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Effect of medicinal plant byproducts on carcass traits, meat composition and sensory attributes in broiler chicken

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ABSTRACT

Several types of medicinal plants are consumed for their pharmacological properties. However, the byproducts generated after their use as herbal products are often unutilized, contributing to environmental pollution despite containing valuable nutrients and bioactive compounds. Therefore, current study was conducted to investigate the efficacy of byproducts derived from three different medicinal plants (*Aloe vera, Camelia sinensis* and *Phylanthus emblica*) on carcass traits, meat chemical composition and sensory attributes of broiler chicken. Four different types of dietary treatments include 1) MPBC0: Control (basal diet without medicinal plant byproduct combinations; 2) MPBC1 = basal diet + 0.2% medicinal plant byproduct combinations; 3) MPBC2 = basal diet + 0.4% medicinal plant byproduct combinations; 4) MPBC3 = basal diet + 0.6% medicinal plant byproduct combinations tested. The result of the present study revealed that among the dietary treatments, MPBC1, MPBC2 and MPBC3 exhibited no negative influence on carcass traits ($P<0.05$); however, some internal organ weight differed among dietary treatments ($P<0.05$). The proximate composition of broiler meat was significantly improved in broilers treated with MPBC1, MPBC2, and MPBC3 compared to those treated with MPBC0 ($P<0.05$). Similarly, sensory evaluation results indicated that broilers treated with MPBC1, MPBC2, and MPBC3 had better meat quality attributes as compared to MPBC0 ($P<0.05$). In conclusion, medicinal plant byproducts could be a potent feed additive source for better meat quality attributes with little alteration on carcass traits and internal organ weight in case of broiler chicken.

Introduction

Among the several varieties of poultry species, chickens are the most popular across the world. Chicken meat is considered a healthy dietary option due to its relatively low fat and cholesterol levels (Kralik *et al*., 2018). Furthermore, chicken continues to be the least

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expensive meat type consumed worldwide, and by 2018, consumption of chicken is predicted to rise by 34% (Suganthi, 2014; Petrová *et al*., 2015). According to a report by Poultry World (2022), global chicken consumption was less than 10 million tonnes in 1960 but surged to over 120 million tonnes by 2021. It is projected that consumption will reach 180 million tonnes by 2050, marking an increase of 1,200% from 1960. U.S. government statistics indicate that such growth would result in chicken consumption rates nearly three times those of pork and ten times those of beef. By 2030, it is expected that chicken will account for 41% of all meat consumption. For the first time, chicken will surpass all other types of protein, particularly animal-based proteins, in global consumption. Health promoting efficacy of medicinal plants due to presence of bioactive compounds gaining interest all over the world as side dish, drink or supplements (Lim, 2012; Matic *et al*., 2018).

There is a wide variety of medicinal plants which are utilizing by human and animal for their pharmacological potential. One notable example is the gooseberry (*Phyllanthus emblica*), a member of the *Euphorbiaceae* family. *Phyllanthus emblica*is not only rich in vitamin C but also provides significant amounts of calcium, phosphorus, iron, beta-carotene, and vitamin B complex. It's high vitamin C content contributes to some of its health advantages. The genus *Aloe* is a succulent plant species, specifically known as *Aloe vera*. It is used in a wide range of consumer products, including beverages, skin lotions, makeup, and ointments for minor burns and sunburns. The drink of *Aloe*, often combined with other medicinal plants are popular in Bangladesh and various other countries for their pharmacological benefits. However, there is limited scientific evidence on the safety and efficacy of *Aloe vera* extracts for livestock and poultry. Traditional tea, made by pouring boiling or warm water over the curled leaves of the Camellia tree (Martin, 2007), is the second most widely consumed beverage in the world after water (Macfarlane and Macfarlane, 2004). Tea comes in various types, with some, like Chinese greens and Darjeeling, having an astringent, slightly bitter, and cooling flavor (Penelope, 2000), while others offer distinct flavor profiles, including hints of sweetness, nuttiness, floral notes, or grassiness. Medicinal plants and their byproducts, whether used alone or in combination, are utilized by both humans and animals for their antioxidant properties and physiological benefits. A combination of *Curcuma longa* and *Aloe vera* (Mehala and Moorthy, 2008b) resulted no significant difference in body weights and feed intake (Mehala and Moorthy, 2008b); however, a significant feed conversion ratio was observed by inclusion of *Aloe vera* and *Curcuma longa* in broilers (Mehala and Moorthy, 2008b).

