Effects of star anise (*Illicium verum* Hook. f) and its extractions on carcass traits, relative organ weight, intestinal development, and meat quality of broiler chickens

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ABSTRACT Star anise (*Illicium verum* Hook. f) has been used as spice and herbal medicine for many years with lacking researches on evaluating its application for improving relative organ weight, intestinal development, and quality of animal products. The experiment was conducted to investigate the effects of star anise, its essential oil and leavings on carcass traits, relative organ weight, intestinal development, and meat quality of broiler chickens. A total of 384 broilers were randomly assigned to 4 treatments with 8 replicates of 12 birds each. The 4 dietary treatments were basal diet (**Control**), basal diet supplemented with 5 g/kg star anise (**Star anise**), basal diet supplemented with 0.22 g/kg essential oil (**Essential oil**), and basal diet supplemented with 5 g/kg leavings (**Leavings**). The concentration of main active components in the experimental diets was 0.204 g trans-anethole/kg of diet. All birds were fed a starter diet (0–21 d) and a grower diet (22–42 d). Birds supplemented with star anise and essential oil had a greater ($P < 0.05$) final body weight (**BW**) than control birds and those supplemented with leavings. However, the carcass yield, half chamber rate, eviscerated rate, and percentages of breast muscle and thigh muscle in birds were similar ($P > 0.05$) among all treatments. Birds supplemented with star anise and essential oil had higher ($P = 0.010$) relative weight of thymus than those in control and leavings groups. Essential oil supplemented groups appeared to contain the highest ($P < 0.05$) villus height in ileum and villus height/crypt depth ratio in ileum and jejunum among all the groups. Meanwhile, among all the groups, breast muscles of essential oil–supplemented groups appeared to contain the lowest ($P = 0.012$) boiling loss but highest ($P < 0.001$) concentration of inosinic acid (inosine 5′-monophosphate, **IMP**). In conclusion, dietary supplementation of 5 g/kg star anise and 0.22 g/kg essential oil improved BW, relative organ weight, and intestinal development, and 0.22 g/kg essential oil can also increase the concentration of IMP but decrease the boiling loss in breast muscles of broilers; however, 5 g/kg leavings had no effect.

Key words: star anise, extractions, carcass trait, meat quality, inosinic acid

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INTRODUCTION

Broiler chicken is one of most widespread farm animals with over 90 billion tons of meat per year (Food and Agriculture Organization, 2017). Owing to the high demands of broiler meats by consumers, the intensive farming which produce large quantities of meat at lowest cost possible was being popular. However, birds are more susceptible to stresses such as infectious diseases and oxidative stress under modern intensification farming systems (Hangalapura et al., 2003). Increased stress and generation of free radicals are responsible for the development of various diseases and decreases in animal production and product quality, leading to greatly reduced efficiency and economic losses (Yang et al., 2019). Owing to the limitation of in-feed antimicrobials as growth promoters, it is necessary to explore feed additives with high efficacy to improve performance and minimize infections (Ren et al., 2018). The use of natural products containing bioactive components showed a promising approach in poultry industry (Alagawany et al., 2019; Khafaga et al., 2019; Reda et al., 2019). Thus, there is an increasing interest in phytogenic feed additives.

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Star anise (*Illicium verum* Hook.f.) has been widely used as spice and herbal medicine for many years in traditional Chinese. Its extractions contained trans-anethole (85–90%) as its main active ingredient and other compounds such as estragole and anisaldehyde (Ciftci et al., 2005; Wang et al., 2011; Ding et al., 2017). It is of note that star anise and its extractions are rich in the characteristic flavor as an aromatic plant (Wang et al., 2011). Star anise and its extracts are generally recognized as safe with antiparasitic, antibacterial, antioxidant, antifungal, and antipyretic properties (Ciftci et al., 2005; Soltan et al., 2008; Hong et al., 2012; Cho et al., 2014). The presences of abovementioned active compounds are responsible for reducing environmental stress and has been proved *in vivo* and *in vitro*. However, there are limited studies focused on the effects of dietary star anise and its extractions on relative organ weight, intestinal development, and quality of broilers' products. In view of this, the aim of this study was to evaluate parameters including the carcass traits, relative organ weight, intestinal development, and meat quality of broilers when fed diets containing star anise and its extractions.

