



Effects of dried okra fruit (*Abelmoschus esculentus* L.) powder on growth, carcass characteristics, blood indices, and meat quality of stored broiler meat

Elwy A. Ashour,^{*} May Bin-Jumah,[†] Eman T. Abou Sayed-Ahmed,[‡] Ali O. Osman,[§] Ayman E. Taha,[#] Maha A. Momenah,[†] Ahmed A. Allam,^{|||} Ayman A. Swelum ,[¶] and Mohamed E. Abd El-Hack ^{*,1}

^{*}*Poultry Department, Faculty of Agriculture, Zagazig University, Zagazig 44511, Egypt;* [†]*Biology Department, Faculty of Science, Princess Nourah Bint Abdulrahman University, Riyadh, Saudi Arabia;* [‡]*Food Science Department, Faculty of Agriculture, Zagazig University, Zagazig 44511, Egypt;* [§]*Biochemistry Department, Faculty of Agriculture, Zagazig University, Zagazig 44511, Egypt;* [#]*Department of Animal Husbandry and Animal Wealth Development, Faculty of Veterinary Medicine, Alexandria University, Edfina 22578, Egypt;* ^{|||}*Department of Zoology, Faculty of Science, Beni-Suef University, Beni-Suef, 65211 Egypt;* and [¶]*Theriogenology Department, Faculty of Veterinary Medicine, Zagazig University, Zagazig 44511, Egypt*

ABSTRACT The present study investigated the impacts of dried okra fruit powder (DOFP), used as a natural feed supplement, on growth, carcass, blood, and meat quality parameters of broilers. A total of 240 unsexed, one-week-old chicks were randomly allotted to 4 equal groups with 6 replicates in each group (i.e., 10 birds/replicate). The dietary treatments consisted of the basal diet as control, and 3 DOFP groups, supplemented with 1.0, 2.0, and 3.0 g DOFP/kg feed, respectively. The results showed that the highest values of live body weight and body weight gain were observed in the group with 1.0 g of DOFP/kg of feed during the fifth week of age and between 1 and 5 wk of age, respectively. During 1 to 3 wk of age, daily feed consumption of chicks fed DOFP-supplemented diets increased numerically with increasing DOFP levels. Dietary treatments significantly depressed liver, thigh, and dressing fat percentages. Chicks fed the diet

containing 1.0 g of DOFP/kg of feed had the lowest values for serum urea and creatinine compared with the other treatment group. In addition, the concentration of liver enzymes decreased with increasing DOFP levels, except for the groups fed 3.0 and 1.0 g of DOFP/kg of diet. Oxidative rancidity of broiler meat samples containing DOFP in their diets was lower than that of the control samples, throughout the storage period. It can be concluded that DOFP is a useful phyto-genic additive, which can lower the percentage of abdominal fat of the carcass, as well as alanine aminotransferase, urea, and creatinine in the blood. Furthermore, all sensory characteristics of the meat were improved by the addition of DOFP to broiler diets. It could be concluded that DOFP can be used as a natural supplement in broiler diets for improving growth performance and reducing abdominal fat, blood creatinine, and urea.

Key words: broilers, okra fruit powder, performance, serum metabolite, meat quality

2020 Poultry Science 99:3060–3069

<https://doi.org/10.1016/j.psj.2020.03.009>

INTRODUCTION

Among the many dietary factors that affect health and production of poultry, antioxidants have a major role in animal survival, maintenance of poultry health, and reproductive and productive rates. Dietary

phyto-genic additives are products derived from plants and added to poultry feed, to improve growth and productive performance. Phyto-genic additives in poultry feed enhance the birds' appetite and feed consumption, stimulate the secretion of digestive enzymes, and activate antioxidants, in addition to having antibacterial, anthelmintic, and antiviral properties that enhance the immune responses (Abd El-Hack et al., 2016, 2019; Saeed et al., 2017, 2018; Shewita and Taha, 2018; Gado et al., 2019; Khafaga et al., 2019). Several studies have confirmed the beneficial effects of phyto-genic additives on growth indices, gut health, nutrient retention, and intestinal microflora. In addition to enhancing immunity functions and

© 2020 Published by Elsevier Inc. on behalf of Poultry Science Association Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Received October 3, 2019.