While a combination of Amla, Tulsi and Turmeric (0.25%, 0.5%) in broilers diet has significantly increased feed intake in broilers (Reddy, 2010). The combination of Aloe vera and Curcuma longa in broiler diets produced a substantial difference in the feed cost per unit live body weight in broiler weights up to six weeks of age, but no significant variations were identified in the carcass characteristics. (Mehala and Moorthy, 2008a, b). *Camelia sinensis* with the combination of *Ginkgo biloba*, and *Citrus junos* after fermentation was reported effective for better broiler performance (Kim *et al*., 2016). *Phyllanthus emblica* was effective for production and diarrhea prevention activity in case of sheep (Bostami *et al*., 2015). It was suggested that *Camelia sinensis*, *Aloe vera*, and *Phylanthus emblica* might be used as feed supplements to improve the growth and cost-effectiveness of broiler chickens (Bostami *et al*., 2020).

Several artificial chemical compounds are used to encourage the development of cattle and poultry, but they pose health risks to people (Kim *et al*., 2016; Bostami *et al*., 2017). In an attempt to avoid using artificial growth boosters, a great deal of work has gone into creating useful feed additives using mixtures of medicinal plants and their byproducts (Windisch *et al*., 2008; Bostami *et al*., 2015; Abdallah *et al*., 2019; Bostami, *et al*., 2020; Bostami *et al*., 2021).

Despite the fact that most agro-industrial outputs include useful plant secondary metabolites, they are still regarded as waste products that pollute the environment. In Bangladesh, *Phyllanthus emblica* is the most common of the several therapeutic herbs. Its chemical composition makes it possible to boost meal absorption, stabilize stomach acid levels, strengthen the liver, nourish the brain, elevate mental clarity, and support healthy cardiac function.

Additionally, it strengthens the lungs, increases fecundity, controls the removal of free radicals, supports a healthy urinary system, improves skin quality, and encourages better hair (Vasudevan & Parle, 2007). This fruit has many health benefits, including cooling the body, removing toxins, boosting energy, toning muscles, protecting the eyes, and acting as an antioxidant. Due to its ability to heal a wide range of illnesses, it is frequently utilized in Ayurvedic therapies (Gaire & Subedi, 2014). It is considered as the powerful antioxidant agent. Numerous health issues stem from oxidative damage, which is the result of body cells using oxygen to generate harmful byproducts called free radicals. Antioxidant substances stop and reverse these deteriorations. It can enhance growth sheep's performance and lower the number of fecal microorganisms (Bostami *et al*., 2015).

Aloe vera is utilized for many purposes in the country, such as herbal drink, cosmetic use and medicinal use by the people. *Aloe vera* gel is used commercially as an ingredient in yogurts, beverages, and some desserts (Reynolds, 2004; Armstrong, 2008), although at certain level of doses, its toxic attributes could be severe whether ingested or topically applied (Andersen, 2011). Traditional medicine uses aloe vera as a skin treatment. The plant is used widely in the traditional herbal medicine of many countries. *Camelia sinensis* is a common and wide drink round the country, where byproducts are wastage after utilization. *Camelia sinensis* contain caffeine, which constitutes about 3% of dry weight of tea, translating to between 30 mg and 90 mg per 250-ml cup based on type and brand (Weinberg *et al*., 2001), and brewing method (Hicks *et al*., 1996). According to a study (Chatterjee *et al*., 2012), there was a considerable difference in the caffeine content of 1 g of black tea, which varied from 22 to 28 mg, and 1 g of green tea, which ranged from 11 to 20 mg. Tea contains polyphenols, which are responsible for its astringency. These are the most abundant compounds in tea leaves, making up 30-40% of their composition (Harbowy, 1997).