MATERIALS AND METHODS

Star Anise (I. verum Hook. f) and its Extractions

Star anise (*I. verum* Hook. f) was purchased from a local market (Wuma market, Tai'an, China), and its essential oil was extracted using a traditional water steam distillation according to our previous studies (Ding et al., 2017). The remaining part of star anise powder which was collected after steam distillation was considered as leavings. The chemical composition of the materials was analyzed by gas-chromatographic based on Ding et al. (2017).

Birds and Experimental Design

The animal care protocol was approved by the Shandong Agricultural University Animal Care and Use Committee (Tai'an, China). The experiment was conducted using male Arbor Acres broiler chicks. A total of 384 broilers (male) were randomly assigned to 4 dietary treatments (8 cages per treatment; 12 birds per cage). The 4 treatments were basal diet (**Control**), basal diet supplemented with 5 g/kg star anise (**Star anise**), basal diet supplemented with 0.22 g/kg essential oil (**Essential oil**), and basal diet supplemented with 5 g/kg leavings (**Leavings**). To obtain a level of 0.204 g trans-anethole/kg of diet, the concentrations of effective components in diets were shown in Table 1. All birds were fed a starter diet (0–21 d) and a grower diet (22–42 d), and all diets (Table 2) were formulated to meet the National Research Council (1994). All birds were inspected daily, and mortalities were recorded.

Chickens were housed in an environmentally controlled room with feeders and nipple drinkers. Feed and water were available ad libitum. The temperature was maintained at 33°C which was then gradually reduced to 26°C at the rate of 3°C per wk and was maintained at this temperature to the end of the experiment. Overhead light was provided continuously for the entire period of experiment.

Growth Performance and Sample Collection

Birds were fed twice daily for ad libitum intake, and feed residue in each cage was weighed daily. Birds in each cage were weighted at day 1 and day 42 of the experiment before feeding to obtain body weight (**BW**). These data were used to calculate average daily gain (**ADG**), average daily feed intake (**ADFI**), and feed conversion rate.

At the end of the experiment (42 d of age), 2 birds per replication (16 birds per treatment) were randomly selected and weighed after 8 h fasting. The birds were then sacrificed by jugular bleeding. One bird per replication was scaled in a hot water bath (60°C for 2 min), and the feathers were removed mechanically after bleeding. The weight of carcass (including organs) was measured after defeathering to determine the carcass yield (including organs). The organs (except the hearts, livers, stomachs, lungs, and kidneys) were removed and weighted to determine the percentage of half chamber rate. Then heads, neck, feet, and organs (except the lungs and kidneys) were removed and weighted to determine the percentage of eviscerated yield. Organs (duodenum, jejunum, ileum, liver, spleen, thymus, and bursa of Fabricius) were isolated and measured to calculate the relative organ weight and intestinal length. The breast and thigh muscles were removed and weighed to determine the percentages of breast and leg muscle. Both breast and muscle were dissected into 2 parts for 1) determining intramuscular fat and inosinic acid (inosine 5′-monophosphate, **IMP**) and 2) analyzing meat quality parameters including pH value, meat color, water holding capacity, and shear force.

Duodenum, jejunum, and ileum in another bird per replication were immediately isolated from the surrounding fat and tissue. Parts of the small intestine were fixed promptly in Bouin's fluid for subsequent analysis of histological examination.

Carcass Traits

Carcass yields (including organs), half chamber rates, and eviscerated rates were calculated by dividing these traits by final live weight after fasting. The percentages of breast muscle and thigh muscle were calculated as a percentage of eviscerated weight.

Relative Organ Weights and Intestinal Lengths

The weights of organs and lengths of small intestines were recorded and then calculated using the following formula:

Table 1. Concentrations of effective components in the experimental diets[1], g/kg.

Items	Control	Star anise	Essential oil	Leavings
Trans-anethole	BD	0.204	0.204	BD
Estragole	BD	0.003	0.003	BD
Anisaldehyde	BD	0.002	0.002	BD

Abbreviation: BD, below detection.
[1]Control, basal diet; Star anise, Control +5 g/kg star anise; Essential oil, Control +0.22 g/kg essential oil; Leavings, Control +5 g/kg leavings.

Relative organ weight (g/kg) = organ weight (g)/live BW (kg); Relative intestinal length (cm/kg) = intestinal length (cm)/live BW (kg).