Accepted March 2, 2020.

¹Corresponding authors: m.ezzat@zu.edu.eg; dr.mohamed.e.abdal-haq@gmail.com

reducing the susceptibility to diseases, such additives also improve carcass yield and quality in poultry (Kim et al., 2011; Ashour et al., 2014; Abd El-Hack and Alagawany, 2015; Alagawany et al., 2015a,b; Zhang et al., 2017). However, studies on the application of phytogetic additives to broiler feed have shown inconsistent results on broiler performance, as reported by Ocak et al. (2008).

Okra (*Abelmoschus esculentus* L.) is a biennial or perennial plant, cultivated for its seeds and healthy fruits (Feng and Xu, 1984). Okra plants can tolerate extended periods of direct sunlight; are resistant to moisture, drought, and heat; and can adapt to a variety of soils (Liu et al., 2008). Throughout the tropical and subtropical regions, okra can be grown twice a year. It can be used as a vegetable, as a medicine for health care, or in manufacturing a beverage (Liu et al., 2008). Okra fruit contains several nutrients; 100 g of dried okra pods contains 2.44 g crude protein, 2.11 g deoxidized sugar, 0.682 g carotene, 1.06 g cellulose, 10.2 mg vitamin B, 1.25 mg vitamin A, 26.5 mg vitamin C, and several minerals, which are slightly higher than the proportions found in common fruits and vegetables (Liu et al., 2007).

Natural antioxidants play an essential role in poultry nutrition, by maintaining antioxidant defenses in their tissues (Fotina et al., 2013; Abd El-Hack et al., 2018a). It is important to supplement the diet with antioxidants, to prevent oxidation of animal feed and the consequent intake of free radicals by the animals (Khafaga and Bayad, 2016a,b; Zhang et al., 2017; Alagawany et al., 2019). Moreover, antioxidants can affect the *in vivo* antioxidative activity; hence, they have a key role in the stability and shelf life of meat. The aim of this study was to investigate the effects of increasing levels of dried okra fruit powder (DOFP), used as a phytogetic feed additive and natural antioxidant, on growth, carcass characteristics, serum parameters, antioxidant activity, and meat quality of growing broilers, from 1 to 5 wk of age.

MATERIALS AND METHODS

Estimation of Bioactive Compounds

Sample Preparation Okra pods were cut and freeze-dried, using a freeze-dryer. The lyophilized products were defatted using hexane. Ten grams of ground okra pods were extracted in methanol (100 mL 10% w/v), by stirring at room temperature for 2 h, followed by filtration through Whatman No. 1 filter paper. The solvent was removed under vacuum, and the residues were lyophilized and preserved at -20°C until used.

Determination of Total Phenolic Contents Total phenolic contents were evaluated using gallic acid at different concentrations, from 20 to 400 $\mu\text{g}/\text{mL}$, as standardized by Singleton et al. (1999).

Determination of Total Flavonoid Contents Total flavonoid contents were evaluated using quercetin at different concentrations, from 20 to 200 $\mu\text{g}/\text{mL}$, as standardized by Ordonez et al. (2006).

Antioxidant Evaluation (DPPH Assay) The antioxidant properties of the okra pod extract were evaluated at different concentrations, from 100 to 1,200 $\mu\text{g}/\text{mL}$, according to Hatano et al. (1988).