It is widely believed that making appropriate use of plant byproducts can reduce feed costs, with the added benefit of supporting animal health and product quality for animal production. *Camelia Sinensis is* a very common drink in Bangladesh and produce huge amount of waste, creating environmental hazards. It was anticipated that a combination of medicinal plants would have synergistic effects on birds in the current study because natural plant materials are composed of primary and secondary bioactive compounds, which can be used in the field of crops or as byproducts in the diet of livestock and poultry (Wald, 2003). However, as far as we are aware, no research has yet looked into how broiler nutrition is affected by combinations of medicinal plant byproducts with *Phylanthus emblica*, Aloe vera, and *Camelia Sinensis*. Therefore, the goal of the current study was to find out how the combination of *Aloe vera*, *Camelia Sinensis* and *Phylanthus emblica* medicinal plant byproducts affected the broiler chicken's carcass features, internal organ weight, meat chemical composition and sensory qualities.

Methodology

Preparation of medicinal plant byproduct combination (MPBC)

Three types of medicinal byproducts available in the local market of Gazipur, Bangladesh were selected for the study. *Camelia Sinens*is waste was gathered from tea stores, *Aloe vera* byproducts were gathered from vending juice shop, and *Phylanthus emblica* were gathered from herbal shop. After collection of *Phylanthus emblica* and byproduct of *Aloe vera* and *Camelia Sinensis* samples was properly processed and prepared following the methodology applied by Bostami *et al*. (2020). Proximate composition of medicinal plant was analyzed following Association of Official Analytical Chemists method (AOAC, 2000).

Experimental design, dietary treatments and bird's husbandry

Healthy Cobb-500-day-old chicks were retrieved from a reputable hatchery. Following completely randomized design there were four treatment groups, each with six replications of ten birds per replicated pen, received 240 chicks in all. Broilers were reared in a well ventilated broiler house with pen size of 100 cm long × 100 cm wide, providing with a floor space of 1000 cm^2/bird. Sufficient lighting was ensured for proper management of the birds. The temperature of the house was maintained based on Cobb-500 broilers manual to meet the requirements. Birds were reared for 35 days diving starter (0 to 3 weeks) and finisher (4 to 5 weeks) period. Commercially formulated diet was provided based on stage of production of the birds. Measurements were made on body weight, feed intake, and feed conversion ratio during the trial which data were recorded weekly basis. Data were recorded for 35 days. Following 35 days rearing period, birds were randomly selected for slaughtering, carcass characteristics were assessed, and a sample of flesh was taken for examination using several criteria. Dietary treatments were: 1) MPBC0: Control (basal diet without byproduct combinations of medicinal plant); 2) MPBC1 = basal diet + 0.2% medicinal plant byproduct combinations; 3) MPBC2 = basal diet + 0.4% medicinal plant byproduct combinations; 4) MPBC3 = basal diet + 0.6% medicinal plant byproduct combinations.

Slaughtering of birds

Every bird was carefully examined to ensure that it was in good condition and had no abnormalities. Enough rest (around two hours) was given to the birds before to their slaughtering, ensuring a stress-free environment for the night. For twelve hours, the birds were given no feed and ad libitum access to water. In accordance with Muslim halal slaughtering practice, birds were slaughtered at 35th day of rearing. Professionals carried out the killing of the birds. The bird's various bodily parts were kept apart. After the carcass was dressed, it was washed appropriately. Following a thorough cleaning, the carcass was refrigerated and kept at 4°C.

Meat sample preparation

Two birds of each replicated pen were selected for slaughtering. After completion of the slaughtering process, each carcass's flesh was collected for investigation of the quality parameters. Following the acquisition of the meat samples, were split up for sensory analysis and meat proximate composition analysis. Meat samples were properly processed and preserved in separate zipper bag for further examination. In the Animal Science and Nutrition laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh, meat samples were examined and tested.

Chemical composition analysis

To determine the proximate composition of meat, the samples were excised and grinded properly with a meat grinder (Ultra Turrax, Germany). The AOAC techniques and recommendations were followed in order to determine the meat samples' moisture content, crude fat content, crude protein content, and crude ash content (AOAC, 2000).

Sensory evaluation

The sensory evaluation of the meat sample was evaluated organoleptically by twelve trained judges from the Faculty of Veterinary Medicine and Animal Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh. The parameters considered by the panelists for sensory evaluation were color, flavour, tenderness, juiciness, palatability and overall acceptability. On preheated grilling devices, each steak was grilled to an internal temperature of 40°C on a preheated grill. The steaks wrapped in aluminum foil and baked at 65°C before being removed. After making the steaks the panelists were invited for sensory evaluation. A scale of 1 to 9 was followed for sample rating where 1 is undesirable flavor, extremely tough and dry and 9 is desirable flavor, extremely tender and juicy. Each panel member was supplied natural water to rinse mouth. The average of the twelve panelists' values were used as sensory score for each sample.

