm particle size) before being mixed into the feeds. The chemical composition of the banana peel powder is presented in **Table 1**.

Birds in the three treatments were reared in closed housing with rice husk bedding under similar management and lighting conditions. They were provided with *ad libitum* access to feed and water. A comprehensive vaccination program against the Newcastle and Gumboro diseases was applied. The experiment lasted for 35 days, following a one-week adaptation period.

Chemical analysis of the diets

The chemical composition of the experimental diets was analyzed at the Laboratory Center of the Faculty of Animal Science, Vietnam National University of Agriculture. Dry matter (DM), crude protein (CP), and ash were determined according to the

corresponding Vietnam Standards (TCVN) TCVN 4326:2001, TCVN 4328-1:2007, TCVN 4331:2001, and TCVN 4327:2007. Crude fiber (CF) was analyzed using ANKOM technology. The ingredient composition and chemical composition of the experimental diets are presented in **Table 1**.

Growth performance and feed conversion determination

To evaluate the effect of the diets on growth performance, production parameters were carefully monitored and recorded throughout the trial. Specifically, the individual body weight (BW) of each bird per replicate was measured weekly on a fixed day in the morning before feeding to ensure data accuracy and consistency. From this data, the average daily gain (ADG) was calculated for each week. Average daily feed intake (ADFI) was determined by weighing the

Table 1. Ingredients and chemical composition of experimental diets

Ingredients	Experimental diets			BPP
	BPP0	BPP7	BPP10	
<i>Ingredients (%)</i>				
Corn	60.20	54.43	51.68	
Soybean meal	34.39	33.36	33.19	
Soybean oil	1.40	1.21	1.13	
Oyster shell powder	1.90	1.90	1.90	
Vitamin–mineral premix	0.25	0.25	0.25	
Banana peel powder	0.00	7.00	10.00	
Lysine	1.00	1.00	1.00	
Methionine	0.50	0.50	0.50	
Cystine	0.35	0.35	0.35	
<i>Chemical composition</i>				
DM (%)	88.99	89.23	88.56	11.56
<i>% DM</i>				
CP	21.95	21.41	21.19	8.14
EE	8.06	7.90	8.58	5.55
Ash	5.19	5.59	6.37	12.03
CF	3.03	3.59	3.81	9.24
Sugar				39.25

Note: BPP: banana peel powder; BPP0: control diet (basal diet without BPP); BPP7: basal diet with 7% BPP; BPP10: basal diet with 10% BPP.

feed provided and subtracting the leftover amount from the previous day. Based on the feed consumption and corresponding weight gain, the feed conversion ratio (FCR) was calculated for each period. Finally, the survivability rate (%) for each treatment was determined by comparing the number of live birds at the end of the experiment to the initial number.

Carcass and meat quality analysis

At the end of the feeding period, evaluations of the carcass and meat quality were conducted. From each treatment, six birds (three males and three females) with body weights closest to the group average were selected for slaughter. After recording the live weight, the carcass characteristics were determined, namely the carcass yield (relative to live weight), breast meat yield, and thigh meat yield.

For meat quality, breast and thigh muscle samples were collected immediately post-mortem. The pH value was measured directly on the muscle at two critical time points: 15 minutes (pH15) and 24 hours (pH24) post-mortem to monitor the biochemical changes. After 24 hours of refrigerated storage at 4°C, the meat surface color was determined using the L* (lightness), a* (redness), and b* (yellowness) indices. The water-holding capacity of the meat was evaluated through two indicators: drip loss, calculated by weighing samples before and after the 24-hour storage period, and cooking loss, calculated based on the change in sample weight before and after a heat treatment. Finally, meat tenderness was measured as shear force (N) using a Warner-Bratzler device on cooked, standardized samples.

Villus height and crypt depth

A segment of the duodenum was collected immediately after slaughter. Each segment was ligated at both ends, infused with 10% neutral buffered formalin, and fixed overnight at room temperature. Samples were then washed, dehydrated through a graded alcohol series, embedded in paraffin, and sectioned at a thickness of 4µm using a microtome. The sections were stained with hematoxylin and eosin (H&E), mounted with Canadian balsam, and

examined under a light microscope (ABX511, Olympus, Tokyo, Japan). Villus height (VH) and crypt depth (CD) were measured using DP-Soft software (Olympus) with three well-oriented villus–crypt units analyzed per bird, and each unit was examined at two different locations.

Statistical analysis

All data were analyzed using SAS software (version 9.4). Data on the growth performance, meat yield, and meat quality were subjected to a two-way ANOVA using the general linear model (GLM) procedure, with dietary treatment and sex as fixed effects. Feed intake and FCR data were analyzed by one-way ANOVA. Mean differences were determined using the Tukey test. Differences were considered statistically significant at $P < 0.05$. Statistical analysis showed that sex had a significant effect on most of the growth traits (following the typical body weight pattern between males and females), but did not affect the meat yield and meat quality characteristics, except for the b^* value. The interaction between sex and experimental diet had no effect on any of the growth parameters and only influenced the meat quality b^* value. In the results section, the study only addressed the effects of the experimental diets on growth, productivity, and meat quality.