Five hundred microliter of the extract was blended with 2,500 μL of the reagent (DPPH in methanol). After incubation for 30 min at room temperature, the absorbance of the extract at 517 nm was listed in parallel with the control (DPPH dissolved in methanol). The antioxidant activity (% inhibition) was calculated using the following formula:

$$\% \text{inhibition} = \left[\frac{(\text{Control absorbance} - \text{absorbance of Sample})}{\text{Control absorbance}} \right] \times 100.$$

Birds, Experimental Design, Housing, and Diets

The study was conducted at the Poultry Research Farm, Faculty of Agriculture, Zagazig University, Zagazig, Egypt. The protocols were approved by the aforementioned institution, based on the ethical guidelines of the Local Experimental Animal Care Committee, of the Institutional Committee of Poultry Department.

In a completely randomized design experiment, a total of 240 unsexed Ross broiler chicks, 1 wk old with initial weight of 110.08 ± 0.28 g, were divided equally into 4 groups, each assigned to an experimental treatment. Each treatment group had 6 replicates consisting of 10 birds each (60 chicks/group). Chicks were housed in floor litter cages (100 cm \times 100 cm \times 40 cm), with fresh water available at all times. The treatment groups were as follows: 1) control (basal feed); 2) basal feed + 1.0 g DOFP/kg feed; 3) basal feed + 2.0 g DOFP/kg feed; 4) basal feed + 3.0 g DOFP/kg feed. Chicks were given the feed in mashed form, from 1 to 5 wk of age. The experimental diets were fed in 2 phases: starter (1–3 wk) and finisher (3–5 wk). Water and feed were offered *ad libitum* to all birds. Table 1 shows the formulation and composition of the basal diets according to NRC (1994).

Growth Measurements

All birds were weighed at weekly intervals. Daily feed consumption (DFC), body weight gain (BWG), and feed conversion ratio (FCR) were cumulatively calculated by period. The wastage feed was recorded daily to estimate the correct feed consumption. At the end of the experiment, 6 birds (3 males and 3 females) were selected randomly to evaluate carcass parameters.

Carcass Traits

Dressed carcasses were weighed, and gizzard, heart, liver, breast, thigh, and abdominal fat were calculated as relative weights (g/kg of slaughter weight). The dressed weight was calculated using the following formula:

$$\text{dressed weight} = \frac{(\text{weight of carcass} + \text{giblets weight})}{\text{slaughter weight}}.$$

Table 1. Composition and chemical analyses of the basal diets.

Items	Basal diets	
	Starter (1–3 wk)	Finisher (3–5 wk)
Ingredients (g/kg diet)		
Yellow maize	571.30	605.30
Soybean meal	316.50	271.50
Gluten meal	65.00	61.00
Di calcium phosphate	17.00	15.00
Limestone	12.40	11.50
Vitamin Premix ¹	3.00	3.00
NaCl	3.00	3.00
DL Methionine	0.50	0.20
L-Lysine HCl	1.30	1.00
Soybean oil	10.00	28.50
Total	1,000	1,000
Calculated analysis ²		
Dry matter %	91.74	90.43
Crude protein %	23.00	21.00
Metabolizable energy MJ/kg diet	12.35	12.97
Calcium %	1.00	0.90
Phosphorous (available) %	0.45	0.40
Lysine %	1.20	1.05
Methionine + cysteine %	0.83	0.74
Crude fibre %	3.56	3.31

¹Growth vitamin and mineral premix. Each 2.5 kg consists of: Vit A 12,000, 000 IU; Vit D3, 2,000, 000 IU; Vit. E, 10 g; Vit k3 2 g; Vit B1, 1,000 mg; Vit B2, 49 g; Vit B6, 105 g; Vit B12, 10 mg; pantothenic acid, 10 g; niacin, 20 g; folic acid, 1,000 mg; biotin, 50 g; choline chloride, 500 mg; Fe, 30 g; Mn, 40 g; Cu, 3 g; Co, 200 mg; Si, 100 mg; and Zn, 45 g.

²Calculated according to [NRC \(1994\)](#).

Blood Indices

Blood samples from slaughtered birds were collected into clean, sterile tubes. Blood samples were allowed to coagulate and then centrifuged at 2328.24 G-force for 15 min to obtain the serum. The serum samples were stored in Eppendorf tubes at -20°C , until further analyses. Samples were analyzed for contents of biochemical components, and parameters were spectrophotometrically determined using commercial diagnostic kits (Bio-diagnostic Company, Giza city, Egypt).

