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Effects of partial substitution of feed with spent coffee grounds on growth performance and carcass quality in broilers

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Abstract The research findings found that the spent coffee grounds (SCG) substitution with 5% and 10% in feed (SCG-5 and SCG-10) which exhibited significant ($P<0.01$) effect on average daily gain with 80.82 and 66.84 g/day as compared to 0% substitution (SCG-0), which 88.62 g/day. While the the affecting on feed conversion ratio was shown in SCG-10 (2.05), which significantly ($P<0.01$) higher than SCG-5 (1.78) and SCG-0 (1.73). Similar to the carcass quality, SCG-10 was significantly ($P<0.01$) exhibited lower carcass weight (2,023.38 g) than SCG-5 and SCG-0 (2,267.48 and 2,319.70, respectively). However, there was no significant difference in the percentage of the carcass. Furthermore, substituting SCG in the feed had no impact on the weight of major muscles, such as the breast and thigh muscles. The inclusion of SCG-10 and SCG-5 was significantly increased in liver weight ($P<0.05$). However, only a high substitution rate of 10% SCG was significantly decreased in abdominal fat ($P<0.01$) as compared to the inclusion levels of 5% and 0% in the feed. In conclusion, substituting 5% SCG into the feed had shown to be a marginal impact on production efficiency, while a 10% SCG substitution rate distinctly influenced both production efficiency and carcass quality.

Keywords: Broiler, Carcass, Coffee grounds, Feed, Growth performance

Introduction

During the period between 1970 and 2005, global commercial production of poultry eggs and meat had experienced a substantial surge. Among various types of animal production, poultry farming reported a notably accelerated growth rate, surpassing other animal farming sectors. This expansion was attributed to efficient feed conversion into poultry products and reduced production expenses associated with intensive poultry farming practices. However, this growth was accompanied by a set of challenges. These challenges

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encompassed aspects like ensuring food safety, safeguarding animal well-being, optimizing production efficiency, managing the housing environment, and implementing effective management strategies (Penz and Bruno, 2011). In the European Union, antibiotic growth promoters (AGPs) as additives in poultry feed were permitted for a significant period. Nevertheless, their usage was prohibited in 2006, primarily due to concerns regarding developing cross-resistance against pathogens and accumulating residues in animal tissues (Castanon, 2007). In the past, there has been a prolonged use of antibiotics to reduce and inhibit bacterial infections, leading to the emergence of antibiotic-resistant bacteria (Mehdi *et al*., 2018). Additionally, antibiotics have been used in conjunction with synthetic antioxidants in animal feed, which can have a direct impact on the health of both humans and animals. Therefore, there are current efforts to study natural antioxidants in poultry farms as an alternative (Pashtetsky *et al.,* 2019). These additives have demonstrated the capacity to enhance growth performance, optimize feed efficiency, bolster nutrient digestion, elevate antioxidant status, strengthen immunological indicators, and contribute to overall poultry health. (Alagawany *et al*., 2019). This is particularly important when considering the added benefits of herbs, such as their accessibility, practical effectiveness, cost efficiency, absence of residual effects, and resistance to antibiotics (Abd El-Hack *et al*., 2020).

Currently, there is ongoing research on the valuable biological compounds found in fresh coffee beans, roasted coffee, and coffee grounds, which possess high levels of antioxidants. These compounds belong to the group of phenolic compounds, such as chlorogenic acid, protocatechuic acid, and flavonoids, all of which are potent antioxidants (Solange *et al*., 2011). Additionally, as Ballesteros *et al.* (2014) reported, coffee grounds also hold nutritional value, comprising approximately 13.5% protein and 72% carbohydrates. Therefore, it can be observed that coffee grounds are a viable byproduct with nutritional value and benefits in controlling various pathogens. Consequently, it has led to the idea of utilizing these coffee grounds, a valuable by-product of this industry, for animal feed production as a replacement for antibiotics or chemicals to control diseases.

The objective was to determine the level of coffee grounds use that minimally affects broiler production efficiency and meat quality.

Materials and methods

Spent coffee grounds preparation

Arabica spent coffee grounds (SCG) post-consumption was supplied by Chao Doi Coffee, a retail coffee shop located in Bangkok province, Thailand, was utilized as the primary raw material for this study. These SCG underwent a drying process using hot air at 65°C for 48 hours. Subsequently, the dried SCG were carefully stored in sealed glass bottles, then maintained at room temperature for further use.

Chemical composition by proximate analysis was conducted to determine various nutritional components in both the SCG and the feed used in the experiment. The methodology was adapted from the AOAC (2000) standard methods (Association of Official Analytical Chemists).