Statistical analyses

All data was subjected to ANOVA using General Linear Models (GLM) function of the Statistical Analysis System (SAS, 2012, SAS Institute, Cary, NC, USA). Each cage was considered as the experimental unit for carcass characteristics, meat chemical composition and sensory evaluation. P<0.05 was regarded as statistically significant at the probability level, and P<0.10 as statistical tendency.

Results

Table 1 represents the effect of MPBC at different concentration on the carcass characteristics of broiler chicken. Among the carcass characteristics, differences were observed in the head, wings, and other body parts (particularly the area associated with the backbone) due to various dietary treatments (P<0.10). Other parameters, however, were not significantly affected (P>0.05).

Table 2 displays the impact of medicinal plant byproduct combinations (MPBC) on the internal organ weights of broiler chickens as a percentage of their live weight. The findings showed that, although there was a difference in some internal organ weight (P<0.05), the majority of the broiler chicken internal organ weight did not differ between the medicinal plant combinations added group and the control group.

Impact of combinations of medicinal plant on the chemical composition of broiler chicken meat was shown in Table 3. The findings on the meat chemical composition of broiler chickens showed that, medicinal plant combinations incorporated group MPBC3 had a higher ash content than the control group (P<0.05). The result implicated that, there was a tendency of changes in case crude protein content of meat in the medicinal plant combinations added group MPBC3 as compare to the no addition of feed additives (P<0.10). Moisture content of meat tended

Table 1. Effect of byproduct combinations of medicinal plant on carcass characteristics of broiler chicken

Parameters	Dietary treatments				SEM	P-value
	MPBC0	MPBC1	MPBC2	MPBC3		
Live weight (kg/bird)	2.34	2.53	2.46	2.73	0.093	0.157
Slaughter weight (kg/bird)	2.26	2.46	2.38	2.62	0.091	0.202
% of Live weight						
Head	2.30[ab]	2.37[a]	2.30[ab]	2.01[b]	0.086	0.073
Neck	2.43	1.92	7.89	2.82	1.102	0.178
Leg	3.75	3.90	3.72	3.29	0.244	0.462
Wing	5.45[a]	4.87[ab]	4.61[b]	4.54[b]	0.202	0.099
Thigh	18.42	17.83	18.61	18.77	0.568	0.700
Breast	26.18	22.40	26.27	26.34	1.295	0.184
Skin	10.22	11.52	8.53	11.48	1.005	0.276
Others	13.27[a]	10.93[b]	13.08[a]	12.00[ab]	0.495	0.054

[abc]Means that have distinct superscripts in the same row exhibit significant differences (P<0.05) and tendency (P<0.10). SEM: Standard error of mean. Dietary treatments: 1) MPBC0: Control (basal diet without combinations of medicinal plant byproducts); 2) MPBC1: Basal diet plus 0.2% combinations of medicinal plant byproducts; 3) MPBC2: Basal diet plus 0.4% combinations of medicinal plant byproducts; 4) MPBC3: Basal diet plus 0.6% combinations of medicinal plant byproducts.

to be higher in MPBC2 as compare to MPBC3 ($P<0.10$).

The impact of combinations of medicinal plant on the sensory evaluation of broiler chicken meat is displayed in Table 4. Incorporation of medicinal plant combinations exhibited superior sensory indices in case of broiler chicken meat. The color context of meat was better in case of MPBC3 as compare to MPBC0 group ($P<0.05$); the flavor was better in case of MPBC1 and MPBC2 relative to that of MPBC0 ($P<0.05$), and overall acceptance score was higher in case of MPBC3 in comparison to MPBC0 ($P<0.05$).

Discussion

Carcass traits and internal organ weight

The results of the study on the impact of medicinal plant byproduct combinations on broiler chicken carcass traits showed that there was no difference in the carcass traits of the broiler chicken in the medicinal plant combinations incorporated group as compared to the control group. Previous study on supplementation of thyme and garlic extract at the rate of 0.3% and 0.6% has no impact on carcass characteristics in case of Cob 500 chicken (Amouzmehr *et al*., 2012). The tendency of difference in the head, wing and other parts might be due to the different percentage of MPBC applied and their associated secondary metabolites of the current study. Previous studies reported that, medicinal plant or their extract can affect carcass characteristics to some extent, while others have reported no impact on these characteristics (Osman *et al*., 2007; Narimani-Rad *et al*., 2011; Adam *et al*., 2020).