Technological and Sensorial Qualities

Color Measurement Color attributes of poultry meat (L^* , a^* , and b^*) were determined using Hunter Lab color analyzer (Hunter Lab color Flex EZ, HunterLab, Reston, VA), according to [Rao et al. \(2011\)](#). The L^* value (lightness index scale) ranges from 0 (black) to 100 (white), a^* value indicates the redness ($+a^*$) or greenness ($-a^*$), and b^* value refers to the yellowness ($+b^*$) or blueness ($-b^*$) of the meat. A minced mix of thigh and breast muscles was placed in petri dishes, filled to the top and placed directly on the colorimeter sensor. The following formula was used to determine the color difference between the treated and untreated samples:

$$\Delta E = [(l - l^*)^2 + (a - a^*)^2 + (b - b^*)^2]^{0.5}$$

where L^* , a^* , and b^* are values of the reference or control sample, and ΔE indicates the total color differences compared to the untreated control.

Thiobarbituric Acid Test Ten grams of the sample from each treatment group was mixed with 100 mL of

refined water for 2 min. The pH of the samples was brought to 1.5, by adding few drops of 4 N HCl, following which the samples were transferred to a refining tube. The blend was distilled, and 50 mL of distillate was collected. Five milliliter of 0.02 mol 2-thiobarbituric corrosive in 90% acidic corrosive (Thiobarbituric acid [TBA] reagent) was added to a vial containing 5 mL of the distillate and mixed properly. The vials were topped and warmed in a bubbling water bath for 30 min to build up the chromogen and then cooled down to room temperature. The absorbance was estimated at 538 nm, against blank containing 5 mL of refined water and 5 mL of TBA-reagent, using a JENWAY6705 UV/VIS Spectrophotometer. The TBA number was determined as malondialdehyde/kg, using the following equation:

$$\text{TBA Number (kg)} = \text{absorbance at 538 nm} \times 7.8$$

pH Value The pH values of beef burger and minced broiler meat samples were measured using a pH meter, according to [Fernández-Ginés et al. \(2005\)](#), and their color was determined according to the tristimulus color system, described by [HunterLab \(1983\)](#), using a HunterLab colorimeter (Hunter Lab Color Flex EZ; HunterLab, Reston, VA). Color was expressed in terms of lightness (L^*), redness (a^*), and yellowness (b^*). Standardization was achieved by calibrating the machine with a standard pink plate ($L^* = +70.9$, $a^* = +22.4$, $b^* = +8.2$). Hunter values were calculated as the average of 3 readings from the same location.

Microbiological Analysis of Chicken Meat

Ten grams of well mixed samples were transferred to conical flaks containing 90 mL of sterilized saline

