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The effect of herbal supplements on the carcass characteristics, fatty acid profile and meat quality attributes of broilers

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ABSTRACT

The present investigation was carried out to determine the effect of two herbal formulations, AV/LMP/10 (T1) (garlic, *Allium sativum*) and AV/HLP/16 (T2) (mixture of gugal, C*ommiphora mukul* and fenugreek, *Trigonella foenum-graecum* with 50:50%), on the carcass characteristics, proximate composition, lipid profile including fatty acids, and meat quality attributes in Vencobb 400 broiler chickens. Broilers fed with the AV/HLP/16 (T2) formulation had significantly (P<0.05) superior carcass characteristics in terms of pre-slaughter weight, head, neck, shank, skin, stomach, intestine, giblet, and wholesale cut yield than the control and broilers supplemented with AV/LMP/10 (T1). Meat obtained from the broilers fed with the T2 formulation had a significantly (P<0.01) higher dressing percentage and lean percentage than the control broilers and the T1 supplemented broilers. Meat obtained from the broilers fed with the T2 formulation had significantly (P<0.01) higher moisture and protein content, and lower fat content than the control birds. Meat obtained from the broilers fed with the T2 formulations had significantly (P<0.01) lower triglycerides and higher phospholipids and cholesterol content than meat obtained from the control birds. A significant (P<0.01) increase was observed in the myristic, palmitic, oleic, palmitoleic, linoleic and behenic acid percentages, and a decrease in the stearic acid percentage in meat obtained from the broilers fed with the T2 formulation. Addition of the T2 formulation significantly (P<0.01) improved the physico-chemical quality and sensory scores of the chicken meat. The results of this study revealed that addition of herbal formulations had a significant effect on the carcass characteristics, proximate composition, fatty acid profile and meat quality attributes in comparison with the control birds.

Key words: broilers; herbal supplements; carcass characteristics; meat quality attributes

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Introduction

Natural products obtained from plants are gaining the interest of consumers as natural additives (TOGHYANI et al., 2010). Natural medicinal products originating from herbs, spices and their products, including essential oils, have been used as feed additives in poultry production (LIPINSKI et al., 2019). The recent ban on the use of antibiotic growth promoters in poultry feeds has drawn the attention of researchers towards the presence of various natural substances, such as medicinal herbs, as a new class of additives to animal and poultry feeds. These medicinal herbs have beneficial properties such as anti-oxidant, anti-microbial and anti-fungal, as well as immune-modulatory and anti-coccidial effects (KHAN et al., 2012). Garlic (*Allium sativum*), Turmeric (*Curcuma longa*), Thyme (*Thymus vulgaris* L.) Aloe vera, onion (*Allium sepa*), Ginger (*Zingiber officinale*, Rosc.), *Astragalus membranaceus*, and Noni (*Morindacitrifolia*) etc., are some of the major plant additives that have been extensively reported as additives to poultry feed for enhanced growth in broilers and better egg production in laying hens (GUO et al., 2004; SUNDER et al., 2014).

In this study, two poly herbal formulations were used for enhancing the performance and also lean meat production of broilers, namely: AV/LMP/10 (T1) which contains garlic (*Allium sativum*), and the hypolipidemic premix AV/HLP/16 (T2) which mainly constitutes guggul (C*ommiphoramukul)* and fenugreek (*Trigonella foenum-graecum)* in a ratio of 50:50 %. *Commiphoramukul* is commonly known as the Indian bdellium tree and over a hundred metabolites of various chemical compositions have been reported from the leaves, stem, latex, root and fruit samples. The gum resin obtained from *Commiphoramukul* (guggul) has been used for thousands of years in Ayurveda (Indian folk medicine) to treat various disorders, including internal tumors, obesity, liver disorders, malignant sores and ulcers, urinary complaints, intestinal worms, leucoderma, sinuses, edema, and sudden paralytic seizures. Guggulsterone has been identified as a bioactive component of this gum resin. This plant steroid has been reported to act as an antagonist of certain nuclear receptors, especially the farnesoid X receptor, which regulates bile acids and cholesterol metabolism (BHATIA et al., 2015). Guggulsterone also mediates gene expression through the regulation of transcription factors, including nuclear factor-kappa B and signal transducer and activator of transcription 3, which plays important roles in the development of inflammation and tumorigenesis (MOHAN et al., 2021). Guggulsterone has been shown to downregulate the expression of proteins involved in anti-apoptotic, cell survival, cell proliferation, angiogenic, metastatic and chemoresistant activities in tumor cells. (BHATIA et al., 2015; MOHAN et al., 2021). *Trigonella foenum-graecum,* commonly known as fenugreek, contains various active constituents, such as flavonoids, alkaloids, coumarins, vitamins and saponins. The most prevalent alkaloids are trigonelline, coumarins, cinnamic acid and scopoletin, which have potential antioxidant and antibacterial effects. It is also known that these constituents reduce fat and cholesterol content and act as an immune booster (QUZIR et al., 2016). Garlic (*Allium sativum*) has been used as a spice and native medicine for many years. The literature describes some of the antibacterial, antifungal, antiparasitic, antiviral, antioxidant, anticholesterolemic, anti-cancerous, and vasodilatory characteristics of garlic (HANIEH et al., 2010). Garlic also contains various constituents, such as allicin, ajoene, and flavonoid compounds, which are considered to be the major bioactive compounds (KIM et al., 2000). These components provide its characteristic flavor and well-known aroma, and have a hypocholesterolemic effect. YEH and LIU (2001) and CHOWDHURY et al. (2002) reported that the components of garlic inhibit cholesterol and fatty acid synthesis in the liver, thus resulting in a lower fat content in meat.