Experimental animal and management design

The research was conducted using male broilers of the Ross 308 breed at 21-days old in total of 108 individuals. The broilers were randomly assigned as a completely randomized design (CRD). They were divided into three experimental groups as follows:- Group 1 was basal diets with 100% complete commercial powdered feed. Group 2 was substituted with 5 % SCG in the commercial feed. Group 3 was substituted with 10% SCG in the commercial feed.

Each experimental group consisted of 3 replicates, with each replicate containing 12 broilers. The broilers were raised in pens with a size of 3 m^2, and the floor was lined with an 8-centimeter-thick layer of rice husk. The experiment was carried out in poultry houses equipped with evaporative cooling systems.

In terms of feeding management, all experimental chickens were provided with *ad libitum* access to feed. The chickens were fed from 0-21 days (before starting the experiment) with powdered starter feed, while at 21-42 days were given with powdered grower-finisher feed as basal diet.

Data collection

Live performance

Chickens were weighed individually at 21, 28, 35, and 42 days of age. The feed given to the birds in each pen and the remained feed were recorded prior to each weighing. Feed intake (FI) was calculated as the difference between the feed given and the feed left. Feed conversion ratio (FCR) was calculated as grams FI divided by body weight. The average daily gain (ADG) was calculated as grams of weight gain divided by the number of days as described by Klompanya *et al.* (2023).

Carcass characteristics

The experimental chickens reached the age of 42 days, a random selection of 3 chickens per replicate was conducted to study carcass quality. The method employed for euthanasia was controlled atmosphere stunning using CO_2, as described by Nielsen *et al*. (2019). After evisceration, carcass weight, breast meat, filet, wing, thigh, drumstick, body, and abdominal fat were recorded. The weight of carcass and cut parts was expressed as a percentage of weight before slaughter as demonstrated by Kamporn *et al.* (2022).

Statistical analysis

The data were analyzed utilizing SAS statistics (SAS Institute, Cary, NC). The individual replicate pen of broilers served as the experimental unit for statistical analysis. Statistical differences in the results among levels (%) of SCG were assessed through one-way ANOVA. To measure the significant difference between means, Duncan's New Multiple Range Test (DMRT) was employed, with a 95% confidence interval serving as the criterion for statistical significance.

Results

Chemical composition analysis

Based on the nutritional composition analysis of the experimental SCG, the chemical components were recorded as follows: Protein: 12.86%, Fat (Ether extract): 3.70%, Fiber: 17.34%, Ash: 1.36%, Nitrogen-free extract (NFE): 48%, Gross energy: 5,184.4 kcal/kg. The mineral component consisted of 0.18% calcium and 0.05% phosphorus. The nutritional components of feed in each experimental group were enumerated as described in Table 1. It varied according to the level of substituting concentrated feed with SCG.

Table 1. Nutritive value of SCG and diets substituted with SCG at different levels

Item	Level of SCG substitution (%)			SCG
	0	5	10	
Proximate analysis				
Dry matter, DM as fed (%)	88.16	88.36	86.21	93.26
Crude protein, CP (%DM)	17.29	17.28	18.16	12.86
Crude fiber, CF (%DM)	3.89	4.92	3.70	17.34
Ash (%DM)	5.58	5.28	6.08	1.36
Ether extract, EE (%DM)	3.89	6.49	6.39	3.70
Nitrogen-free extract, NFE	54.77	54.39	51.88	48.00
Gross energy, GE (kcal/kg)	4,055.60	4,114.40	4,025.10	5,184.40
Mineral				
Calcium (%DM)	0.57	0.53	0.95	0.18
Phosphorus (%DM)	0.18	0.18	0.23	0.05

Effect on the growth performance

The study investigated the partial replacement of feed with SCG and its impact on the broiler chicken's production performance, specifically focusing on body weight in different age groups. The results indicated that at 21-day old were no statistically significant differences in body weight among the groups. However, at the 28, 36 and 42-day old, group 3 exhibited a significantly lower average body weight compared to groups 1 and 2 (P<0.01) (Table 2).

Interestingly, throughout the entire experimental period spanning from day 21 to day 42, a consistent lower in average body weight was observed in correlation with the increasing proportion of SCG used in the diet.

Body weight gain findings indicated that during the age range of 21-28 days, group 3 (393.89 g) exhibited significantly lower average weight gain compared to group 2 and the control (532.22 g, 567.78 g), with statistical significance (P<0.01). However, during the periods of 29-35 and 35-42 days, the average body weight gains did not show statistically significant differences among the groups. Nevertheless, when considering the entire experimental period of 21-42 days, group 3 (1,403.56 g) had significantly lower average weight gain compared to group 2 and the control (1,697.22 g and 1,861.11 g), with statistical significance (P<0.01) (Table 2).

