

Carcass and meat quality of broiler chickens reared on herb residues

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ABSTRACT

This study was conducted to determine the effects of herb residues on carcass and meat quality in broilers. A total of 160 chicks were divided into four groups, each with four replicates of 10 chicks; the chicks were provided *ad libitum* access to a control diet or the same diet supplemented with *Zingiber cassumunar*, *Kaempferia galangal*, or *Curcuma aromatica* residues at 0.3% feed. At 42 days of age, 20 chicks from each group were slaughtered, and the carcass and meat quality were determined. All experimental groups demonstrated lower abdominal fat weight, and the *K. galangal* group had a significantly higher total visceral organ weight than that of the control group ($P < 0.05$). The experimental groups demonstrated improved color of the breast muscle, breast fillet muscle, skin, and abdominal fat ($P < 0.05$). The shear force value of the breast muscle increased in the *K. galangal* group, whereas that of the thigh muscle increased in all experimental groups ($P < 0.05$). The highest overall acceptability of raw and cooked chicken breast meat was produced by 0.3% *C. aromatica* residue supplementation ($P < 0.05$). These findings suggest that the inclusion of 0.3% *C. aromatica* residue in the diets resulted in improved overall acceptability of breast meat without negatively affecting dressing percentage.

Keywords: Carcass, meat quality, broiler chickens, herb residues, *Curcuma aromatic*

INTRODUCTION

Chicken is a major protein food source for humans, and broiler chickens are the most important poultry (Choi *et al.*, 2015). It is well known, feed expenditure makes up a considerable percentage of the cost of livestock production. Therefore, in recent years, nonconventional feedstuff has been investigated for poultry diets

(Sugiharto *et al.*, 2018)). Many phytogetic sources have been investigated as alternatives to chemical antibiotics for poultry and livestock (Hashemi and Davoodi, 2010). A growing number of scientific publications have focused on phytogetic feed additives for the poultry industry since the prohibition of antibiotics as growth promoters in 1999 (Islam, 2018). Herbs can be used extensively to feed broiler chickens without

Table 1. Curcumin of herb residues

Active ingredients	<i>Zingiber cassumunar</i> residue	<i>Kaempferia galangal</i> residue	<i>Curcuma aromatica</i> residue
Curcumin (% w/w)	0.30	0.02	0.79

Table 2. Chemical composition of herb residues^a

Chemical analysis	<i>Zingiber cassumunar</i> residue	<i>Kaempferia galangal</i> residue	<i>Curcuma aromatica</i> residue
Dry matter (g/kg)	996.7	930.3	897.4
Crude protein (g/kg)	96.6	64.0	52.7
Crude fiber (g/kg)	15.6	23.1	2.2
Crude fat (g/kg)	27.5	23.2	14.9
Crude ash (g/kg)	58.2	76.8	27.6
Gross energy (MJ/kg)	17.94	16.84	17.91

^a Dry matter.

causing a detrimental effect on growth performance (Borazjanizadeh *et al.*, 2011). The key mode of action of herbs can be attributed predominantly to the maintenance of feed hygiene and to the beneficial effects on the gastrointestinal microbiota through the regulation of pathogens (An *et al.*, 2019), stimulation of immune responses, appetite and feed intake, improvement of digestive enzyme secretion, and antibacterial, antiviral, and antioxidant activities (Hosseini-Vashan *et al.*, 2012).

A study by Lokaewmanee *et al.* (2020) demonstrated that a diet with 3 g/kg *Curcuma aromatica* (CA) residues from herbal medicine processing improved the feed efficiency and productive index in broiler chickens owing to increased body weight gain. *Curcuma aromatica* could be due to their essential oils and their main component, which stimulates the digestive process in animals (Daneshyar, 2012). Widiastuti *et al.* (2019) found an increase in carcass yield in a group fed turmeric (*Curcuma domestica*) compared to the control. Much attention in recent years has been focus on herbs which were used traditionally for centuries to improve the sensory characteristics (Daneshyar, 2012). There are no reports on the effect of dietary herb residues on the carcass or meat quality of broiler chickens. Thus, this study aimed to investigate the effects of different herb residue dietary supplements on the carcass, meat quality and organoleptic study of broiler meat.