The exact mechanism of action of these herbal formulations is not clear, but experimental studies have suggested that they increase gut microflora, which positively affects host nutrition, health and growth by better utilization of nutrients (HASHEMI and DAVOODI, 2011). It has been reported that the curcumin in turmeric enhances the activities of digestive enzymes such as pancreatic lipase, amylase, trypsin and chymotrypsin (KHAN et al., 2012; TIWARI et al., 2014). Keeping this in mind, the present investigation was designed to determine the efficacy of two herbal formulations (AV/LMP/10 (T1) and AV/HLP/16 (T2) on carcass characteristics, proximate composition, lipid profile including fatty acids, and meat quality attributes in Vencobb 400 broiler chickens.

Materials and methods

About two hundred and seventy day old (Vencob 400) broiler chicks were procured, wing banded and randomly distributed into three treatment groups with 6 replicates, each consisting of 15 birds. The test substances (AV/LMP/10 and AV/HLP/16) were procured from M/S Ayurvet Limited, Katha (Vill), Baddi (P.O) Solan (Dist), India. The basal diets were formulated for pre-starter (0-14days), starter (15-28 days) and finisher (29-42 days) phases, and their ingredient composition, along with the calculated values of important nutrients, are presented in Table 1. The basal diets during each phase were iso-nitrogenous and iso-caloric. Ingredients such as palm oil, L-Lysine and DL-Methionine were also used to meet the dietary concentration of protein, lysine and methionine, as per ICAR 2013 specifications for broiler diets. The birds fed with the basal diet without any herbal supplements comprised the control group (C), and the two other groups were given the basal diet supplemented with AV/LMP/10 at 1 kg/t of feed (T1) and AV/HLP/16 at 1 kg/t of feed (T2), respectively. All the birds were offered food and water *ad libitum*. The birds were maintained for up to 42 days under uniform management conditions.

Table 1. Percentage of ingredient composition and chemical composition of broiler basal diet in different phases.

Ingredients (%)	Pre starter diet	Starter diet	Finisher diet
Maize	47.93	48.85	55.3
Soybean meal	42.55	41.33	35.35
De-oiled rice bran	1	1	1
Palm oil	4.8	5.3	5
Mineral mixture	2.0	2.0	2.0
Mineral mixture*	0.2	0.17	0.13
Chemical composition (% dry matter basis)			
Dry matter	90.12	90.72	91.58
Crude protein	22.09	21.54	19.52
Crude fat	6.19	6.18	6.29
Crude Fiber	6.05	6.09	6.28
Total ash	10.18	10.51	10.71
Acid insoluble ash	2.13	2.21	2.41
NFE	55.49	55.68	57.20
Calcium	1.02	1.01	1.09
Available P	0.66	0.58	0.57
Lysine**	1.20	1.07	0.93
Methionine**	0.48	0.48	0.41
ME(K.Cal/Kg)**	3001	3050.3	3102

*Contained NaCl-2.5 %; Fe, 0.35% ;Ca-25; P-15; and Cu-100; Mn-200; Co-50; I-100 ppm.
**Calculated values
NFE-Nitrogen free extract; ME- Metabolizable energy

Carcass and meat quality attributes. Feed was withdrawn 6 hours before the scheduled time of slaughter, and all the birds were slaughtered and bled for 90 seconds, scalded at 55±1°C for 2 min and mechanically defeathered. The feet were removed and the carcasses were manually eviscerated, washed, and allowed to drip for 5 min. The weights of the head and shank, feathers, skin, intestines and giblets were determined using an electronic balance. The dressing percentage was calculated by dividing the warm carcass weight by the shrunk live weight of the animal, and expressing the result as a percentage (modified kosher method). The chickens were cut-up manually into parts and the weights of the cut-up parts were recorded using an electronic digital balance.