Histological Analysis

Sections of duodenum, jejunum, and ileum were dehydrated using graded alcohol concentrations as well as xylene after fixed in Bouin's fluid for 24 to 48 h and were subsequently embedded in paraffin. Meanwhile, 5 μm sections were cut on a Leica microtome (RM 2235, Germany), mounted on coated glass slides, and dried overnight at 37°C. Then the samples were dewaxed and rehydrated using xylene and graded alcohol concentrations before being stained with hematoxylin and eosin. Sections were dehydrated and cleared with xylene, then sealed in clear resin.

The measurements were performed with an optical microscope using DigiLab-C software. Six points were selected for microscopical investigation of villus height and cryptal depth on each slice. Villus height was measured from the tip of villus to the crypt opening, and the crypt depth was measured from the base of the crypt to the level of the crypt opening. The villus height/crypt depth (**V/C**) ratio was calculated using the following formula (Choi et al., 2011; Du et al., 2016):

The V/C ratio (μm/μm) = villus height (μm)/crypt depth (μm).

Table 2. Ingredients and nutrient compositions of experimental diets.

Items	Starter 0 to 21 d	Grower 22 to 42 d
Ingredients, %		
Corn	58.40	63.09
Soybean meal	35.40	29.50
Soy oil	2.20	3.48
Limestone	1.62	1.98
Calcium hydrogen phosphate	1.28	0.90
Sodium chloride	0.23	0.23
Choline chloride	0.09	0.09
DL-Methionine	0.28	0.25
Lysine	0.10	0.08
Premix[1]	0.40	0.40
Chemical composition[2]		
Metabolizable energy, kcal/kg	3,229	3,298
Crude protein, %	21.92	19.91
Calcium, %	1.12	0.93
Available phosphorus, %	0.48	0.35
Lysine, %	1.23	1.07
Methionine, %	0.49	0.38

[1]Supplied per kilogram of diet: vitamin A, 8,050 IU; cholecalciferol, 3,000 IU; vitamin E, 30 mg; vitamin K3, 5 mg; thiamin, 2.58 mg; riboflavin, 12.5 mg; choline chloride, 800 mg; calcium pantothenate, 13 mg; niacin, 45 mg; biotin, 0.20 mg; folic acid, 1.20 mg; Mn, 100 mg; Fe, 80 mg; Zn, 58 mg; Cu, 8.8 mg; Se, 0.28 mg.
[2]The chemical composition of the diets was determined according to AOAC (1990) methods except metabolizable energy and available phosphorus, which were calculated values. They were calculated according to "feed description and proximate composition" in Feeding standard of chicken (People's Republic of China, NY/T 33-2004).

Meat Quality

The pH values of the breast and thigh muscles was determined using a pH meter (PH5+, Tenovo International Co., Ltd., Beijing, China) equipped with an insertion electrode.

The meat color parameters (L* = Lightness, a* = redness, and b* = yellowness) were determined by an Easy-to-use Color Reader (CR-10, KonicaMinolta, Tokyo, Japan).

The water-holding capacity was reported as drip loss and boiling loss using procedure described by Yang et al. (2010) and were calculated using the following formula:

Drip loss (%) = [(initial weight–final weight)/initial weight] × 100%;

Boiling loss (%) = [(raw weight–cooked weight)/raw weight] × 100%

Shear force was determined using a texture analyzer (C-LM3B, Tenovo International Co., Ltd., Beijing, China) and was expressed in N. It was measured perpendicular to the axis of muscle fibers in 6 replicates for each treatment.

The intramuscular fat of muscles was analyzed by the official methods of Association of Official Analytical Chemists (AOAC, 1990), expressed as a percentage of fresh muscle weight.

Concentration of IMP

The flavor trait was analyzed by determining IMP concentration in the preprocessing of breast muscle according to the procedure described by Zhang et al. (2008). The obtained solution was filtered through a 0.45-nm membrane filter before being used for a high-performance liquid chromatography (Waters 515, Milford, MA) analysis. The mixture of 8% methanol and 92% phosphoric acid solution of 0.5% concentration (V/V) was applied as mobile phase. The flow rate was 1.0 mL/min. Detection was performed at a wavelength of 254 nm with the column (250 mm × 4.6 mm) maintained at a constant temperature (30°C).

Statistical Analyses

This experiment was designed as a complete random design, and cages were considered as experimental unit. All the parameters were analyzed by the general linear model procedure followed by Duncan's multiple ranges test of SAS software (version 8.2, SAS Institute Inc., Cary, NC). The level of significant difference was set at $P < 0.05$.