Atay (2023) reported that the addition of 0.5% medicinal and aromatic plants to broiler chicken diets had no significant effect on carcass or visceral organs weight; however, impacted on carcass yield. Result depicted that, among the internal organs head, wings, and other body parts (particularly the area associated with the backbone) were differed among dietary treatments in the current study. Supporting to the present findings, Tekeli *et al*. (2006) reported that, internal organs and

Table 2. Effect of byproduct combinations of medicinal plant on internal organ weight of broiler chicken (% of Live weight)

Parameters	Dietary treatments				SEM	P-value
	MPBC0	MPBC1	MPBC2	MPBC3		
Crop	0.68	0.56	0.41	0.46	0.060	0.120
Proventriculus	0.55	0.53	0.46	0.46	0.060	0.570
Gizzard	1.64^{a}	1.80^{a}	1.68^{a}	1.17^{b}	0.064	0.001
Pancreas	0.22	0.24	0.19	0.22	0.014	0.146
Small intestine	6.66^{a}	5.70^{b}	5.75^{b}	6.40^{a}	0.173	0.008
Large intestine	0.26	0.19	0.23	0.22	0.024	0.378
Caecum	0.81^{ab}	0.63^{bc}	0.84^{a}	0.55^{c}	0.049	0.014
Heart	0.54^{a}	0.31^{c}	0.44^{b}	0.41^{b}	0.019	<0.0001
Liver	2.18	2.18	1.98	2.18	0.082	0.460
Gall bladder	0.07	0.06	0.05	0.06	0.012	0.701
Spleen	0.14^{a}	0.11^{ab}	0.08^{b}	0.14^{ab}	0.016	0.103
Kidney	0.75^{a}	0.57^{b}	0.62^{b}	0.55^{b}	0.035	0.010
Bursa	0.26^{a}	0.14^{b}	0.19^{b}	0.16^{b}	0.023	0.016

^{abc}Means that have distinct superscripts in the same row exhibit significant differences ($P<0.05$) and tendency ($P<0.10$). SEM: Standard error of mean. Dietary treatments: 1) MPBC0: Control (basal diet without combinations of medicinal plant byproducts); 2) MPBC1: Basal diet plus 0.2% combinations of medicinal plant byproducts; 3) MPBC2: Basal diet plus 0.4% combinations of medicinal plant byproducts; 4) MPBC3: Basal diet plus 0.6% combinations of medicinal plant byproducts.

Table 3. Effect of byproduct combinations of medicinal plant on meat chemical composition of broiler chicken

Parameters	Dietary treatments				SEM	P-value
	MPBC0	MPBC1	MPBC2	MPBC3		
Moisture (%)	74.98^{ab}	74.78^{ab}	75.96^{a}	74.51^{b}	0.427	0.146
Crude ash (%)	1.08^{b}	1.10^{b}	1.10^{b}	1.15^{a}	0.014	0.023
Crude fat %	4.57^{a}	4.23^{a}	3.50^{a}	3.71^{a}	0.318	0.200
Crude protein %	21.71^{b}	21.37^{b}	22.18^{ab}	23.55^{a}	0.495	0.074

^{abc}Means that have distinct superscripts in the same row exhibit significant differences (P<0.05) and tendency (P<0.10). SEM: Standard error of mean. Dietary treatments: 1) MPBC0: Control (basal diet without combinations of medicinal plant byproducts); 2) MPBC1: Basal diet plus 0.2% combinations of medicinal plant byproducts; 3) MPBC2: Basal diet plus 0.4% combinations of medicinal plant byproducts; 4) MPBC3: Basal diet plus 0.6% combinations of medicinal plant byproducts.

digestive tract can be differed due to supplementation of medicinal plant (*Yucca schidigera, Oreganum vulgare, Thymus vulgaris, Syzigium aromaticum* and *Zingiber officinale*).