The percentage of moisture, crude protein, crude fat and ash in the meat obtained from the broilers was determined as per the methods recommended by AOAC (2002). Total triglycerides can be indirectly calculated by subtracting the sum of total phospholipids, total cholesterol and total free fatty acids from the total lipids (VAN HANDEL and ZILVERSMIT et al., 1957). Phospholipids were determined by the method of MARINETTI (1962). Total cholesterol content was determined as per HANEL and DAM (1955). For fatty acid profile, extraction of total lipids was conducted with a modified method based on that developed by FOLCH et al. (1957). Extraction of total lipids was performed with a solvent mixture of chloroform, that is, methanol of different polarities. The ratio of the extraction solvent was 15 cm^3/g of tissue, divided into a three-part composition: chloroform:methanol at 2:1, chloroform:methanol at 1:1, and chloroform:methanol at 1:2. The total lipid homogenates in each solvent were extracted for 30 min by stirring (700 rpm) and then centrifuged for 10 min at 3,000 rpm at 20°C. Total lipid extracts were combined and concentrated in a UNIVAPO 100H rotary evaporator, equipped with a UNICRYO MC 2L cooling unit (Uniequip, Planegg, Germany). Fatty acids from the total lipid extract were converted to methyl esters by transesterification with methanolic HCl, according to the international standard procedure, ISO 5509 (2000). The resulting methyl esters of fatty acids were prepared for analysis by gas chromatography. In the sample of the total lipids, methyl nonadecanoic acid (C19:0) was used as an internal standard. Analysis of fatty acid methyl esters was performed with an SRI 8610 C gas chromatograph (SRI, Torrance, CA) equipped with a flame ionization detector. The temperatures of the injector and detector were 150°C and 240°C, respectively. Chromatography was performed on an 007 Carbowax 20 M capillary column (007-CW-60–0.25 F Quadrex fused, Woodbridge, CT; length 60 m, with an internal column diameter of 0.25 mm, active-layer thickness of 0.25 mm, serial no. 140122 D). The initial column temperature was 150°C for 3 min, which was then increased to 230°C by heating for 87°C/min and held at this temperature for 5 min. The carrier gas, hydrogen, was used at a flow rate of 60 mL/min in the split mode. Collection and processing of results were conducted with the computer program PeakSimple3D, version 2.97.

The pH of breast muscle 24 hours after slaughter was measured using a digital pH meter (Systronics, μ-Controlled pH system, Model No: 361) with a glass probe electrode. The percentage drip loss was measured by the standard bag method proposed by HONIKEL (1987). The color parameters of breast muscle were monitored by evaluating the Hunter L*, a* and b* values using Color Tec PCM + (Color Tec Associates Inc., Clinton, NJ, USA). The Hunter L (lightness) value was measured on the outer surface of the cut chicken breast pieces from three randomly chosen spots. The estimation of the water holding capacity of the breast muscle was determined according to the method of WARDLAW et al. (1973). The cooking yield of the breast muscle was derived by recording the differences between pre- and post-cooking weights, and expressed as a percentage. Shear force value (SFV) was estimated using Warner-Brazler shear force apparatus, and the SFV was recorded in kg/cm^2. Sensory characteristics, *viz.,* color, flavor, juiciness, tenderness, and the overall acceptability of cooked breast meat cut samples, were assessed by subjecting them to a semi-trained five-member panel from the staff of the department, as per the KEETON (1983).

Statistical analysis. The data collected were subjected to one way ANOVA according to the general linear model procedure from the statistical package for social sciences (SPSS) version 22. A significance level of P≤0.01 was used in all tests. When analysis of variance indicated a significant treatment effect, Duncan's multiple range test was used to compare the treatments, and the results were expressed as the mean average value ± standard error.

Ethical approval. The research was approved by the Institutional Animal Ethics Committee of the College of Veterinary Science, Sri Venkateswara Veterinary University, Andhra Pradesh, India, with Ref. No. 281/go/ReBi/S/2000/CPCSEA/CVSc/TPTY/033/LPT/2019)

Results

Carcass Characteristics. The addition of herbal formulations significantly (P<0.01) influenced the carcass characteristics of the broilers fed with herbal formulations (Table 2). A significantly (P<0.01) higher pre-slaughter weight, head and shank yield, skin yield, stomach and intestine yield, and giblet yield was found in broilers fed with herbal formulations in comparison with broilers fed with the control diet. The mean pre-slaughter weight of the broilers ranged from 2048.08 g in the control to 2287.65 g in broilers fed with AV/HLP/16 supplemented feed (T2). The mean percentage head and shank yield was 5.39; 6.27 and 6.51 for the control, T1 and T2, respectively. The skin percentage was 11.92; 12.69 and 12.60 in the control, T1 and T2 birds, respectively. The mean percentage stomach and intestine yield was 6.57; 7.94 and 7.89 for the control, T1 and T2, respectively. No significant (P>0.01) difference was found in the stomach and intestine yield of the birds fed with AV/LMP/10 (T1) and AV/HLP/16 (T2) formulations. The mean percentage giblet yield recorded in the broilers was 5.74; 6.23 and 6.20 in the control, T1 and T2, respectively. The giblet yield was significantly (P<0.01) higher in the herbal formulation groups, and there was no significant difference (P>0.01) between T1 and T2.

Table 2. Mean±SE values of the carcass characteristics of broilers affected by the addition of herbal formulations.