In term of ADG, the period of 21-28 days, group 3 (56.27 g/day) exhibited a significantly lower daily weight gain compared to the group 2 and control (76.03 g/day and 81.11 g/day, respectively), with statistical significance (P<0.01). However, during the age ranges of 29-35 and 35-42 days, the ADG did not exhibit statistically significant differences among the groups. Nevertheless, upon considering the entire experimental period of 21-42 days, it was observed that group 3 (66.84 g/day) had a significantly lower daily weight gain compared to group 2 and control (80.82 and 88.62 g/day, respectively), with statistical significance (P<0.01) (Table 2).

At the first week of the experiment, the control and group 2 had FI (935.00 and 880.56 g/bird) higher significantly (P<0.01) comparable with group 3 (790.83 g/bird). While inconcistent results had been found at second and third weeks since starting for substitution. However, when the FI was summarized for the whole period, it was found that group 2 had highest (3,395.56 g/bird) significantly (P<0.01) than control and group 3 (3,194.44 and 3,150.83 g/bird, respectively). The same results had been found when the average daily feed intake (ADFI) was calculated (Table 2).

The efficiency of feed usage is exhibited as the proportion of feed consumption and weight gain for FCR calculation. The results revealed that the lowest FCR was found in the control group at all periods. In accordance with the summary of whole period (21-42 days) that illustrated the best FCR in control group (1.73), followed by group 2 (1.78). While the significantly highest (P<0.01) had been found in group 3 (2.05) (Table 2).

Table 2. Growth performance parameters of broiler chicks as affected by SCG powder supplementation (Mean±SD)

Item	Level of Spent coffee grounds (SCG) (%)			P-value
	0	5	10	
Body Weight (g)				
21 days	913.33±6.01	916.11±3.47	916.67±2.89	0.6254[ns]
28 days	1,481.11±22.01[a]	1,448.33±30.41[a]	1,310.56±25.02[b]	0.0004[**]
36 days	2,078.33±166.55[a]	2,030.56±40.96[a]	1,853.33±5.77[b]	0.0009[**]
42 days	2,774.44±166.55[a]	2,613.33±40.96[a]	2,320.22±68.19[b]	0.0055[**]
Body Weight Gain (g)				
21-28 days	567.78±17.51[a]	532.22±21.15[a]	393.89±23.71[b]	0.0002[**]
29-35 days	597.22±36.22	582.22±13.57	542.78±22.69	0.0966[ns]
36-42 days	696.11±111.21	582.78±76.09	466.89±73.51	0.0524[ns]
21-42 days	1,861.11±160.61[a]	1,697.22±44.17[a]	1,403.56±65.88[b]	0.0046[**]
Average Daily Gain (ADG)				
21-28 days	81.11±2.50[a]	76.03±3.88[a]	56.27±3.39[b]	0.0002[**]
29-35 days	85.32±5.18	83.18±1.94	77.54±3.24	0.0965[ns]
36-42 days	99.44±15.89	83.25±10.87	66.70±10.50	0.0524[ns]
21-42 days	88.62±10.23[a]	80.82±14.35[b]	66.84±9.13[b]	0.0046[**]
Feed Intake (g/bird)				
21-28 days	935.00±15.00[a]	880.56±3.85[a]	790.83±61.10[b]	0.0080[**]
29-35 days	1,147.22±15.12[b]	1,192.22±27.40[ab]	1,235.00±46.46[a]	0.0436[*]
36-42 days	1,112.22±25.46[b]	1,322.78±66.79[a]	1,125.00±59.23[b]	0.0050[**]
21-42 days	3,194.44±1,241.72[b]	3,395.56±1,192.13[a]	3,150.83±1,283.11[b]	0.0026[**]
Average Daily Feed Intake (g/bird/day)				
21-28 days	133.57±2.14[a]	125.79[a]±0.55[a]	112.98[b]±8.73[b]	0.0080[**]
29-35 days	163.89±2.16[b]	170.32±3.92[ab]	176.43±6.64[a]	0.0436[*]
36-42 days	158.89±3.64[b]	188.97±9.54[a]	160.71±8.46[b]	0.0050[**]
21-42 days	456.35±177.39[b]	485.08±170.31[a]	450.12±183.30[b]	0.0026[**]
Feed Conversion ratio (FCR)				
21-28 days	1.65±0.07[b]	1.66±0.09[b]	2.01±0.07[a]	0.0016[**]
29-35 days	1.93±0.12[b]	2.05±0.04[b]	2.28±0.01[a]	0.0039[**]
36-42 days	1.62±0.21[b]	2.29±0.25[a]	2.39±0.35[a]	0.0275[*]
21-42 days	1.73±1.61[b]	1.78±1.78[b]	2.05±2.03[a]	0.0025[**]

[a, b] Different superscripts in the same row indicate statistical differences, * Means within a row indicates significantly with P<0.05, ** Means within a row indicates highly significantly with P<0.01, ns Non significantly differences.