Table 3. Effects of star anise, essential oil, and leavings on growth performance of broilers.[1]

Items	Control	Star anise	Essential oil	Leavings	SEM	*P*-value
Final body weight, g	2,451.4[c]	2,505.9[a,b]	2,541.3[a]	2,455.2[b,c]	17.528	0.004
Average daily gain, g/d	57.5[b]	58.7[a,b]	59.6[a]	57.5[b]	0.543	0.032
Average daily feed intake, g/d	102.2[b]	104.7[a,b]	106.2[a]	101.9[b]	0.966	0.014
Feed:gain, g:g	1.779	1.783	1.782	1.771	0.021	0.974

[a-c]Means within a row with different letters differ significantly ($P < 0.05$).
[1]Data are means for 8 replicates per treatment.

RESULTS

Growth Performance

All birds performed healthy, and no mortality was detected throughout the entire experimental period. Birds supplemented with star anise and essential oil had a greater BW at day 42 ($P < 0.05$) than control birds and those supplemented with leavings. Additionally, birds supplemented with essential oil also had greater ADG and ADFI during the entire experimental period ($P < 0.05$) compared with those in the Control and Leavings (Table 3).

Carcass Traits

Supplementation of essential oil significantly increased ($P < 0.05$) the carcass weight and thigh muscle weight and tended to increase ($0.05 < P < 0.1$) the half chamber weight and eviscerated weight of birds compared with the Control (Table 4). However, there was no observed significant ($P > 0.05$) differences of the carcass yield (including organs), half chamber rate, eviscerated rate, and percentages of breast and thigh muscle in birds among all treatments.

Relative Organ Weights and Intestinal Lengths

Birds supplemented with star anise and essential oil had higher ($P = 0.010$) relative weight of thymus than those in Control and Leavings. However, the relative weights and lengths of duodenum, jejunum, and ileum and the relative weights of liver and bursa of Fabricius in birds were similar ($P > 0.05$) among all treatments (Table 5). Birds fed star anise and essential oil showed increased ($P = 0.020$) relative weight of spleen as compared with those in Control and Leavings.

Intestinal Histology

Birds supplemented with star anise and essential oil had higher ($P < 0.05$) villus height and V/C ratio in jejunum than those in Control and Leavings (Table 6). Among all the groups, essential oil-supplemented groups appeared to contain the highest ($P < 0.05$) villus height in ileum and V/C ratio in ileum and jejunum. In contrast, the crypt depth in duodenum of birds was lowest ($P = 0.002$) among all the groups.

Meat Quality

No significant differences of pH, meat color, shear force, and intramuscular fat were detected on breast and thigh muscle among the treatments in broilers (Table 7). However, birds fed essential oil showed lowest ($P < 0.05$) boiling loss in breast muscle and drip loss in thigh muscle among all the groups.

Concentration of IMP

Birds supplemented with essential oil obtained highest ($P < 0.001$) concentration of IMP among all the groups (Figure 1). However, supplementation of star anise and its leavings has no significant effects ($P > 0.05$) on the concentration of IMP in birds as compared with those in Control.

Table 4. Effects of star anise, essential oil, and leavings on carcass traits of broilers.[1]

Items	Control	Star anise	Essential oil	Leavings	SEM	*P*-value
Live weight, g	2,425.6[b]	2,480.5[a]	2,485.9[a]	2,429.6[b]	19.033	0.026
Carcass weight (including organs), g	2,255.8[b]	2,309.3[a]	2,319.3[a]	2,257.1[b]	18.332	0.005
Half chamber weight, g	2,105.4	2,150.6	2,155.3	2,116.2	19.567	0.056
Eviscerated weight, g	1,688.2	1,733.9	1,752.6	1,698.3	25.116	0.093
Breast muscle weight, g	479.3	491.9	494.7	482.7	13.959	0.703
Thigh muscle weight, g	364.7[b]	376.6[a,b]	382.4[a]	364.1[b]	7.656	0.042
Carcass yield (including organs), %	93.00	93.10	93.30	92.90	0.239	0.667
Half chamber rate, %	86.80	86.70	86.70	87.10	0.482	0.931
Eviscerated rate, %	69.60	69.90	70.50	69.90	0.942	0.914
Brest muscle rate, %	28.39	28.37	28.23	28.42	0.630	0.997
Thigh muscle rate, %	21.60	21.72	21.82	21.44	0.520	0.959

[a-b]Means within a row with different letters differ significantly ($P < 0.05$).
[1]Data are means for 8 replicates per treatment.