Carcass characteristics	Treatments		
	Control	T1	T2
Pre slaughter weight (g)	2048.08±0.31 [a]	2196.25±0.28 [b]	2287.65±0.63 [c]
Head and Shank (%)	5.39±0.17 [a]	6.27±0.14 [b]	6.51±0.25 [c]
Skin (%)	11.92±0.20 [a]	12.69±0.17 [b]	12.60±0.42 [ab]
Stomach and Intestine (%)	6.57±0.09 [a]	7.94±0.22 [b]	7.89±0.15 [b]
Giblet (%)	5.74±0.15 [a]	6.23±0.30 [b]	6.20±0.07 [b]
Carcass weight (g)	1309±0.19 [a]	1506±0.22 [b]	1629±0.35 [c]
Dressing Percentage	63.85±0.28 [a]	68.59±0.27 [b]	71.09±0.27 [c]
Lean (%)	0.84±0.05 [a]	0.92±0.20 [b]	0.91±0.14 [b]
Bones (%)	0.45±0.14	0.44±0.29	0.43±0.37
Meat: Bone ratio	1.87±0.23 [a]	2.09±0.08 [b]	2.17±0.28 [c]
Neck (%)	3.36±0.11 [a]	4.08±0.12 [b]	4.25±0.26 [c]
Wings (%)	8.16±0.32 [a]	10.10±0.05 [b]	10.98±0.37 [c]

Table 2. Mean±SE values of the carcass characteristics of broilers affected by the addition of herbal formulations. (continued)

Carcass characteristics	Treatments		
	Control	T1	T2
Breast (%)	28.17±0.47 [a]	31.15±0.17 [b]	34.43±0.22 [c]
Back (%)	6.23±0.36 [a]	7.17±0.25 [b]	7.09±0.29 [b]
Thigh (%)	15.59±0.23 [a]	17.98±0.33 [b]	18.27±0.10 [c]
Drumstick (%)	8.27±0.17 [a]	9.97±0.19 [c]	9.63±0.08 [b]

Mean values with different superscripts within row differ significantly(P<0.01).

T1= Broilers fed with basal diet supplemented with AV/LMP/10 @1 kg/ton of feed.

T2= Broilers fed with basal diet supplemented with AV/HLP/16 @1 kg/ton of feed.

Broilers fed with AV/HLP/16 formulation (T2) had significantly (P<0.01) higher carcass weight (g), dressing percentage, lean percentage and meat bone ratio than broilers fed with the control diet and broilers fed with the AV/LMP/10 formulation (T1). The mean carcass weights were 1309; 1506 and 1629(g) in the control, T1 and T2 birds, respectively. A dressing percentage of 63.85; 68.59 and 71.09 was found in the control, T1 and T2, respectively. Broilers fed with the herbal formulations had significantly (P<0.01) higher lean percentage than the control, and no significant (P>0.01) difference was observed between the lean percentage of broilers fed with the AV/HLP/16 formulation (T2) and the AV/LMP/10 formulation (T1). The addition of herbal formulations did not influence (P>0.01) the bone percentage significantly. The meat-bone ratio was 1.87; 2.09 and 2.17 in the control, T1 and T2, respectively.

Broilers fed with the AV/HLP/16 formulation (T2) had significantly (P<0.01) higher neck, wings, breast and thigh percentage than the broilers fed with the control diet and AV/LMP/10 (T1) (Table 2). The neck percentage ranged from 3.36 to 4.25 per cent in the control birds and T2 birds, respectively. Broilers fed with the AV/HLP/16 formulation (T2) had significantly (P<0.01) higher (10.98 %) wing percentage than broilers fed with the AV/LMP/10 formulation (10.10 %) and control (8.16 %) broilers. The percentage breast yield was 28.17; 31.15 and 34.43 in the control, T1 and T2, respectively. The range of percentage thigh yield was from 15.59 to 18.27, and the range of drumstick percentage was 8.27 to 9.97. Broilers fed with herbal formulations had significantly (P<0.01) higher back percentage compared to the control. There was no significant (P>0.01) difference between the back percentage of broilers fed with the AV/HLP/16 formulation (T2) and the AV/LMP/10 formulation (T1).

Proximate and Biochemical parameters. Addition of herbal formulations to the feed significantly (P<0.01) influenced the proximate composition of the meat (Table 3). Meat obtained from broilers fed with the herbal formulations had significantly (P<0.01) higher percentage of moisture and protein content than control birds. The control birds' meat had a significantly (P<0.1) higher percentage of fat than the meat obtained from broilers fed with herbal formulations. The range of fat percentage was 1.97 to 2.42. Addition of herbal formulations did not (P<0.01) influence the total ash percentage significantly.

The meat obtained from the broilers fed with herbal formulations varied significantly (P<0.01) in lipid profile (Table 3). The meat obtained from broilers fed with herbal formulations had significantly (P<0.01) higher triglycerides, lower phospholipids and cholesterol content than meat obtained from birds fed with the control diet. Higher triglyceride content (g/kg) was observed in T1 samples than in the control and T2 groups of birds. The phospholipid content (g/kg) in the control, T1 and T2 was 7.12; 5.45 and 6.08, respectively and the cholesterol content (g/kg) in the control, T1 and T2 was 0.59; 0.41 and 0.39, respectively. The cholesterol content did not differ significantly (P>0.01) between meat obtained from the broilers fed with the herbal formulations, but the phospholipid content differed significantly (P<0.01) between meat obtained from broilers fed with herbal formulations.

Table 3. Mean±SE values of proximate and biochemical parameters of broilers meat affected by addition of herbal formulations.