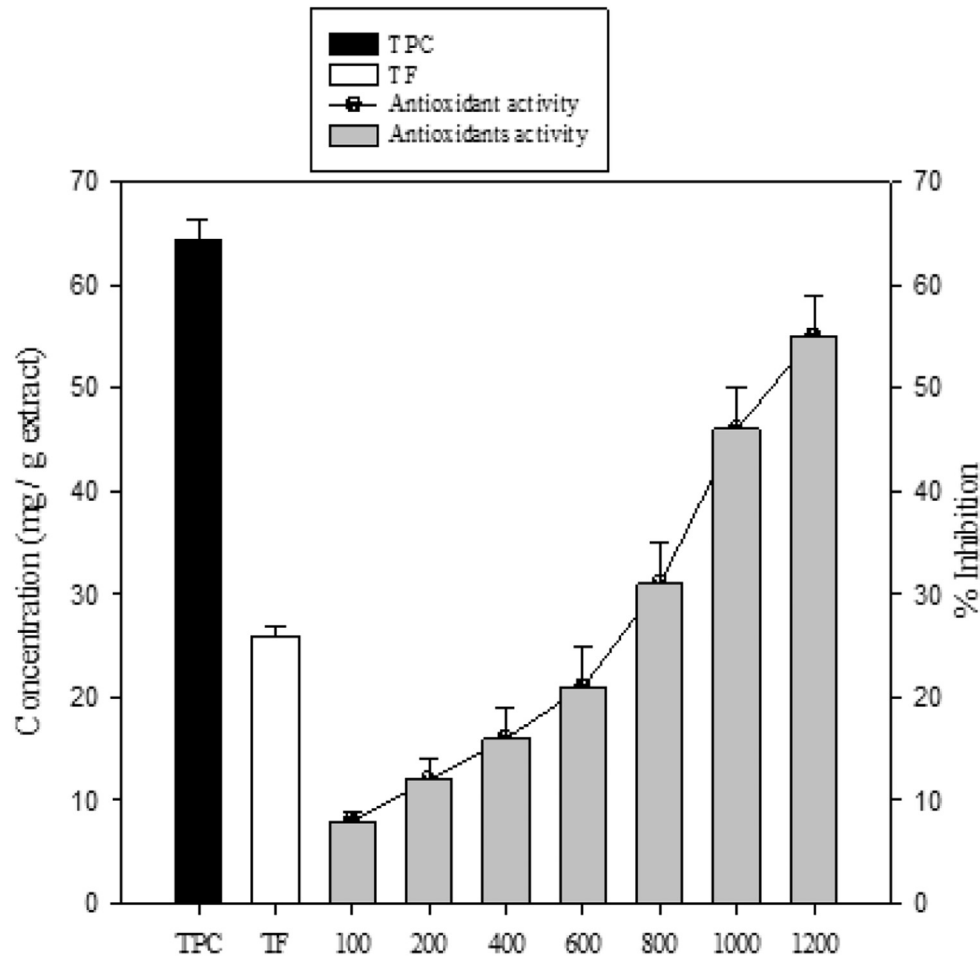


Figure 1. Total phenolic content (TPC), total flavonoid (TF) content, and antioxidants activity of okra pods methanolic extract at different concentrations (100, 200, 400, 600, 800, 1,000, and 1,200 µg/mL) by using DPPH assay.

solution (0.85% NaCl) and serially diluted until a 1:10 dilution was achieved.

Total Viable Bacteria Count Total duplicate sets of Petri dishes were used, 1 mL aliquots from 10^{-1} to 10^{-6} dilutions in standard plate count agar (PCA, Biolife cod. No. 402145) by using a pipette and then melted in following steam. The agar was cooled to 44°C–46°C and then poured into the Petri dishes. Aliquots were immediately mixed with the agar medium by rotating and tilting the Petri dishes. After solidification, the Petri dishes were inverted and incubated for 48 h at 37°C. The aerobic colonies were counted and multiplied by the dilution factor, according to the American Public Health Association (APHA, 1992).

Psychrophilic Bacteria Total psychrophilic bacteria were enumerated according to APHA (1992), using a plate count media. The method followed was same as the typical procedure used for total bacteria count, except incubation was carried out for 5 D at 7°C in a refrigerator.

Mold and Yeast One milliliter of the aliquot was poured promptly into a Petri dish containing 10 to 15 mL of Rose Bengal (Biolife code No.401991), chloramphenicol agar, and chloramphenicol antibacterial

supplement (cod. No. 421840003) and heated at 44°C to 46°C. The aliquots were mixed with the agar medium by rotating and tilting. The Petri dishes were incubated for 3 to 5 D at 25°C. The number of mold and yeast was evaluated per mL of samples and multiplied by the dilution factor (APHA, 1992).

Statistical Analysis

Data were analyzed statistically using one-way analysis of variance, using GLMs in SPSS (2008). Differences among groups were considered to be statistically significant at $P < 0.05$. The standard error of mean was also calculated. Data of bacterial counts were log-transformed before being analyzed by analysis of variance. The applied model was as follows:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where Y_{ij} = an observation, μ = the overall mean, T_i = effect of DOFP inclusion levels (0, 1, 2, 3), and e_{ij} = random error. The significant differences were assessed using Duncan's multiple range test. Results were

Table 2. Growth performance parameters of broiler chicks under different levels of dried okra fruit powder supplementation.