Effect on the carcass quality of broiler

When the chickens reached 42-days old, repeated random sampling of 3 individuals was examined for carcass weight and the percentages each part. The results revealed that the live weight before slaughter in group 3 (2,573.33 g/bird) was significantly lower ($P<0.05$) than both control and group 2 (2,843.33 and 2,853.33 g/bird respectively). The same trend was observed in the defeater weight (warm carcass, included internal organs), significantly ($P<0.01$). The significant lowest ($P<0.01$) carcass weight (chilled carcass without internal organs) was also found in group 3 (2,023.38 g/bird), while control and group 2 (2,319.70 and 2,267.48 g/bird, respectively).

Upon analyzing the percentage distribution of dressed carcass parts, it was observed that the percentages of breast, inner breast, thigh, drumstick, abdomen, soft breastbone, head and neck, feet, ribs, keel, and heart did not exhibit statistically significant differences.

Table 3 The weight of carcass and cutting parts percentage of different SCG powder substitution groups at 42 days (Mean±SD)

Item	Level of Spent coffee grounds (SCG) (%)			P-value
	0	5	10	
Live weight (g)	2,843.33±65.01^{a}	2,853.33±187.47^{a}	2,573.33±192.53^{b}	0.0126*
Defeater weight (g)	2,565.67±85.57^{a}	2,570.70±159.05^{a}	2,290.27±195.14^{b}	0.0090**
Carcass weight (g)	2,319.70±59.35^{a}	2,267.48±176.89^{a}	2,023.38±166.15^{b}	0.0064**
Carcass (%)	81.59±1.83	79.43±2.19	78.61±1.89	0.0514^{ns}
Breast (%)	27.93±1.74	26.61±1.52	25.99±1.79	0.1595^{ns}
Fillet (%)	5.23±0.38	4.78±0.48	5.05±0.38	0.2064^{ns}
Wings (%)	10.31±0.24^{b}	10.15±0.39^{b}	10.93±0.51^{a}	0.0102*
Thigh (%)	15.09±0.29	16.14±1.08	15.67±0.69	0.0898^{ns}
Drumstick (%)	11.77±0.68	11.86±0.43	11.79±0.30	0.9449^{ns}
Tail (%)	0.79±0.11	0.84±0.29	0.94±0.32	0.4588^{ns}
Keel cartilage (%)	0.61±0.19	0.64±0.29	0.47±0.19	0.3905^{ns}
Neck (%)	4.79±0.41	4.92±0.58	4.63±1.01	0.7709^{ns}
Head (%)	2.59±0.11	2.62±0.32	2.69±0.16	0.8338^{ns}
Feet (%)	4.24±0.34	4.35±0.08	4.55±0.21	0.0947^{ns}
Skeleton (%)	16.35±0.84^{b}	16.65±0.79^{b}	19.08±1.49^{a}	0.0010**
Trim (%)	0.05±0.06	0.12±0.13	0.03±0.05	0.1575^{ns}
Abdominal fat (%)	1.07±0.17^{a}	0.99±0.22^{a}	0.46±0.08^{b}	<0.0001**
Liver (%)	1.78±0.17^{b}	2.29±0.33^{a}	2.49±0.42^{a}	0.0142*
Gizzard (%)	1.39±0.13	1.69±0.32	1.53±0.23	0.1341^{ns}
Heart (%)	0.46±0.09	0.42±0.04	0.47±0.06	0.3681^{ns}

$^{a, b}$ Different superscripts in the same row indicate statistical differences, * Means within a row indicates significantly with $P<0.05$, ** Means within a row indicates highly significantly with $P<0.01$, ^{ns} Non significantly differences

However, when considering the percentages of wings, group 3 (10.93%) exhibited a significantly higher value ($P<0.05$) than both the control and group 2 (10.31% and 10.15% respectively). Similarly, for the skeleton, group 3 (19.08%) demonstrated a significantly higher value ($P<0.05$), compared to group 2 and control (16.65% and 16.35% respectively). In contrast, the percentage of abdominal fat in group 3 (0.46%) was lower than both group 2 and control (0.99% and 1.07% respectively), with statistical significance ($P<0.01$). Additionally, for the liver percentage, group 3 (2.49%) had a significantly higher value than group 2 and control (2.29% and 1.78% respectively), with statistical significance ($P<0.05$).