MATERIALS AND METHODS

Preparation of Herb Residues

The herb residues were collected from the Laboratory of Chemistry, Department of Science, Faculty of Science and Engineering, Kasetsart University Chalermprakiat Sakon Nakhon Province Campus, Thailand. *Zingiber cassumunar* (ZC), *Kaempferia galangal* (KG), and CA extracts were produced by extraction with 95% ethyl alcohol and evaporation using a rotary vacuum evaporator. Essential oils from the solvent extracts were used for cosmetics, whereas all herb residues were dried for 1 day in an oven at 65°C and then ground and passed through a 2-mm sieve. Active ingredients in the herb residues, determined using a gas chromatography-mass spectrometry system from the Central Laboratory (Thailand) Company Limited, Thailand, are shown in Table 1. The dry matter, crude protein, crude fiber, crude fat, crude ash, and gross energy contents of the herb residues were determined using standard methods according to the Association of Official Analytical Chemists are shown in Table 2. The herb residues were stored in plastic bags at ambient temperature before being mixed into the feed.

Birds and Experimental Design

The animal protocols were approved by the Animal Care and Use Committee of Kasetsart University, Thailand (Certificate of Approved ID: ACKU64-CSC-002). The experiment was performed using 160 individual broilers (Ross 308 strain), divided into four treatment groups with four replicates of 10 birds each. A corn- and

soy- Table 3. Ingredients and nutrient composition of the starter diet and grower diet

Ingredient	Starter diet (7–21 days)	Grower diet (22–42 days)
Maize	513	620
Soybean meal	328	250
Fish meal	61	34
Rice bran oil	64	63
Oyster shell	11	11
Dicalcium phosphate	9	8
Salt	4	4
DL-methionine	2	2
Concentrate mixture ^a	8	8
Nutrient composition (g/kg)		
Crude protein	230	200
Crude fiber	40	40
Crude fat	40	60
Calcium	10	8
Available phosphorus	5	4
Metabolizable energy (g/kg)	13.40	13.40

^aConcentrate mixture included (per kg of diet): trans-retinyl acetate 12 000 IU, cholecalciferol 2000 IU, DL- α -tocopheryl acetate 12 IU, menadione 1.50 mg, thiamine 1.50 mg, riboflavin 4 mg, pyridoxine 2 mg, cyanocobalamine 15 μ g, biotin 0.30 mg, pantothenic acid 10 mg, folic acid 0.5 mg, nicotinic acid 60 mg, copper 6 mg, manganese 60 mg, zinc 60 mg, iron 20 mg, preservative 6.25 mg, and feed supplement 25 mg.

bean-based diet (Table 3) formulated to meet nutrient requirements was provided unmodified to the control group. In the ZC, KG, and CA groups, a diet containing 0.3% of the respective residue was provided. The herb residues were first mixed with a premixture, then with the other dietary ingredients, and stored in plastic bags before feeding. The experimental diets were prepared daily. The diet was offered to the broiler chickens twice daily *ad libitum*, and all birds had free access to water. The light cycle consisted of constant light, and the birds were reared in open-sided houses, with the temperature maintained at 33°C during the rainy season in northeastern Thailand.

Carcass and Meat Quality Measurements

At 42 days of age, 20 chicks from each treatment group (five birds/replicate) were selected randomly, marked, and slaughtered by decapitation under light anesthesia with diethyl ether. The head, viscera, and shanks were removed. The carcass was rested for 1 h to remove excess water and then weighed. The breasts, wings, thighs, and drumsticks were removed and then weighed individually. The visceral organs were excised carefully and weighed individually. The total abdominal fat content was also deter-

mined.

Color Measurement

Color measurements were performed at 24 h postmortem, using a CR-310 Chroma Meter (Minolta, Osaka, Japan). The instrument was calibrated on the CIE LAB color space system using a white calibration plate (Calibration Plate CR-A43, Minolta). The colorimeter used D65 illuminant, with a standard observer position of 10° and a 1-cm-diameter aperture. The color was determined by the three following parameters: L*: lightness (value between 0=black and 100=white), b*: redness (<0=green, >0=red) and b*: yellowness (<0=blue, >0=yellow). Color measurements were taken at three locations on each sample and then averaged. Averages for the meat surface, skin, and abdominal fat were used for statistical analyses.