Proximate and Biochemical parameters	Treatments		
	Control	T1	T2
Total Moisture (%)	71.18±0.22 [a]	73.98±0.21 [b]	73.94±0.27 [b]
Total Protein (%)	19.12±0.14 [a]	21.63±0.29 [b]	21.59±0.15 [b]
Total Fat (%)	2.42±0.07 [b]	1.97±0.17 [a]	2.01±0.09 [a]
Total Ash (%)	2.68±0.19	2.72±0.23	2.66±0.33
Triglycerides (g/kg)	4.19±0.48 [a]	4.77±0.11 [c]	4.60±0.37 [b]
Total Phospholipids (g/kg)	7.12±0.26 [c]	5.45±0.08 [a]	6.08±0.22 [b]
Cholesterol (g/kg)	0.59±0.20 [b]	0.41±0. 22[a]	0.39±0.40 [a]
Fatty acid profile (%)			
Myristic acid	0.56±0.11 [a]	0.75±0.24 [b]	0.78±0.08 [b]
Palmitic acid	19.40±0.19 [c]	18.22±0.10 [a]	18.50±0.17 [b]
Stearic acid	4.38±0.28 [b]	3.98±0.26 [a]	4.01±0.26 [a]
Oleic acid	40.82±0.41 [a]	42.78±0.28 [c]	42.55±0.14 [b]
Linolic acid	28.72±0. 18[a]	31.28±0.17 [b]	33.57±0.19 [c]
Linolenic acid	1.27±0.20 [a]	1.39±0.28 [ab]	1.35±0.08 [b]
Arachidic acid	0.16±0.27	0.18±0.25	0.15±0.27
Behenic acid	0.42±0.19 [a]	0.56±0.10 [b]	0.68±0.16 [c]
Palmitoleic acid	4.13±0.23 [a]	5.97±0.17 [c]	5.54±0.11 [b]

Mean values with different superscripts within row wise differ significantly(P<0.01).
T1= Meat from broilers fed with basal diet supplemented with AV/LMP/10 @1 kg/ton of feed.
T2= Meat from broilers fed with basal diet supplemented with AV/HLP/16 @1 kg/ton of feed.

Fatty acid profile. Addition of herbal formulations to the feed significantly influenced (P<0.01) the fatty acid composition of the broiler meat (Table 3). A significantly (P<0.01) higher percentage of myristic, oleic, linolic, linolenic, behenic and palmitoleic acid, and a lower percentage of palmitic and stearic acid was found in the meat obtained from broilers fed with the herbal formulations. The meat from the broilers fed with AV/LMP/10 (T1) had a significantly lower (P<0.01) palmitic acid percentage than the control and T2. The percentage of palmitic acid in the control, T1 and T2 was 19.40; 18.22 and 18.50, respectively. The meat obtained from the broilers fed with the AV/LMP/10 formulation (T1) had a significantly higher (P<0.01) oleic acid percentage than the control and T2. The percentage of linolic acid in the control, T1 and T2 was 28.72; 31.28 and 33.57, respectively. The meat obtained from the broilers fed with the AV/HLP/16 formulation (T2) had a significantly (P<0.01) higher percentage of linolic acid than the control and T1. A significantly (P<0.01) higher linolenic acid percentage was found in the meat obtained from the broilers fed the herbal formulations. The addition of herbal formulations to the broiler feed did not significantly (P>0.01) influence the percentage of arachidic acid in the meat. Percentages of behenic acid of 0.42; 0.56 and 0.68 were found in the control, T1 and T2 bird meat. In the present study, Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) were not detected in meat obtained from the control, T1 and T2 birds. The percentages of palmitoleic acid in the control, T1 and T2 birds were 4.13; 5.97 and 5.54, respectively. The meat obtained from the broilers fed with the AV/LMP/10 formulation (T1) had a significantly (P<0.01) higher percentage of palmitoleic acid than the control and T2.

Physico-chemical characteristics. The addition of herbal formulations significantly (P<0.01) lowered the pH as well as the drip loss percentage of the meat obtained from the treated broilers in comparison with the control broilers (Table 4). There was no significant difference (P>0.01) between the pH and drip loss percentage of the meat obtained from the two treated groups of broiler birds (T1 andT2). The meat obtained from the broilers fed with the AV/HLP/16 formulation (T2) had a significantly (P<0.01) higher cooking yield and water holding capacity than the control and T1 treated birds. The addition of herbal formulations significantly (P<0.01) influenced the shear force value of the meat obtained from the control and treated broilers. Significantly higher lightness (L^*) and yellowness (b^*), and lower redness (a^*) values were observed in the meat obtained from the broilers fed with the AV/HLP/16 formulation (T2). The lightness (L^*) values of the control, and T1 and T2 treated broiler meat were 48.35; 50.67 and 51.29, the redness (a^*) values were 6.54; 5.09 and 5.25, and the yellowness values were 11.15; 13.44 and 13.65, respectively.

Table 4. Mean±SE values of physico-chemical and sensory characteristics of broilers meat affected by addition of herbal formulations.