Items	LBW (g)			BWG (g)			DFC (g/D)			FCR (g feed/g gain)		
	1 wk	3 wk	5 wk	1–3 wk	3–5 wk	1–5 wk	1–3 wk	3–5 wk	1–5 wk	1–3 wk	3–5 wk	1–5 wk
DOFP (g/kg diet)												
0.0	110.67	521.33	1827.35	47.97 ^c	162.12	105.05 ^b	29.34	93.29 ^a	61.31	1.64	1.74	1.72
1.0	110.00	565.33	1912.75	54.24 ^a	164.98	109.61 ^{a,b}	32.52	96.24 ^a	64.38	1.68	1.72	1.71
2.0	110.33	579.67	1791.65	52.79 ^{a,b}	158.17	105.49 ^b	33.52	86.57 ^b	60.05	1.58	1.83	1.76
3.0	109.33	519.00	1793.05	52.04 ^b	170.31	111.17 ^a	29.26	91.00 ^{a,b}	60.13	1.78	1.87	1.85
SEM	0.28	11.36	23.33	0.74	1.78	1.04	0.81	1.35	0.83	0.03	0.33	0.30
<i>P</i> value	0.427	0.118	0.223	<0.000	0.163	0.040	0.121	0.043	0.223	0.154	0.281	0.347

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: BWG, body weight gain; DFC, daily feed consumption; DOFP, dried okra fruit powder; FCR, feed conversion ratio; LBW, live body weight; SEM, standard error of mean.

expressed as mean values and standard error means. Statistical significance statements were based on $P < 0.05$.

RESULTS AND DISCUSSION

Estimation of Bioactive Compounds

Secondary metabolites, such as phenolic compounds, excreted by plants are mostly accountable for their antioxidant properties (Kanatt et al., 2010). The total phenolic and flavonoid contents of okra pods were 65 mg GAE/g extract and 25 mg QE/g extract, respectively (Figure 1). DPPH examination has been applied to evaluate the free radical-scavenging capacity of several plant extracts. Okra pod extract showed DPPH-dependent radical scavenging capacity with an SC50 value of 1,034 $\mu\text{g}/\text{mL}$.

Growth Performance

The effects of DOFP supplementation on growth performance of broiler chicks during the experimental periods are shown in Table 2. There were no statistical differences in LBW and BWG between the treatments for all studied periods, except BWG at 3 to 5 wk of age. The highest values for LBW and BWG were observed in chicks fed 1.0 g DOFP/kg feed, at 5 wk of age and during the entire experimental period (1–5 wk of age), respectively. Although not significant, there was a marked improvement in growth rate of chicks supplemented with DOFP, during the entire experimental period. This observed improvement in LBW may be

due to the presence of compounds in the phytochemical additive that enhance digestion, absorption, and utilization of nutrients by the broilers. It might also be due to the bioactive components, which enhance the utilization and efficiency of feed, resulting in improved growth. Plant-derived supplements can minimize the bacterial resistance resulting from the use of antibiotics as growth enhancing supplements (Abd El-Hack et al., 2018b; Arif et al., 2019). Fotina et al. (2013) demonstrated that optimal antioxidant supplementation to broiler diets is important to maintain the best growth rate, immune-competence, and meat quality. Similarly, Zhang et al. (2017) found that feed supplementation of Danzhou chicken diets with 0.5, 1.0, and 1.5% okra powder resulted in a significantly higher average daily gain than the control group. Conversely, Marzoni et al. (2014) reported that adding a mixture of natural antioxidants to broiler diets did not have any impact on growth performance. Furthermore, Cardoso et al. (2012) found that piperine, used as a phytochemical additive, did not affect the growth indices, in either the initial or the growing periods of broilers.