Table 5. Effects of star anise, essential oil, and leavings on relative organ weights and intestinal lengths of broilers.[1]

Items	Control	Star anise	Essential oil	Leavings	SEM	*P*-value
Relative weight, g/kg BW						
Duodenum	5.465	5.305	5.339	5.227	1.034	0.987
Jejunum	11.190	11.608	10.910	10.579	1.582	0.769
Ileum	7.905	7.996	7.949	7.964	1.357	1.000
Liver	17.42	17.50	17.62	17.43	0.771	0.975
Spleen	1.152^{c}	1.232^{a,b}	1.259^{a}	1.160^{b,c}	0.057	0.020
Thymus	5.111^{b}	5.360^{a}	5.347^{a}	5.088^{b}	0.142	0.010
Bursa of Fabricius	0.657	0.659	0.638	0.647	0.033	0.738
Relative length, cm/kg BW						
Duodenum	14.961	14.727	14.660	14.511	1.719	0.980
Jejunum	33.913	32.956	33.396	33.755	5.064	0.991
Ileum	33.546	33.497	33.707	34.351	4.780	0.991

[a-c]Means within a row with different letters differ significantly ($P < 0.05$).
[1]Data are means for 8 replicates per treatment.

DISCUSSION

Growth Performance

The general trend in poultry industry is to provide a more safe feed to enhance the physiological and productive indicators (Elnesr et al., 2019). Our preliminary study have found that broilers supplemented with star anise essential oil at the rate of 200 mg/kg of diet had a greater BW at day 21 and day 42 compared with those without supplementation (Ding et al., 2017). Meanwhile, addition of star anise oil could quadratically enhance ADFI of laying hens from day 1 to day 28 (Yu et al., 2018). Similar in those studies, our results demonstrated that the in-feed star anise and essential oil possessed abilities to increase the final BW by approximately 2.26 and 2.49%, respectively, as compared with the control group. Besides, the addition of essential oil to the diets improved ADG and ADFI by approximately 3.72 and 3.91%, respectively, as compared with the control group. This phenomenon may because of the enhanced palatability contributed by aromatic flavor of essential oil and the improved gut health by its bioactive compounds with antioxidant, antimicrobial, and antiinflammation properties (Amad et al., 2011; Reisinger et al., 2011).

Carcass Traits

The addition of essential oil to the diets improved the carcass weight (including organs) and thigh muscle weight by approximately 4.02 and 6.27% respectively, as compared with the control group. Which were consistent with the results of the final BW. However, there was no significant difference in the examined percentages of carcass characteristics among all treatments. The results of carcass traits revealed that essential oil improved carcass weight (including organs) without altering percentages of relevant carcass characteristics. This may be explained that carcass traits increased as similar rate as BW growth during bird development. Additionally, no changes on percentage of carcass traits of broilers after supplementing essential oil were also detected in previous studies (Soltan et al., 2008; Hong et al., 2012).

Development of Organs and Intestines

The health of organs and intestines is important for predicting health status of broilers. The present results showed that the relative weight of spleen and thymus were 1.09-fold and 1.05-fold higher, respectively, in birds supplemented with 200 mg/kg star anise oil of diet relative to those of the control birds. In contrast, similar

Table 6. Effects of star anise, essential oil, and leavings on intestinal histology in broilers.[1]

Items	Control	Star anise	Essential oil	Leavings	SEM	*P*-value
Villus height, μm						
Duodenum	1,122.5	1,125.7	1,111.9	1,116.2	41.330	0.964
Jejunum	1,053.2^{c}	1,110.5^{b}	1,155.2^{a}	1,049.4^{c}	26.411	<0.001
Ileum	879.7^{b}	882.8^{b}	947.5^{a}	882.3^{b}	35.110	0.049
Crypt depth, μm						
Duodenum	202.0^{a}	197.6^{a}	181.5^{b}	193.7^{a}	5.607	0.002
Jejunum	157.8	154.0	158.8	157.5	5.512	0.637
Ileum	136.5	137.0	141.1	138.6	7.279	0.803
Villus height/Crypt depth ratio, μm/μm						
Duodenum	5.569^{b}	5.706^{b}	6.128^{a}	5.776^{b}	0.247	0.042
Jejunum	6.678^{b}	7.184^{a}	7.296^{a}	6.662^{b}	0.299	0.019
Ileum	6.452^{b}	6.447^{b}	6.730^{a}	6.398^{b}	0.136	0.019

[a-c]Means within a row with different letters differ significantly ($P < 0.05$).
[1]Data are means for 8 replicates per treatment.