Results and Discussion

Survivability rate

As shown in **Table 2**, the survival rate of broilers varied across growth stages but did not differ significantly among treatments ($P > 0.05$). Over the entire rearing period, survival rates were 83.33% in BBP0, 88.10% in BBP7, and 96.97% in BBP10. Although not statistically significant, the data indicated a positive trend, with banana peel supplementation, particularly at 10%, potentially improving broiler survival.

This effect may be attributed to bioactive compounds in banana peels, such as flavonoids, tannins, phlobatannins, alkaloids, glycosides, and terpenoids. These phytochemicals exhibit a range of beneficial properties, including antibacterial, growth-promoting, antioxidant,

Table 2. Survival rate (%) of broilers

Age (weeks)	Experimental diets			SEM	P-value
	BPP0	BPP7	BPP10		
2	97.62	100	100	1.94	0.63
3	97.44	95.24	97.62	2.50	0.78
4	90.08	97.44	97.44	4.13	0.39
5	96.97	100.00	97.62	2.37	0.63
6	100.00	94.84	97.22	2.31	0.35
Overall	83.33	88.10	96.97	7.53	0.88

Note: BPP: banana peel powder; BPP0: control diet (basal diet without BPP); BPP7: basal diet with 7% BPP; BPP10: basal diet with 10% BPP

stress-reducing, anti-cholesterol, antihypertensive, immunostimulatory, and anti-inflammatory effects (Chueh *et al.*, 2019; Saeed *et al.*, 2025). Overall, banana peel supplementation did not adversely affect survival, thereby allowing a clearer assessment of its effects on growth performance and feed efficiency.

Growth performance

The growth performance of broilers fed diets with different levels of BPP are presented in **Table 3**. Although there were no significant differences ($P > 0.05$) in IW and ADG among the treatments, birds fed BPP10 showed the highest FW and WG, with values of 1498.53 g and 1355.91 g, respectively. These differences were statistically significant ($P = 0.05$) when compared to BPP0, suggesting that the inclusion of 10% BPP in the diet can positively influence broiler growth.

FI and FCR did not differ significantly across treatments ($P = 0.72$ and $P = 0.59$, respectively). However, birds fed the 10% BPP diet showed a numerically lower FCR (2.22) compared to the control (2.29) and 7% BPP (2.41) groups, indicating a trend towards improved feed efficiency with a higher BPP inclusion rate.

In this study, BPP contained relatively high levels of sugar, fat, and energy (**Table 1**), suggesting its potential to partially replace conventional energy sources in poultry diets. Adekeye *et al.* (2021) successfully reduced the

inclusion of traditional energy-rich feed ingredients, such as corn and wheat bran, by incorporating cassava peel meal into broiler rations. Their findings indicated that supplementing the diet with up to 150 kg ton⁻¹ of cassava peel meal improved growth performance while also reducing feed costs. Badr *et al.* (2019) evaluated the use of prickly pear fruit peel powder as a substitute for yellow corn and reported enhancements in the growth rate and feed conversion ratio across all the tested inclusion levels (5%, 10%, and 15%). Similarly, Dumorné *et al.* (2018) used 5%, 10%, 15%, and 20% banana peel powder to replace part of a soybean meal diet. They found no significant effect on body weight, but the birds fed with 15% BPP had the highest daily weight gain. Our study found that the dietary inclusion of 10% BPP in the diet improved FW, WG, ADG, and FCR. The improved growth performance in the chickens could be attributed to the biological activity of various active compounds in banana peels. According to Chueh *et al.* (2019), banana peel contains 872.7 mg 100g⁻¹ phenol; 91.9 mg 100g⁻¹; 65.9 mg 100g⁻¹ epigallocatechin; and 10.3 mg 100g⁻¹ epigallocatechin gallate, and these compounds exhibit antioxidant, antibacterial, and immunomodulatory activities, thereby increasing the nutrient digestibility, protein efficiency, and growth of broilers (Akuru *et al.*, 2020). Studies on other types of fruit by-products also reached the same result. Akbarian *et al.* (2015) demonstrated that citrus peel extracts increased growth hormone and triiodothyronine

Table 3. Growth performance of broilers

Items	Experimental diets			SEM	P-value
	BPP0	BPP7	BPP10		
IW	264.49	252.74	290.78	19.36	0.16
FW	1364.46	1354.56	1498.53	161.59	0.05
WG	1231.57	1224.32	1355.91	148.47	0.05
ADG	31.25	30.54	33.64	4.19	0.16
FI	72.35	74.71	76.74	3.77	0.72
FCR	2.29	2.41	2.22	0.13	0.59