Meat chemical composition

In general, the diet, age, genetics, sexual maturity, care, and environmental circumstances of the source animal will determine the meat's approximate composition and nutritional value. Higher crude protein content in the meat is the indicator of superior meat quality. In the current study, crude protein content tended to be elevated in the MPBC2 and MPBC3 group as compared to no addition of MPBC. Consistently, previous research findings also depicted that *Mentha arvensis* and *Geranium thunbergii* plant extract supplementation was linked to a greater crude protein level of leg meat compared to the control group in case of broiler (Yang *et al*., 2020). When garlic, red pepper, and black pepper were added to the diet, the protein content of the chicken flesh significantly improved (Puvača *et al*., 2015). This may be the case because oxidation of animal muscles, which degrades meat's nutritional value and organoleptic features, is the main driver of meat quality degradation (Insani *et al*., 2008). *Mentha arvensis* and *Geranium thunbergii* contain phenolics that can halt these processes and improve the quality of the meat.

It was postulated that, birds treated with *Mentha arvensis* and *Geranium thunbergii* influenced on elevation of crude protein and crude fat content while

Table 4. Effect of byproduct combinations of medicinal plant on sensory attributes of broiler chicken

Parameters	Dietary treatments				SEM	P-value
	MPBC0	MPBC1	MPBC2	MPBC3		
Color	5.88^{b}	5.88^{b}	6.50^{ab}	7.00^{a}	0.277	0.026
Flavor	4.88^{b}	6.38^{a}	6.00^{a}	5.62^{ab}	0.345	0.036
Tenderness	6.62^{a}	6.62^{a}	5.62^{a}	6.38^{a}	0.316	0.145
Juiciness	6.62^{a}	6.50^{a}	6.00^{a}	6.50^{a}	0.390	0.684
Palatability	5.38^{a}	6.12^{a}	6.38^{a}	6.26^{a}	0.343	0.186
Overall acceptability	5.88^{b}	6.26^{ab}	6.88^{ab}	7.16^{a}	0.328	0.041

^{abc}Means that have distinct superscripts in the same row exhibit significant differences (P<0.05) and tendency (P<0.10). SEM: Standard error of mean. Dietary treatments: 1) MPBC0: Control (basal diet without combinations of medicinal plant byproducts); 2) MPBC1: Basal diet plus 0.2% combinations of medicinal plant byproducts; 3) MPBC2: Basal diet plus 0.4% combinations of medicinal plant byproducts; 4) MPBC3: Basal diet plus 0.6% combinations of medicinal plant byproducts.

suppressed the moisture content (Yang *et al*., 2020). Osman *et al*. (2007) stated that, moisture and ash content can be influences by medicinal plant (Eucalyptus, Pamegranate, Tilia and Thyme) supplementation with 0.2% inclusion level. Inconsistent to the current findings, the results of Gardzielewska *et al*. (2003) depicted that, echinacea (*Echinacea purpurea*), ginger (*Zingiber officinale*), and garlic (*Allium sativum*) to broiler chicken diets did not influence the meat's moisture content. Medicinal plant byproducts can improve intestinal health and general physiology in broilers, resulting in greater water uptake and retention (Tashla *et al*., 2020).

The considerable rise in crude ash level in MPBC3 could be attributed to the greater mineral content of medicinal plant byproducts. Aloe vera, Camellia sinensis, and Phyllanthus emblica may provide vital minerals such as calcium, phosphorus, and magnesium, which contribute to the ash level (De Ancos *et al*., 2015; Egbuna *et al*., 2022; Solaberrieta *et al*., 2022). Higher concentrations of crude protein content in case of medicinal plant byproducts group may offer extra amino acids required for protein synthesis. The secondary metabolites may influence in the protein translation in the medicinal byproduct added group. Medicinal plant as well as their byproducts contain bioactive compounds and amino acids (Abdallah *et al*., 2019; Galali *et al*., 2020). Aloe vera, Camellia sinensis, and Phyllanthus emblica and their byproducts contain a range of amino acids, namely lysin, threonine, valine, isoleucine, arginine, glutamine, leucine, valine, arginine that are critical for protein synthesis, might be attributable to the muscle growth, composition and overall health in broiler chickens (Kumar & Pandey, 2013; Abdallah *et al*., 2019).