No significant impacts on DFC were observed in treatments during the first and the entire experimental periods (1–3 and 1–5 wk of age). During the entire period (1–5 wk of age), DFC increased numerically ($P < 0.05$) with increasing DOFP levels. The highest feed intake was recorded in chicks fed 3.0 g DOFP/kg feed, while the lowest intake was recorded with the control diet. Effects of DOFP supplementation on FCR were not significant in any of the experimental periods. However, diets supplemented with DOFP at the level of 1 g/kg

Table 3. Carcass characteristics of broiler chicks under different levels of dried okra fruit powder supplementation.

Items	Carcass traits (relative to preslaughter weight %)							
	Carcass	Dressing	Liver	Heart	Gizzard	Abdominal fat	Breast	Thigh
DOFP (g/kg diet)								
0.0	69.18 ^a	74.41 ^a	2.79 ^a	0.50	1.94	1.08	34.15 ^b	30.97 ^a
1.0	66.76 ^b	71.85 ^b	2.48 ^{a,b}	0.51	2.11	0.97	34.75 ^b	29.07 ^b
2.0	68.91 ^{a,b}	73.43 ^{a,b}	2.34 ^{b,c}	0.44	1.74	0.76	36.67 ^a	28.76 ^b
3.0	68.01 ^a	72.45 ^{a,b}	1.97 ^c	0.46	2.00	0.94	35.73 ^{a,b}	29.17 ^b
SEM	0.37	0.38	0.10	0.02	0.06	0.06	0.36	0.29
<i>P</i> value	0.042	0.045	0.008	0.323	0.116	0.238	0.027	0.004

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: DOFP, dried okra fruit powder; SEM, standard error of mean.

Table 4. Blood serum biochemical parameters of broilers under different levels of DOFP supplementation.

Items	Liver function		Kidney function		Protein fractions			
	AST (IU/L)	ALT (IU/L)	Urea (mg/dL)	Creatinine (mg/dL)	TP (mg/dL)	Alb (mg/dL)	Glob (mg/dL)	A/G ratio
DOFP (g/kg diet)								
0.0	10.24 ^b	122.02 ^a	44.36 ^a	0.53 ^b	6.54 ^b	3.23 ^b	3.31 ^a	0.97 ^b
1.0	11.38 ^a	109.98 ^b	25.89 ^d	0.53 ^b	6.42 ^c	3.19 ^b	3.23 ^a	0.99 ^b
2.0	10.05 ^b	106.72 ^c	26.60 ^c	0.60 ^a	6.53 ^b	3.21 ^b	3.32 ^a	0.97 ^b
3.0	10.00 ^b	121.69 ^a	27.55 ^b	0.59 ^a	7.16 ^a	4.27 ^a	2.88 ^b	1.48 ^a
SEM	0.18	2.08	2.32	0.01	0.09	0.14	0.05	0.07
<i>P</i> value	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: A/G ratio, albumin/globulin ratio; Alb, albumin; ALT, alanine aminotransferase; AST, aspartate transaminase; DOFP, dried okra fruit powder; Glob, globulin; SEM, standard error of mean; TP, total protein.

feed resulted in the best FCR, during the second and the entire experimental periods. Our results are in agreement with those of Scheuermann et al. (2009), Hussein et al. (2018), and Kishawy et al. (2019) who stated that phytochemical additives can enhance the intake and conversion of feed; however, the mode of action of these additives is not clear. This positive effect is due to the enhancement of BWG, as shown in Table 2. It might also be due to the synergetic effects of the chemical constituents of DOFP. Kohlert et al. (2000) theorized that the active components of plant-derived supplements are absorbed in the gut by enterocytes and quickly metabolized by the body. These active components induce alterations in permeation characteristics and membrane dynamics and in protein synthesis associated with cytoskeletal function, which increases the absorptive surface area of the small intestine, as explained by Khajuria et al. (2002). In contrast, Cho et al. (2014) reported that phytochemical additives do not have any significant effects on feed intake and FCR.