Meat quality attributes	Treatments		
	Control	T1	T2
Physico-chemical characteristics			
pH	5.98 ±0.15 ^{b}	5.68±0.27 ^{a}	5.71±0.09 ^{a}
Drip loss (%)	5.37±0.10 ^{b}	3.29±0.30 ^{a}	3.33±0.17 ^{a}
Cooking yield (%)	71.86±0.28 ^{a}	75.78±0.22 ^{b}	76.96±0.26 ^{c}
Water holding capacity (%)	34.29±0.19 ^{a}	37.57±0.14 ^{b}	39.07±0.37 ^{c}

Table 4. Mean±SE values of physico-chemical and sensory characteristics of broilers meat affected by addition of herbal formulations. (continued)

Meat quality attributes	Treatments		
	Control	T1	T2
Shear Force Value (N)	9.62±0.28 [c]	8.59±0.08 [b]	8.11±0.19 [a]
Lightness (L^*) values	48.35±0.10 [a]	50.67±0.23 [b]	51.29±0.11 [c]
Redness (a^*) values	6.54±0.17 [b]	5.09±0.35 [a]	5.25±0.27 [a]
Yellowness (b^*) values	11.15±0.11 [a]	13.44±0.39 [b]	13.65±0.25 [c]
Sensory characteristics			
Colour	6.28±0.27 [a]	6.58±0.34 [b]	6.91±0.17 [c]
Flavour	6.71±0.11	6.69±0.40	6.73±0.28
Tenderness	6.35±0.19 [a]	6.89±0.27 [bc]	6.77±0.09 [b]
Juiciness	6.49±0.07 [a]	6.84±0.21 [b]	6.79±0.23 [b]
Overall acceptability	6.43±0.11 [a]	6.79±0.25 [b]	6.98±0.14 [c]

Mean values with different superscripts within row wise differ significantly(P<0.01).
T1= Meat from broilers fed with basal diet supplemented with AV/LMP/10 @1 kg/ton of feed.
T2= Meat from broilers fed with basal diet supplemented with AV/HLP/16 @1 kg/ton of feed.

Sensory characteristics. The addition of herbal formulations significantly (P<0.01) increased the various sensory scores, *viz*., the color, tenderness, juiciness and overall acceptability of meat obtained from the treated broiler birds (Table 4). The meat obtained from the broilers fed with the AV/HLP/16 formulation (T2) had significantly higher color scores than the control and T1 treated birds. The addition of herbal formulations did not significantly influence (P>0.01) the flavor scores of the meat. The tenderness scores of the meat from the control, T1 and T2 treated birds were 6.35; 6.89 and 6.77, respectively, and the meat obtained from the broilers fed with the AV/LMP/10 formulation (T1) had significantly (P<0.01) higher tenderness and juiciness scores than the control and T2 treated birds. Significantly (P<0.01) higher overall acceptability scores were awarded to the meat obtained from the broilers fed with the AV/HLP/16 formulation (T2) than the control and T1 treated birds.

Discussion

Carcass characteristics. The differences between the carcass characteristics of broilers fed with herbal formulations could be due to the different active ingredients in the tested products. The active components in poly herbal supplements have stimulatory effects on pancreatic secretions by increasing the secretions of digestive enzymes, which can lead to greater amounts of nutrients such as amino acids being digested and absorbed from the digestive tract, and this then improves the carcass traits. Furthermore, this might be due to the improvement of the digestibility of the feed ingredients by the inclusion of herbal dietary supplements (JAMROZ et al., 2003), and the growth promoting effect of herbal formulations. Similar trends were observed by ISSA AND ABO OMAR, (2013) in broilers fed with medicinal plants.

The linear improvement in carcass development through the inclusion of polyherbal formulations in the current study may be due to the appropriate utilization of the protein made available to the chickens in their feed (ELBUSHRA, 2012). The higher yield of cut up parts could be due to protein metabolism being stimulated by the polyherbal formulations added to the broilers feed, which causes higher digestibility, leading to better muscular development. In addition, the herbal formulations used in this study contain several functional ingredients, such as guggulsterone, flavonoids, alkaloids, coumarins and vitamins, etc. as well as many essential minerals (calcium, phosphorus, iron, zinc and magnesium) which significantly increase the growth and overall performance of birds, thus yielding higher carcass yield (LIPINSKI et al., 2019). The findings of this study are in close agreement with the findings of ABBAS (2010), who found similar results in broilers fed with 1% and 2% fenugreek seed powder, and DELIMARIS (2013) who also reported an improvement in the dressing percentage of broilers supplemented with fenugreek seed powder by up to 3% of their diet, due to higher dry matter and crude protein intake.