Drip Loss

Fresh samples from the breast muscle at day 0 were individually weighed and recorded as the initial weight (W1). The samples were then sealed in polyethylene plastic bags, vacuum-packaged, and refrigerated at 4°C. After 1, 3, 5, and 7 days of storage, the samples were removed from the bags, gently blotted dry, and weighed

(recorded as W2, the final weight). The drip loss was calculated as the percentage difference from the initial weight. The sample weight after 1 and 7 days of storage was divided by the initial sample weight using the following equation: drip loss (%) = $100 \times \{(W1-W2)/W1\}$ (Wang *et al.*, 2015).

Cooking Loss

Sample cooking and preparation were carried out using a modified version of the method described by Abdullah *et al.* (2010). After 1, 3, 5, and 7 days of storage at -18°C, chicken breast samples were weighed (W1) and defrosted from -18°C overnight to 4°C, then rested at room temperature (25°C) for approximately 1 h before cooking. Each breast was heated at 95°C for 3-5 min to a core temperature of approximately 75°C. Temperature probes were used to monitor the internal temperature. The sample was then lightly blotted dry and weighed (W2). Cooking loss was calculated according to the following formula: cooking loss (%) = $100 \times \{(W1-W2)/W1\}$ (Zhang *et al.*, 2015).

Shear Force

The procedure described by Malovrh *et al.* (2009) was used to determine the shear force across the muscle fibers using a TA.XT Plus Texture analyzer apparatus (Stable Micro Systems, Surrey, UK) fitted with a 25-kg load cell. A TA-7 Warner-Bratzler shear-type blade was used. The chicken breast meat was cut into slices

2.5 cm thick and 2.5 cm wide. The speed of the blade was 2 mm/s and the passage of the blade through the sample slice was 25 mm. Shear force data were collected and analyzed to obtain the maximum force required to shear through the sample.

Sensory Analysis

The procedure described by Lokaewmanee and Promdee (2018) was used for sensory analysis. Sensory analysis (n=30) was conducted to evaluate the acceptability of chicken breast meat from broilers fed diets with or without herb residues. Panelists consisted of students, staff, and faculty of the Kasetsart University Chulalongkornrajavidyalaya University Sakon Nakhon province campus. Chicken breasts were thawed at 2°C-4°C for 24 h before sensory testing and cooked to an internal temperature of 75°C-77°C. Cooked breasts were then cooled at room temperature for 15 min, cut into 2.5-cm cubes, and kept warm (60°C-70°C) until the panel evaluation. Random three-digit numbers were assigned to identify the samples. The sample order was randomized to address sampling order bias. Water and unsalted crackers were provided, and the panelists were asked to expectorate and rinse their mouths between samples. Each panelist was asked to evaluate the chicken breast samples for color, flavor, odor, taste, and overall acceptability.

Statistical Analysis

All data collected were subjected to one-

Table 4. Effects of residue from herbal medicine processing on broiler carcass quality (7-49 days of age; mean±SE)

	Diet treatments				SEM	p-Value
	Control	ZC	KG	CA		
Dressing (%)	85.23	83.71	84.23	84.46	0.37	ns
Breast weight (% BW)	33.34	32.98	31.39	33.15	0.29	ns
Wing weight with bone (% BW)	10.76	10.75	10.65	10.63	0.08	ns
Thigh weight with bone (% BW)	18.19	18.28	17.16	17.53	0.18	ns
Drumstick weight with bone (% BW)	13.60 ^b	14.29 ^a	13.79 ^{ab}	14.20 ^a	0.09	*
Abdominal fat weight (% BW)	2.26 ^a	1.79 ^b	1.57 ^b	1.61 ^b	0.07	**
Total visceral organ weight (% BW)	9.38 ^c	9.94 ^c	12.89 ^a	10.31 ^b	0.25	*

Control group, basal diet; ZC, KG, and CA groups, basal diet containing 3 g/kg *Zingiber cassumunar*, *Kaempferia galangal*, or *Curcuma aromatica* residue, respectively; **= highly significant (P<0.01); *= significant (P<0.05); ns= not significant (P>0.05)

way analysis of variance according to the procedure by Steel and Torrie (Steel and Torrie, 1980). Significantly different means were determined according to the Duncan method (Duncan, 1955). Differences between means were analyzed at a significance level of 0.05 using Tukey's test. The results of the statistical analyses are shown as the mean±SE. The statistical model formula was: $Y_{ij} = \mu + T_i + e_{ij}$ where Y_{ij} = observation in the j^{th} , μ = general mean, T_i = fixed kinds of herb residue effects and e_{ij} = random error component in the (i-j)th unit. Significant was set at P-value<0.05.