Note: BPP: banana peel powder; BPP0: control diet (basal diet without BPP); BPP7: basal diet with 7% BPP; BPP10: basal diet with 10% BPP; IW: initial weight (g); FW: final weight (g); WG: weight gain (g); ADG: average daily gain (g/head/day); FI: feed intake (g); FCR: feed conversion ratio

(T3) levels, thereby promoting growth. Ahmadipour *et al.* (2021) showed that pomegranate peel extract enhanced antioxidant enzyme activity (CAT, SOD) and reduced lipid peroxidation. In addition, Pourhossein *et al.* (2015) found that dried orange peel enhanced immune responses, increasing IgG, IgM, lysozyme activity, and the relative weight of immune organs.

Carcass characteristics and meat quality

Table 4 shows the effects of different levels of banana peel powder on the carcass yield and meat quality of broilers. Banana peel inclusion in the place of corn-soybean meal in the broiler diets did not affect all the measured carcass yield traits ($P > 0.05$). In the same direction, most of the quality parameters of the thigh and breast meat showed no significant differences among the experimental diets ($P > 0.05$), except for the pH and b* values of the thigh meat, and the L* and b* values of the breast meat ($P < 0.05$). In the thigh meat, pH₁₅ was highest in the BPP0 diet and lowest in the BPP10 diet. Thigh yellowness (b*) also differed significantly ($P = 0.02$), with the highest value in the control group (19.49), while BPP7 and BPP10 were lower (~16.9), suggesting that banana peel powder reduced yellowness. For the breast meat, significant differences were observed in the color traits. Lightness (L*) was higher in BPP7 (62.52) and BPP10 (62.08) compared with BPP0 (59.64) ($P = 0.02$). Yellowness (b*) was also markedly affected

($P < 0.001$), with the highest value in the control (22.58), while BPP inclusion in the diet reduced this parameter to 20.11 in BPP7 and 18.62 in BPP10. This indicates that banana peel powder can enhance lightness but decrease yellowness, thereby altering the meat's appearance.

The pH of meat is determined by the glycogen content and the rate of adenosine triphosphate (ATP) breakdown in the muscles of poultry after slaughter (Laack, 2001). The pH level of meat is closely linked to several key quality traits such as texture, moisture loss during cooking, and overall juiciness (Allen *et al.*, 1998). According to Husak *et al.* (2008), meat with a higher pH tends to preserve its preferred color and water-retention capacity more effectively. In poultry, meat with a pH lower than 5.77 is classified as PSE (pale, soft, and exudative) meat (Kissel *et al.*, 2009), while meat with a pH higher than 6.27 is referred to as DFD (dark, firm, and dry) meat (Barbut *et al.*, 2005). In this study, the 24-hour post-mortem pH values remained below 6 and showed no significant differences across dietary treatments, suggesting that incorporating up to 10% banana peel powder in the diet does not negatively impact meat quality.

In this study, chickens fed diets containing banana peel powder exhibited higher breast meat lightness compared to the control group. This finding is in agreement with the results of Nuriyasa *et al.* (2022), who reported increased breast meat lightness in hens fed diets supplemented with fermented banana peels. The

Table 4. Effects of different levels of banana peel powder supplementation on the carcass yield and meat quality of broilers (n = 6)

Traits	Experimental diet			SEM	P-value
	BPP0	BPP7	BPP10		
<i>Carcass yield</i>					
Live body weight (g)	1473.33	1548.33	1421.67	127.47	0.61
Carcass weight (g)	991.00	1040.17	932.00	87.66	0.48
Thigh weight (g)	92.83	105.33	86.00	10.55	0.21
Breast weight (g)	121.33	116.00	106.05	12.79	0.52
Heart weight (g)	8.00	8.50	8.50	1.09	0.87
Liver weight (g)	32.83	32.50	34.33	4.09	0.89
Gizzard weight (g)	32.00	25.67	29.00	2.59	0.09
<i>Meat quality</i>					
<i>Thigh</i>					
pH15	6.31 ^b	6.44 ^a	6.21 ^c	0.10	<0.001
pH24	5.93	5.92	5.93	0.06	0.89
L* (lightness)	59.87	60.36	61.43	2.49	0.29
a* (redness)	8.89	9.96	9.68	1.32	0.12
b* (yellowness)	19.49 ^a	16.88 ^b	16.93 ^b	2.54	0.02
Cooking loss (%)	20.24	20.12	21.14	4.74	0.97
<i>Breast</i>					
pH15	6.33	6.35	6.21	0.17	0.16
pH24	5.82	5.81	5.86	0.07	0.28
L* (lightness)	59.64 ^b	62.52 ^a	62.08 ^a	2.65	0.02
a* (redness)	8.56	8.41	8.97	1.02	0.39
b* (yellowness)	22.58 ^a	20.11 ^b	18.62 ^b	2.35	<0.001
Cooking loss (%)	19.04	14.82	12.72	2.83	0.12