Proximate and biochemical parameters. The chemical composition of meat depends on different factors, such as the provenance of the broilers, sex, age, nutritional status, and the part of the carcass (YESUF et al., 2017). The high moisture content of the breast muscles in the non-supplemented treatment makes the meat more succulent. These results agree with ISMOYOWATI et al. (2016) who studied ducks fed with bay leaves. An inverse relationship was found between the triglyceride and phospholipid, and cholesterol content of meat obtained from the control and treated birds. This may be due to a reduction in the growth and activity of the intestinal microflora responsible for bile salt catabolism. The different active components, such as flavonoids, alkaloids, coumarins (cinnamic acid and scopoletin), vitamins, saponins and trigonelline, cause a reduction in the intestinal bacterial population (QUZIR et al., 2016). Further, these active components also lower the deconjugation of bile salts that leads to reduced impairment of fat emulsification and lipid absorption, hence resulting in lower triglycerides and total cholesterol content in meat obtained from broilers fed with herbal formulations. The changes in lipid profile may be attributed to the lipid lowering effect of the active components in the herbal formulations, such as guggulsterone, flavonoids, alkaloids, coumarins, vitamins and saponins etc., (SHARMA et al., 1996; QUZIR et al., 2016). Guggulsterone, which is a plant steroid, has been reported to work as an antagonist of certain nuclear receptors, especially the farnesoid X receptor, which regulates bile acids and cholesterol metabolism. Furthermore, the polyherbal formulations included fenugreek which had fat reducing activity due to the presence of lecithin and choline. Similar to these findings, REDDY et al., (2002) reported that inclusion of the herbal feed additives may reduce the cholesterol content of chicken meat and meat products. ISMOYOWATI et al. (2016) reported that the inclusion of bay leaf at 9% reduced cholesterol in duck meat.

Fatty acid profile. The term “healthy fatty acids” refers to essential fatty acids (EFA) that is, those polyunsaturated fatty acids (PUFA) that must be provided by foods because these cannot be synthesized in the body yet are necessary for health (KAUR et al., 2014). There are two families of EFA, omega-3 (ω-3) and omega-6 (ω-6). The double bonds in these ω-3 fatty acids are in a cis-configuration i.e. the two hydrogen atoms are on the same side of the double bond. The healthy fatty acid profile in meat raised with herbal supplements added to the diet might be due to the active components which could activate the process of fatty acid β-oxidation, and thus result in a lower fat deposition (CRESPO and ESTEVE-GARCIA, 2001; NEWMAN et al., 2002). Similarly, NKUKWANA et al. (2014) suggested that dietary supplementation of moringa leaf (*Moringa oleifera*) extract could increase the content of unsaturated fatty acids in broiler muscles. Polyunsaturated fatty acids could be deposited in the muscle through dietary supplementation (WOODS and FEARON, 2009), and thus the different active ingredients in herbal formulations might be responsible for the increase in the unsaturated fatty acid content of breast muscle observed in the treated broilers. The present results are similar to the observation of

KIRUBAKARAN et al. (2011) that the inclusion of basil leaf meal at 1 and 2 g/kg contributed significantly to elevating the yolk linolenic acid. SANTOSO et al. (2017) found that addition of fermented *Sauropusandrogynus* leaf powder to a poultry diet increased the linolenic acid in broiler meats. This research might help to maintain broiler chickens without the need for antibiotics as a feed additive, and to develop organic farming for broiler chickens. In addition, the present study might help to develop enriched meats (these meats contain lower fat but higher protein, mineral, methionine, linolenic acid with no antibiotic residue), which will meet consumer demands.

Physico-chemical characteristics. The lower pH values of meat obtained from birds fed with herbal additives might be due to the establishment of ultimate pH in meat obtained from treated birds. The present result is consistent with previous work by CHEN et al. (2008), who revealed that dietary supplementation with garlic elevated pH values in pork meat. Conversely, a higher drip loss value in the pectoralis muscle of broilers was found after feeding them a diet including oxidized oil (ZHANG et al., 2011). The cooking loss in the current study was lower for the meat obtained from the broilers fed with herbal formulations, which might have resulted from the high protein content of their diet, and also the ability of protein to hold water during cooking, which in turn reduces the loss of water during cooking. Water-holding capacity (WHC) is one of the most important quality attributes of meat, regarding its processing suitability. In the present study, a decrease in WHC was found in the meat of the control birds, but a significantly higher WHC was found in the meat of the treated birds. There was a clear relationship between drip loss and WHC. Similar to these results, BHASAKR REDDY et al., (2018) concluded that addition of flax seed flour had influenced the water holding capacity of meat. The addition of herbal formulations significantly ($P<0.01$) lowered the shear force value of meat obtained from treated broilers in comparison with the control broilers. The lower shear force value of meat obtained from treated broilers might be due to more water retention and tenderness of muscle. Dietary supplementation of ginger extract decreased the Warner-Bratzler Shear Force (WBSF) value (increased tenderness) of buffalo meat (NAVEENA and MENDIRATTA, 2004).

It could be interpreted that dietary supplementation modifies meat color by reducing myoglobin oxidation and activating mechanisms that modify the pigment distribution in the meat. The enhancement of oxidative stability was supposed to be the main reason for meat color improvement. Myoglobin, one of the most important proteins responsible for meat color, is oxidized immediately after slaughter, and this causes a change in meat color from purplish red or purplish pink to cherry red, and then discoloration is observed (MANCINI and HUNT, 2005). The enhanced oxidative stability of breast muscle observed in the groups supplemented with polyherbal formulations might have resulted from the potentially antioxidant properties of the herbal formulations. YOUNG et al. (2003) showed that a dietary oregano extract increased the a^* value in chicken meat compared to meat resulting from the control diet. Contrary to this result, dietary supplementation of garlic decreased L*, a*, and b* values in pork meat (CHEN et al., 2008).