RESULTS AND DISCUSSION

Carcass Quality

The dressing percentage and the weight of the breast, wings, and thighs were not significantly different among the groups, except for the drumstick weight with bone, which was significantly higher in the ZC and CA groups (Table 4; P<0.05). The ZC, KG, and CA groups displayed a lower abdominal fat weight, whereas the KG group had significantly increased total visceral organ weight (Table 3; P<0.05). The objective of current study was to determine whether herb residues added to the diet of broiler chickens would improve the carcass and meat quality. For

phytogenic sources, the mechanism for growth promotion has not been investigated thoroughly, but based on previous research (Molette *et al.* 2003; Chen *et al.* 2017; Revathi and Malathy, 2013); the effect is probably due to antioxidant activity. Among these natural antioxidant sources, the rhizomes of the plant family *Zingiberaceae* contain a chain-breaking antioxidants and efficiently protect animals against oxidation stress-induced damage (Sahin *et al.*, 2012). ZC, KG, and CA are all members of *Zingiberaceae* (Kumar *et al.*, 2013). In this study, the significantly higher drumstick and total visceral organ weight observed in the broilers fed herb residues may have had a positive effect on body weight gain. Our previous study indicated that ZC, KG, and CA residues significantly increased body weight gain and average daily gain Lokaewmanee *et al.* (2020). Dietary herb supplements have received widespread attention because of concerns about the safety of synthetic antioxidants and an increasing demand for natural and healthy food (Zhang *et al.*, 2015). In the present study, herb residue supplementation also enhanced the drumstick and total visceral organ weight. Curcumin, isolated from the rhizomes of *Zingiberaceae*, is the main bioactive ingredient and is an antioxidant (Karami *et al.*, 2011). Multiple studies have evaluated the effects of curcu-

Table 5. Effects of residue from herbal medicine processing on the color value of chicken breast muscle, breast fillet muscle, skin, and abdominal fat (mean±SE)

	Diet treatments				SEM	p-Value
	Control	ZC	KG	CA		
Breast						
Lightness (L*)	58.53 ^{bc}	56.92 ^c	60.59 ^b	61.99 ^a	0.55	**
Redness (a*)	1.20 ^b	2.55 ^a	1.63 ^{ab}	1.72 ^{ab}	0.16	*
Yellowness(b*)	2.85 ^b	5.81 ^a	3.96 ^b	5.45 ^a	0.25	**
Breast fillet						
Lightness (L*)	54.05 ^{ab}	52.43 ^b	54.14 ^{ab}	55.69 ^a	0.41	*
Redness (a*)	1.48 ^b	4.58 ^a	1.96 ^b	1.72 ^b	0.28	**
Yellowness(b*)	4.49	5.27	6.03	6.35	0.21	ns
Skin						
Lightness (L*)	68.83	70.21	69.25	69.56	0.41	ns
Redness (a*)	4.72 ^{ab}	3.67 ^b	4.28 ^b	5.85 ^a	0.26	*
Yellowness(b*)	19.23	20.09	17.76	19.70	0.45	ns
Abdominal fat						
Lightness (L*)	75.35 ^a	72.07 ^b	71.52 ^b	75.19 ^a	0.40	**
Redness (a*)	1.95 ^{ab}	1.11 ^b	3.06 ^a	2.30 ^{ab}	0.23	*
Yellowness(b*)	15.32 ^a	14.44 ^a	11.30 ^b	15.28 ^a	0.56	*

Control group, basal diet; ZC, KG, and CA groups, basal diet containing 3 g/kg *Zingiber cassumunar*, *Kaempferia galangal*, or *Curcuma aromatica* residue, respectively; **= highly significant (P<0.01); *= significant (P<0.05); ns= not significant (P>0.05)

Table 6. Effects of residue from herbal medicine processing on the shear force value of chicken breast and thigh muscle (mean±SE)