Table 7. Effects of star anise, essential oil, and leavings on pH, meat color, water-holding capacity, shear force, and intramuscular fat of broilers.[1]

Items	Control	Star anise	Essential oil	Leavings	SEM	*P*-value
Brest muscle						
pH 45 min	6.30	6.44	6.33	6.42	0.048	0.148
pH 24 h	5.88	5.85	5.85	5.88	0.080	0.981
pH 48 h	7.07	7.12	7.13	7.10	0.118	0.983
Meat color						
L*	47.0	47.0	47.2	46.9	0.948	0.994
a*	0.7	0.7	0.7	0.6	0.063	0.979
b*	7.6	7.6	7.5	7.7	0.438	0.984
Drip, %	6.279[a]	6.275[a]	5.866[b]	6.294[a]	0.096	0.012
Boiling, %	21.02	20.96	20.86	20.77	0.426	0.976
Shear force, N	13.13	13.11	12.69	13.06	0.515	0.921
Intramuscular fat, %	2.655	2.670	2.525	2.584	0.102	0.731
Thigh muscle						
pH 45 min	6.57	6.62	6.52	6.52	0.071	0.694
pH 24 h	6.15	6.18	6.18	6.18	0.127	0.998
pH 48 h	7.33	7.30	7.33	7.33	0.123	0.997
Meat color						
L*	51.7	51.7	52.4	52.2	1.357	0.975
a*	3.9	3.4	3.4	3.6	0.289	0.600
b*	8.6	8.5	8.5	8.6	0.477	0.996
Drip, %	7.879[a]	7.817[a]	7.253[b]	7.849[a]	0.129	0.007
Boiling, %	12.69	12.38	12.45	12.70	0.374	0.900
Shear force, N	8.94	8.96	8.67	8.91	0.133	0.402
Intramuscular fat, %	2.724	2.744	2.726	2.744	0.116	0.999

[a-b]Means within a row with different letters differ significantly ($P < 0.05$).
L*, Lightness; a*, Redness; b*, Yellowness.
[1]Data are means for 8 replicates per treatment.

results by Cho et al. (2014) and Amad et al. (2011) did not observe any differences in relative organ weights in broilers fed essential oil derived from thyme and star anise. The different compositions and concentrations of the bioactive compounds in essential oil may explain the inconsistency. Additionally, supplementation with essential oil could affect intestinal morphology by increasing villus height and V/C ratio. Similar results were reported by Reisinger et al. (2011), revealing qualitative increases in villus height of ileum in broilers after feeding a mixture of oregano, anise, and citrus peel. Hong et al. (2012) also demonstrated that villus height in duodenum was higher in broilers fed with essential oil extracted from oregano, anise, and citrus peel. However, the mechanisms about the effects of bioactive compounds on improving intestinal morphology were not fully understood. The improvement of intestinal morphology by star anise and its essential oil may be because of antimicrobial and antioxidant properties of bioactive compounds. Numerous previous studies have demonstrated that the essential oil extracted from herbs have ability to inhibit growth of pathogenic bacteria such as *Clostridium perfringens*, *Escherichia coli*, and so on (Wang et al., 2011; Hong et al., 2012; Cho et al., 2014).

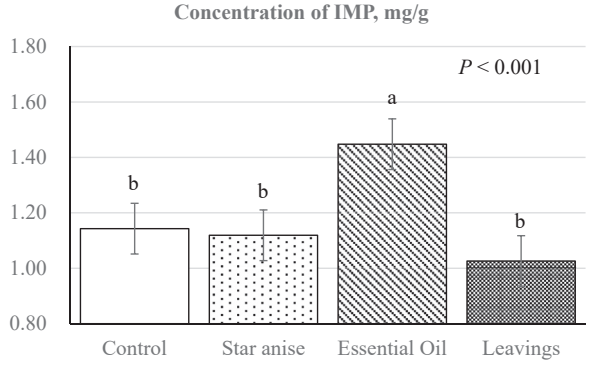

Figure 1. Concentration of IMP in breast muscle among the Control, Star anise, Essential oil, and Leavings group. [a-b]Means within a row with different letters differ significantly ($P < 0.05$). Abbreviation: IMP, inosine 5′-monophosphate.