Sensory evaluation of meat

From the consumer's perspective, the most important elements for a satisfying meal are tenderness, flavor, and juiciness (Saha *et al*., 2009). Supplementation of *Mentha arvensis* and *Geranium thunbergii* to broiler chicken diets upgraded the flavor, texture, juiciness, palatability and overall acceptability of the meat (Yang *et al*., 2020). To some extent, research findings explored that, addition of natural antioxidants to lamb, pigs, and chickens show different types of results, such as neutral effect, positive or negative impact on the meat's sensory traits (Chaves *et al*., 2008). Furthermore, Džinić *et al*. (2015) demonstrated that adding 2% garlic to poultry feed resulted in the meat developing a distinctively strong taste and aroma. Depending on the preferences of the consumer, this flavor attribute may be either beneficial or undesirable. Conversely, the use of plant extracts in this study resulted in an overall improvement in meat quality features without any unusual smell.

The MPBC3 group exhibited a significantly higher color score than MPBC0 and MPBC1, with MPBC2 being intermediate. The higher color score in MPBC3 could be due to the higher concentration (0.6%) of medicinal plant byproducts, which may contain pigments or compounds enhancing meat coloration. Medicinal plants like Curcumin from turmeric (*Curcuma longa*), Allicin from garlic (*Allium sativum*) and Flavonoids from green tea (*Camellia sinensis*) often have bioactive compounds that influence the deposition of pigments in the meat, leading to a more appealing color (Wang *et al*., 2017). MPBC1 and MPBC2 had significantly higher flavor scores than MPBC0, with MPBC3 being intermediate. The improved flavor in MPBC1 and MPBC2 could be attributed to the presence of phytochemicals in the medicinal plants, which might enhance the flavor profile of the meat. However, intermediate flavor score for MPBC3 is not clear, warrants further detail study on function of specific bioactive agents derived from the medicinal plant byproducts. Types of bioactive compounds derived from medicinal plants or their byproducts can influence lipid oxidation and the overall sensory attributes, resulting in a better flavor.

Polyphenols in Green tea have strong antioxidant properties that reduce lipid oxidation, enhancing the stability and shelf life of meat. They also contribute to flavor through their influence on oxidative processes and microbial activity. Tanin in *Phyllanthus emblica* and Curcumin in Turmeric (*Curcuma longa*) acts as a potent antioxidant, reducing lipid oxidation and improving meat color and flavor (Luciano *et al*., 2009; Jakubczyk *et al*., 2020). It also provides a distinct color and flavor, which can enhance the visual and sensory appeal of meat. Allicin in Garlic has antimicrobial and antioxidant properties, which help preserve meat quality and flavor by inhibiting spoilage and oxidative rancidity (Wang *et al*., 2017). MPBC3 had a significantly higher overall acceptability score than MPBC0, where MPBC1 and MPBC2 were intermediate. The higher overall acceptability in MPBC3 is likely due to the combined effects of improved color and flavor. Consumers generally prefer meat that is visually appealing and has a desirable color and flavor, which can enhance through antioxidant properties and bioactive compound of medicinal plant or their byproducts, especially the catechin in the *Camelia sinensis* (Luciano *et al*., 2009; Mustafa, 2013; Wu *et al*., 2019; Jakubczyk *et al*., 2020).

Conclusion

Byproducts derived from medicinal plants (MPB) *Phylanthus emblica, Aloe vera* and *Camelia Sinensis* could ensure better meat composition and sensory attributes with a few changes on the carcass traits and internal organ weight. Therefore, MPB demonstrating the promising potential as natural source for sustainable poultry industry especially for broiler production to avoid utilization of synthetic growth promoters.

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Conflict of interest

Authors declare no conflict of interest regarding this research and publication.

Author contributions

Conceptualization, A.B.M.R.B, M.R.I.K.; methodology, A.B.M.R.B.; software, A.B.M.R.B., M.D.H.; validation, A.B.M.R.B.; resources, A.B.M.R.B., M.D.H., M.R.H.; data curation, A.B.M.R.B., M.D.H.; writing—preparation of the initial draft, A.B.M.R.B.; writing, review and editing, A.B.M.R.B., M.D.H., A.S.M.S., M.R.H., M.R.I.K.; visualization, A.B.M.R.B.; supervision, A.B.M.R.B.; project administration, A.B.M.R.B.; revenue acquisition, A.B.M.R.B. All authors have reviewed the manuscript in its current form and given their approval.

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