Sensory characteristics. The higher sensory scores of meat obtained from broilers fed with herbal formulations could be related to the antioxidant activity of the phenolic compounds, that minimizes protein and lipid oxidation, which could improve the meat quality. Furthermore, establishment of ultimate pH and the higher WHC of the meat also result in more juiciness, which in turns enhances the palatability of meat. The active components in herbal additives caused an overall improvement in muscle quality, which also significantly improved the sensory scores. These outcomes agree with earlier work by JANG et al. (2008), who documented that feeding broiler chickens a diet including a dietary medicinal herb extract mix enhanced the overall palatability of the meat. The overall acceptability of meat products is mostly influenced by flavor, juiciness and texture attributes. During sensory evaluation of meat products, product acceptability is affected by many factors, which may be related to the individual, the food, or the environment in which the meat/food is consumed. Acceptability is a subjective measure based on hedonics (pleasure), which in turn is influenced by the sensory properties of the meat products, previous exposure to it and subsequent expectations, contextual factors, the individual's culture, physiological status (i.e., hunger, thirst, and the presence/absence of illness), and many other variables. The measurement of food acceptance is highly complex, and relies on psychometrics (scales) and/or behavioral models (food-choice models) (MURRAY and BAXTER, 2003). Furthermore, addition of garlic bulb and garlic husk to broiler diets resulted in a more desirable texture in a sensory evaluation test (KIM et al., 2009), and in this study one of the active components in the T2 diet is garlic. However, feeding different levels of a mixture of six herbs did not affect the tenderness, juiciness, aroma, and palatability of the longissimus muscle of pigs (GRELA, 2000; JANZ, 2007).

Conclusions

On the basis of the above results, it may be concluded that broiler feed supplemented with a AV/HLP/16 formulation (T2) (mixtures of C*ommiphora mukul* and *Trigonella foenum graecum)* led to better carcass characteristics than in the control and broilers fed with that AV/LMP/10 formulation (T1). Further, the meat obtained from the broilers fed with the herbal formulations had higher moisture and protein, and lower fat than the meat obtained from the control birds. Meat obtained from broilers fed with the AV/HLP/16 herbal formulation had significantly (P<0.01) lower triglyceride, cholesterol and higher healthy fatty acid profile percentages than meat from the control and the group fed the AV/LMP/10 formulation (T1), which might be due to the hypolipidemic action of the AV/HLP/16 formulation. In addition, meat obtained from broilers fed with the AV/HLP/16 formulation had better physico-chemical attributes and superior sensory scores than meat obtained from the control and AV/LMP/10 treated birds. Addition of 1 kg/ton of herbal supplements enhanced the performance and lean meat quality of broilers.

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SAŽETAK

Ovo je istraživanje provedeno kako bi se ustanovio učinak dviju biljnih formulacija, AV/LMP/10 (skupina T1) (češnjak, *Allium sativum*) i AV/HLP/16 (skupina T2) (mješavina dobivena od stabla smirne mukul (*Commiphora mukul*) i piskavice (*Trigonella foenum-graecum*) u omjeru 50 : 50 %) na svojstva trupa, kemijski sastav - uključujući lipidni status i masnokiselinski sastav te kvalitetu mesa Vencobb 400 tovnih pilića. U odnosu na piliće kontrolne skupine i onih hranjenih formulacijom AV/LMP/10 (T1), pilići hranjeni formulacijom AV/HLP/16 (T2) imali su znakovito (P<0,05) kvalitetnija svojstva trupa s obzirom na tjelesnu masu prije usmrćivanja te dijelove trupa kao što su glava, vrat, bataci, koža, organi trbušne šupljine, crijeva, iznutrice i veleprodajni komadi pilića. Tovni pilići u skupini T2 imali su znakovito veći (P<0,01) postotak mesa od kontrolne skupine i skupine T1. Meso pilića iz skupine T2 imalo je znakovito veći (P<0,01) sadržaj vode i proteina te manji sadržaj masti od pilića u kontrolnoj skupini. Meso tovnih pilića u skupini T2 imalo je znakovito manje vrijednosti (P<0,01) triglicerida i veće vrijednosti fosfolipida i kolesterola nego meso pilića u kontrolnoj skupini. Znakovit je bio porast (P<0,01) postotka miristinske, palmitinske, oleinske, palmitoleinske, linoleinske i behenske kiseline te smanjenje vrijednosti stearinske kiseline u mesu tovnih pilića iz skupine T2. Dodatak biljne formulacije u skupini T2 znakovito je poboljšao (P<0,01) fizikalno-kemijska i senzorička svojstva mesa tovnih pilića. Rezultati ovog istraživanja pokazali su da dodatak biljnih formulacija prehrani tovnih pilića znakovito utječe na svojstva trupa, kemijski - uključujući lipidni i masnokiselinski sastav te kvalitetu mesa pilića u odnosu na kontrolnu skupinu.

Ključne riječi: tovni pilići; biljni dodaci prehrani; svojstva trupa; kvaliteta mesa