Meat Quality

Muscle pH is one of the most important postslaughtering parameters for meat quality. The low pH is associated with the accumulation of lactic acid by anaerobic respiration which could influence water-holding capacity (Zhang et al., 2008; Qi et al., 2010).

Meat color is a critical parameter affecting the decision of deboned and skinless raw meat products in market by consumers (Zhang et al., 2008; Qi et al., 2010). It could be altered by many factors such as age, species, and muscle protein such as myoglobin and intramuscular fat. In this study, we did not observe any changes on muscle pH and color in broilers among all the treatments. Which were consistent with the similar observation by Hong et al. (2012) and Cho et al. (2014).

Water-holding capacity measured by drip loss and boiling loss is an important parameter reflecting the juiciness and tenderness of meat products (Yang et al., 2010). Overall, the data demonstrated significant reduction in drip loss of both breast and thigh muscles when birds supplemented with essential oil. Lower drip loss indicated a higher water-holding capacity and improved

muscle juiciness. A similar increase on water holding capacity were also detected by Hong et al. (2012), showing that the tenderness and juiciness of breast and thigh muscles were improved in birds fed essential oil compared with those in control and antibiotic groups. A possible explanation for improved overall acceptance may be related to the functional properties of the bioactive compounds, but the mechanism is not clear.

Shear force value is an index for describing meat tenderness. It was inversely related to the tenderness (Qi et al., 2010) and was affected by the histological properties of myofibers (Zhang et al., 2008). Besides, the content of intramuscular fat plays an important role in meat quality (flavor and juiciness) of chickens (Qi et al., 2010). However, there were no significant differences among treatments in shear force and intramuscular fat of breast and thigh muscle.

Concentration of IMP

Inosine 5′-monophosphate is a dietary nucleotide that plays an important role in meat flavor that affecting consumers' acceptances (Zhang et al., 2008). The results of this study indicated that the variation of IMP concentration of breast muscle in birds fed with essential oil were 1.27-, 1.29- and 1.41-fold higher respectively, as compared with those in Control, Star anise, and Leavings. However, supplementation of star anise and its leavings have no contributions to improve the concentration of IMP in birds compared with those in Control. The increased concentration of IMP in breast muscle of broilers by essential oil may be related to its licorice flavor (Wang et al., 2011). Meanwhile, essential oil was rich in several effective compounds such as trans-anethole, anisaldehyde, and estragole (Ciftci et al., 2005; Wang et al., 2011; Ding et al., 2017), which may be responsible for the increased concentration of IMP in the breast muscle.

An interesting finding of this study was that essential oils extracted from star anise may have potential as in-feed additives to improve growth performance, relative organ weight, carcass traits, intestinal development, and meat quality. Compared with essential oils, star anise and its leavings showed less improvements on most of those parameters. As the same substance in different forms, star anise and essential oil show effects in different degrees. Additionally, it appeared that essential oil increased the ability of star anise in this experiment especially in villus height and crypt depth of small intestines, drip loss of muscle, and concentration of IMP. This may be because of the higher purity and better absorption of bioactive compounds in essential oils compared with star anise and leavings in broilers. Star anise has shown numerous pharmacological benefits including antiparasitic, antibacterial, antioxidant, antifungal, and antipyretic (Ciftci et al., 2005; Soltan et al., 2008; Hong et al., 2012; Cho et al., 2014) because of bioactive compounds such as trans-anethole, estragole, and anisaldehyde (Ciftci et al., 2005; Wang et al., 2011; Ding et al., 2017). This may also explain the no effects of leavings on those parameters because little bioactive compounds remained after extraction. In conclusion, the isolation of the essential oil from star anise may have potential.

CONCLUSIONS

Supplementation of star anise and essential oil at the levels of 5 g/kg and 0.22 g/kg of diet respectively have potentials for increasing final BW and relative weight of spleen and thymus. However, only dietary essential oil supplementation was detected to change the ADG, ADFI, villus height and crypt depth of small intestines, drip loss of muscles, and concentration of IMP in broilers as compared with other groups, indicating essential oils extracted from star anise have more benefits on meat quality and morphology compared with star anise, whereas leavings had no effect on all of those parameters.

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