	Diet treatments				SEM	p-Value
	Control	ZC	KG	CA		
Breast	42.64 ^b	47.43 ^b	69.91 ^a	40.52 ^b	2.13	**
Thigh	87.76 ^b	108.70 ^a	119.65 ^a	108.70 ^a	4.07	*

Control group, basal diet; ZC, KG, and CA groups, basal diet containing 3 g/kg *Zingiber cassumunar*, *Kaempferia galangal*, or *Curcuma aromatica* residue, respectively; **= highly significant (P<0.01); *= significant (P<0.05)

Table 7. Effects of residue from herbal medicine processing on cooking loss and drip loss of chicken breast meat during 7-day postmortem storage (mean±SE)

	Diet treatments				SEM	p-Value
	Control	ZC	KG	CA		
Cooking loss (%)						
0	21.52	21.89	21.28	21.46	1.67	ns
1	17.24	17.42	17.13	18.23	1.39	ns
3	6.85	6.33	6.17	6.58	0.40	ns
5	4.76	4.89	4.44	4.73	0.40	ns
7	4.66	4.81	4.60	4.79	0.43	ns
Drip loss (%)						
1	2.53	2.36	1.90	3.21	0.28	ns
3	5.26	5.34	3.79	5.25	0.30	ns
5	6.97	6.87	5.41	7.40	0.37	ns
7	8.52	8.58	6.76	8.80	0.37	ns

Control group, basal diet; ZC, KG, and CA groups, basal diet containing 3 g/kg *Zingiber cassumunar*, *Kaempferia galangal*, or *Curcuma aromatica* residue, respectively; ns= not significant (P>0.05)

min on the performance of broiler chickens (Abou-Elkhair *et al.* (2014); Olukosi *et al.* (2014). It seems that the dietary herb residues increased the drumstick and total visceral organ weight. The beneficial effects related to composition and relationship between the gut microbiota and herbs. The gut microbiota can act as a functional barrier to prevent pathogens from invading organs and tissues and it plays an important role in immunity and maintenance of overall health (An *et al.*, 2019).

The ZC, KG, and CA groups had a lower abdominal fat weight than that of the control group. Abdominal fat in broilers is regarded as waste in the poultry industry because it represents a reduction in revenue and consumer acceptability and increases the cost of treating effluent from processing (Nouzarian *et al.*, 2011). Our results indicate that herb residue supplementation in the broiler diet has the potential to lessen this waste by reducing abdominal fat deposition. In accordance with our results, Emadi and Kermanshahi (2007) stated that broiler diet sup-

plementation with turmeric rhizome powder (5-7.5 g/kg of feed) reduced the abdominal fat content markedly. Similarly, Wang *et al.* reported that supplementation with turmeric rhizome extract (100-300 mg/kg of feed) reduced the abdominal fat ratio markedly (Wang *et al.*, 2015). Turmeric (*Curcuma longa*) is a tropical plant native to southern and southeastern tropical Asia (Sugiharto *et al.*, 2011), which is also included in *Zingiberaceae* with ZC, KG, and CA (Kumar *et al.*, 2013). The noted decrease in abdominal fat might be due to the influence of curcumin on adipocyte apoptosis withdrawing glucose from the blood, as reported by Sugiharto *et al.* (2011). The results of this study suggest that incorporating 0.3% ZC, KG, or CA residue into the broiler diet has a positive effect. These residues may help maintain a harmonious gut environment by enhancing nutrient balance and proper metabolism.

Meat Quality

Consumers are currently concerned about

Table 8. Effects of herb residue from herbal medicine processing on the sensory score of chicken fed with or without herb residue (mean \pm SE)

	Diet treatments				SEM	P-Value
	Control	ZC	KG	CA		
Raw chicken breast						
Meat color	3.48	2.72	3.08	3.28	0.10	ns
Skin color	2.36 ^c	3.64 ^a	3.04 ^b	3.28 ^{ab}	0.10	**
Odor	2.28 ^b	2.52 ^b	3.04 ^a	2.56 ^b	0.07	*
Overall acceptability	2.36 ^c	3.12 ^b	2.68 ^c	4.00 ^a	0.09	**
Cooked chicken breast						
Tenderness	3.76 ^a	3.44 ^a	2.84 ^b	2.92 ^b	0.08	**
Juiciness	2.52	3.04	2.84	2.64	0.07	ns
Taste	2.44 ^c	2.76 ^{bc}	2.96 ^{ab}	3.16 ^a	0.71	**
Flavor	2.16 ^c	2.76 ^b	3.00 ^{ab}	3.24 ^a	0.08	**
Herb odor	0.00 ^b	2.52 ^a	2.56 ^a	2.36 ^a	0.42	**
Overall acceptability	3.00 ^b	2.56 ^c	3.52 ^a	3.64 ^a	0.08	**