Note: BPP: banana peel powder; BPP0: control diet (basal diet without BPP); BPP7: basal diet with 7% BPP; BPP10: basal diet with 10% BPP. Means within a row with different superscripts (a, b, c) differ significantly ($P < 0.05$).

inclusion of banana peel powder in the diet also resulted in reductions in the yellowness of both thigh and breast meat compared to the control group, which exhibited the highest yellowness values. This outcome is fully understandable, as the control diet was formulated with yellow maize, a cereal grain that contains β -carotene, a compound known for its yellow pigmentation properties (Nogareda *et al.*, 2016).

Villus height and crypt depth

The effects of dietary banana peel powder (BPP) on the intestinal morphology of broiler chickens at day 42 are presented in **Table 5** and

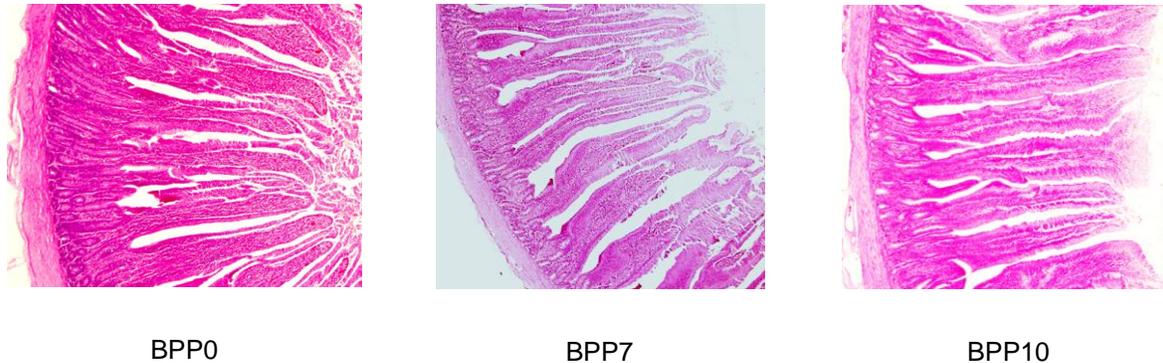
Figure 1. There were no statistically significant differences observed in the villus height, crypt depth, or the villus height to crypt depth ratio (V:C).

There are very few reports addressing the effects of dietary banana peel and its compounds on the function of the gut in broiler chickens. Several previous studies on fruit by-products have reported that no statistically significant differences were observed in the villus height and crypt depth in the duodenum, jejunum, and ileum when broiler chickens were fed apple, blackcurrant, and strawberry pomace (Colombino *et al.*, 2020). It is well known that an

Table 5. The villus height and crypt depth of broiler chickens (n = 6)

Items	Experimental diets			SEM	P-value
	BPP0	BPP7	BPP10		
Villus height (μm)	1622.05	1789.30	1706.57	51.71	0.46
Crypt depth (μm)	355.08	292.80	357.51	26.08	0.17
V:C ratio	4.80	5.89	4.83	0.39	0.12

Note: BPP: banana peel powder; BPP0: control diet (basal diet without BPP); BPP7: basal diet with 7% BPP; BPP10: basal diet with 10% BPP. V:C ratio: the villus height to crypt depth ratio

**Figure 1.** Histological representation of the duodenal villi of broiler chickens

increase in the villus height combined with a reduction in the crypt depth can enhance nutrient absorption, decrease gastrointestinal secretions, improve disease resistance, and ultimately lead to a better overall growth performance (Emami *et al.*, 2012). On the contrary, a lower villus height and greater crypts depth are associated with poor digestion, less absorption of nutrients, and poor growth performance (Qaisrani *et al.*, 2014). Based on the results of this study, it can be concluded that the inclusion of banana peel powder in the diet did not significantly affect the villus height, crypt depth, or the villus height to crypt depth ratio in the duodenum of broiler chickens. It is reasonable to hypothesize that banana peel utilization does not negatively influence gut development or nutrient absorption.

Conclusions

The inclusion of 10% banana peel powder in the diet tended to improve the final body weight and body weight gain during the experimental period, without affecting the feed conversion ratio, intestinal morphology, or carcass yield. In

terms of meat quality, broiler chickens fed banana peel powder exhibited higher lightness and lower yellowness. These findings suggest that banana peel powder, when incorporated at a 10% inclusion level, is a safe and effective agricultural by-product that may enhance the growth performance in broiler chickens and contribute to sustainable poultry production.

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