Discussion

The results on the chemical composition of the SCG used in the experiment found that it contained nutritive components such as high protein and carbohydrate content. This aligned with the findings of previous research conducted by Ballesteros *et al*. (2014), Narita and Inouye (2014) and Kourmentza *et al.* (2018), investigated the chemical composition of SCG and identified approximately 13.5% protein, 2.3% fat, and 1.3% ash content. The ash content also reflects the significant presence of essential mineral elements in coffee grounds. Furthermore, the total dietary fiber content is notably elevated, reaching up to 61%, with insoluble dietary fiber accounting for 51% of this total. The total carbohydrate content also amounts to around 72%, with a predominant contribution from hemicellulose at 39%. Jha and Mishra (2021) highlighted that the digestive system of poultry possesses limitations in effectively breaking down certain nutritional constituents such as insoluble dietary fiber and complex carbohydrates, including hemicellulose and lignin. Elevated levels of these constituents can lead to hindrance in nutrient utilization and consequently affect growth.

The results of a study on the impact of using SCG as a partial replacement for feed on broiler performance, it was found that in the group using SCG in quantities of less than 5% in the feed, had a slight negative impact on production performance. However, it was also observed that there was an increase in feed consumption and a higher feed conversion ratio compared to the control group. Scheuermann *et al.* (2009) illustrated that supplementing with phytogenic additives can enhance feed efficiency in broilers, although the exact quantity for such supplementation is not yet certain. Nevertheless, it was found to improve body weight gain. Upon evaluating the results of the present experiment, it was observed that a notable adverse impact on production performance would occur when substituting SCG at higher levels, particularly at 10%. The substitution of 5% SCG resulted in an increased feed consumption, which may be attributed to the necessity for nutrient compensation to enhance growth efficiency. Importantly, this substitution had no effect on FCR.

Peric *et al*. (2009) reported that the influence of supplementing phytogenic additives stimulates growth and reduces the need for antibiotics, which can have implications for the health and resistance of bacteria. Similarly, Jimenez-Zamora *et al*. (2015) and Panusa *et al.* (2013) reported that SCG are a natural source of various antioxidants, including tannic acid, chlorogenic acid, caffeine, antioxidant polysaccharides, and melanoidins (compounds formed during coffee roasting). These antioxidants are beneficial for feed due to their ability to combat various forms of oxidative stress. Ashour *et al.* (2020) conducted a study on the effects of supplementing green coffee powder in broiler chicken feed, with a group supplemented at a rate of 2.5 grams per kilogram of feed. This supplementation had several positive impacts on the chickens. Firstly, it increased their feed intake, resulting in higher body weights. Additionally, it led to a reduction in the feed-to-weight gain ratio, indicating improved feed efficiency. Moreover, it helped to be lower abdominal fat levels, like the findings in the study by Yachai *et al.* (2022), which investigated the effects of coffee silverskin supplementing in Thai native chicken (Pradu-Hangdum) diets. The group supplemented at a rate of 2.0 grams per kilogram of feed showed improved growth performance and carcass quality. The levels of antioxidants in chicken meat also increased, contributing to better meat quality. Furthermore, there were improvements in the histological parameters of the intestines, indicating enhanced gut health. When compared to the current study, which utilized a different coffee product not previously examined, substitute in the feed with high levels of by-product after consumption, the experiments aimed to identify the maximum level with minimal impact on both growth performance and meat quality. The results indicated that the substitution should not exceed 5%, as this percentage has no significant effect on overall growth performance and meat quality. The results also showed a similar outcome to that of Yachai *et al*. (2022), indicating a reduction in abdominal fat corresponding to the percentage of substitution of SCG.

Interestingly, the substitution with SCG led to an enlargement of the liver, even at a 5% substitution level. This could be attributed to an increase in the metabolism of certain compounds present in SCG. This observation suggests the need for intensive investigations into liver function in future studies.

Further studies should investigate the supplementation of SCG in quantities below 5%, to determine the optimal dosage that can enhance production performance, improve overall health, and maintain high carcass quality.

Acknowledgments

The research was carried out in adherence to the principles outlined in The Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes, as outlined by the National Research Council of Thailand. The study was granted approval by the Animal Care and Use Committee at King Mongkut's Institute of Technology Ladkrabang, with the approval number ACUC-KMITL-RES/2022/001. The authors would like to thank the Animal Reseach and Innovation Center (ARIC), Department of Animal Production Technology and Fisheries, School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang for providing the necessary facilities.

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