Control group, basal diet; ZC, KG, and CA groups, basal diet containing 3 g/kg *Zingiber cassumunar*, *Kaempferia galangal*, or *Curcuma aromatica* residue, respectively; **= highly significant (P<0.01); *= significant (P<0.05); ns= not significant (P>0.05)

Meat color: 1 = gray, 2 = grayish-yellow, 3 = pale yellow, 4 = quite yellow, 5 = pinkish-yellow. Skin color: 1 = grayish-yellow with green spots, 2 = grayish-yellow, 3 = pale yellowish-pink, 4 = quite yellowish-pink, 5 = yellowish-pink. Odor: 1 = off-odor, 2 = unpleasant, 3 = fair, 4 = good, 5 = pleasant. Overall acceptability: 1 = unacceptable, 2 = fair, 3 = good, 4 = pleasant, 5 = excellent. Tenderness: 1 = very tough, 2 = tough, 3 = fair, 4 = good, 5 = excellent. Juiciness: 1 = very dry, 2 = dry, 3 = fair, 4 = juicy, 5 = very juicy. Taste: 1 = unacceptable, 2 = quite unacceptable, 3 = fair, 4 = good, 5 = excellent. Flavor: 1 = unacceptable, 2 = quite unacceptable, 3 = fair, 4 = good, 5 = excellent. Herb odor: 1 = very strong, 2 = strong, 3 = fair, 4 = mild, 5 = none.

¹Control group, basal diet; ZC, KG, and CA groups, basal diet containing 3 g kg⁻¹ *Zingiber cassumunar*, *Kaempferia galangal*, or *Curcuma aromatica* residue, respectively.

meat quality and are demanding safer and healthier products (Bou *et al.*, 2009). In response to the demand for natural products, the meat and poultry industry is actively seeking natural products to increase the oxidative stability of meat and extend its shelf life (Karre *et al.*, 2013). There were no significant differences in the yellowness (b*) of the breast fillet or skin between treatments (P>0.05; Table 5). Regarding the color value of the breast muscle and abdominal fat, significant differences between treatments were observed (P<0.05; Table 5). Including herb residues in the diet resulted in a darker color (higher a* values), and samples from the 0.3% CA group exhibited the highest skin redness (a*) values. There are no published studies on the effect of dietary CA residue supplementation on raw meat color to compare with these findings. The color and appearance of fresh meat are seen as indicators of quality and freshness. Chicken muscle color is affected by a variety of factors including

age, environment, and feed. The color of raw muscle is due to the light-scattering properties and normally ranges from pink to red because of the muscle pigments hemoglobin and myoglobin (Haščik *et al.*, 2015). In this study, although supplementation with herb residues from the extracts improved the color of broiler meat, ZA residue increased the redness (a*) of the breast and breast fillet while CA residue increased the redness (a*) of the skin. Interestingly, this may indicate that adding 0.3% CA residue to feed modifies the skin color by increasing the redness (a*) and may modify the pigment distribution in the skin. Therefore, it seems that the beneficial effect of CA on skin redness is due to its own color. The abundance of activities of *Zingiberaceae* family is due to curcuminoids, which are yellow pigments found in its rhizomes (Liu *et al.*, 2019).

Supplementation with CA was expected to increase the redness of chicken skin because the herb residue contains α -curcuminoid (16.27%

area) and β -curcuminoid (28.14% area). Nishiyama *et al.* (2005) reported that dietary *C. longa* induced a color change. In contrast, Hang *et al.* (2018) supplemented the diet of broiler chickens with curcuminoids (20, 40, 60, and 80 mg/kg) and found no effects on the lightness or redness of chicken skin. The inconsistency in these results may have been caused by the harvest at different growth stages or the different forms of the supplements.

The Warner-Bratzler shear force results showed that the feed additives tested significantly improved the texture of the chicken breast and thigh meat (Table 6). An increase in the shear force value (decreased meat tenderness) was observed in the breast muscle samples with herb residue supplementation. According to Chen *et al.* (2007) tenderness is the most important factor in consumers' perception of palatability and quality of meat products. Therefore, this attribute has drawn much attention from researchers. Min *et al.* (2012) observed a significant difference between broilers fed distillers' dried grains in solubles and a control group, with respect to the shear force, which almost doubled (24.29-42.32 N) compared with that of the control (12.79 N). Similarly, dietary supplementation with ginger extract decreased the shear force value (increased tenderness) of buffalo meat (Abbood *et al.*, 2017). Schilling *et al.* (2010) found that low shear force values (15.1-16.3 N), which indicate very tender meat, would be highly acceptable to consumers. Surprisingly, in this study, KG was effective in increasing the shear force value of breast chicken meat, whereas ZC, KG, and CA were effective in increasing the shear force value of thigh chicken meat. Based on these results, it is suggested that a diet with herb residue can reduce the tenderness of thigh chicken meat owing to an increase in the shear force value.

There were no significance differences ($P>0.05$) between groups in cooking loss and drip loss for 1-7 days of postmortem storage (Table 7). The cooking loss and drip loss were not affected by the dietary group. Woelfel *et al.* (2002) reported a positive correlation between cooking loss and drip loss. The results of this study are in accordance with the previous work of Abbood *et al.* (2017) who demonstrated that the addition of the herb *Borreria latifolia* to broiler diets had no significant impact on drip loss. Moreover, including 60 g/kg of rapeseed meal in a turkey diet had no effect on the drip

loss (Mikulski *et al.*, 2012). Another study with broilers indicated that dietary supplementation with quercetin did not affect cooking loss (Golimytsi *et al.*, 2014). Ri *et al.* (2017) found no differences in cooking or drip loss in the breast muscle with oregano powder supplementation. Conversely, lower cooking loss in duck breast meat was found after feeding ducks a diet including dried oregano powder (Park *et al.* 2015) Zhang *et al.* (2011) indicated that dietary supplementation with oxidized oil increased drip loss in broilers.

The effects of dietary supplementation with residues from herbal medicine processing on the sensory scores of raw and cooked chicken breast of broiler chickens are presented in Table 8. No significant difference ($P>0.05$) was found between groups in meat color of the raw chicken breast or juiciness of the cooked chicken breast. However, significant differences between the dietary groups in skin color, odor, and overall acceptability of raw chicken breast were found ($P<0.05$). The highest scores for tenderness of the cooked chicken breast were noted in the control and ZC groups, whereas the highest score for taste and flavor was noted in the CA group. The highest score for herb odor of the cooked chicken breast was noted in the ZC, KG, and CA groups, whereas the highest score for overall acceptability was noted in the KG and CA groups. The results of the sensory evaluation test revealed that the addition of 0.3% CA had a significant influence on the overall acceptability of raw and cooked chicken breast, compared with that of the control group. This high score reflects more preference for the taste, flavor, and herb odor of the cooked chicken breast. These outcomes are concordant with the results of Jang *et al.* (2008), who observed that a medicinal herb extract mix enhanced the acceptability of meat. The monoterpenoids, sesquiterpenoids, and curcuminoids have antimicrobial, antifungal, and antioxidant activities (Revathi and Malathy, 2013). The increased overall acceptability of the CA group could be related to the antioxidant activity, which may have minimized protein and lipid oxidation to improve the meat quality. In the current study, 0.3% of CA residue increased the overall acceptability of raw and cooked chicken breast meat.

CONCLUSION

Dietary supplementation with 0.3% CA res-

idue had a positive impact on drumstick weight with bone, redness (a*) of the skin and yellowness (b*) of the breast and abdominal fat. CA residue increased the shear force value of the thigh, but decreased the tenderness of the cooked chicken breast. Supplementation with CA residue increased the overall acceptability of raw and cooked chicken breast meat. It seems that dietary supplementation of 0.3% CA residue improved overall acceptability of breast meat without negatively affecting dressing percentage.

CONFLICT OF INTEREST

All authors declare that they have no conflict of interest.

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