Carcass Characteristics

The results showed that thigh, breast, carcass, dressing, and liver fat percentage differed significantly ($P < 0.05$) between the treatment groups (Table 3). The highest values of dressing and thigh yields were observed in broilers fed the control diet, while the lowest values of these traits were recorded in chicks fed 1.0 and 2.0 g DOFP/kg feed, respectively. Birds feeding on DOFP supplemented diets showed lower values of abdominal fat than the controls, at 5 wk of age

Table 5. Blood serum immunological parameters of broilers under different levels of DOFP supplementation.

Items	IgM ($\mu\text{g/mL}$)	Lysozymes ($\mu\text{g/mL}$)
DOFP (g/kg diet)		
0.0	226.50 ^d	12.45 ^d
1.0	260.18 ^b	22.52 ^c
2.0	261.36 ^a	24.59 ^b
3.0	259.07 ^c	26.42 ^a
SEM	4.41	1.63
<i>P</i> value	<0.001	<0.001

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: DOFP, dried okra fruit powder; IgM, immunoglobulin M; SEM, standard error of mean.

($P < 0.05$). On the other hand, the highest value of carcass weight was observed in birds fed the control diet. Feeding birds with 2.0 g DOFP/kg feed resulted in the best breast yield. Antioxidants reduce the activity of cytosolic malic enzyme, leading to suppressed abdominal fat deposition. Marzoni et al. (2014) proved that supplementation of a mixture of natural antioxidants did not influence slaughter yield of broiler chickens. Furthermore, Zhang et al. (2017) reported that the slaughter weight of a group fed 0.5% okra added to basal diet was significantly increased, while other indices were not significantly different from the control group. Cabuk et al. (2006), in their study on the impacts of a blend of herbs on weights of broilers' internal organs, did not report any significant effects on the body weight of treated broilers at 21 and 42 D of age.

Blood Serum Parameters

The effects of DOFP supplementation on serum biochemical parameters of broiler chicks are listed in Table 4. DOFP treatment had significant effects on all serum parameters ($P < 0.05$). It is evident that increasing the DOFP level in the diet led to a gradual decrease in serum total-urea, ALT, and globulin ($P < 0.05$ or $P < 0.01$), while there was an increase in creatinine values ($P < 0.01$), which is strongly supported by the studies of Swain and Johri (2000) and Biswas et al. (2011). Plants such as okra are rich in bioactive compounds, such as phenolic and flavonoid compounds and vitamin C, which act as antioxidants and strengthen

Table 6. Meat pH of broilers under different levels of DOFP supplementation after storage.

Items	Meat pH after storing for:			
	Time zero	1 mo	2 mo	3 mo
DOFP (g/kg diet)				
0.0	6.31 ^a	6.10 ^b	6.13 ^b	5.76 ^b
1.0	6.12 ^b	6.04 ^{b,c}	5.91 ^c	5.50 ^c
2.0	6.03 ^a	6.00 ^a	5.72 ^a	5.56 ^a
3.0	5.90 ^c	5.87 ^c	5.46 ^d	5.40 ^c
SEM	0.05	0.06	0.06	0.09
<i>P</i> value	<0.001	0.002	<0.001	0.023

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: DOFP, dried okra fruit powder; SEM, standard error of mean.

Table 7. Meat TBA of broilers under different levels of DOFP supplementation after storage.

Items	Meat TBA after storing for			
	Time zero	1 mo	2 mo	3 mo
DOFP (g/kg diet)				
0.0	0.45	0.46 ^c	0.46 ^c	0.53 ^a
1.0	0.47	0.47 ^b	0.47 ^b	0.48 ^c
2.0	0.47	0.48 ^a	0.49 ^a	0.49 ^b
3.0	0.43	0.43 ^d	0.44 ^d	0.45 ^d
SEM	0.01	0.01	0.01	0.01
<i>P</i> value	0.077	<0.001	<0.001	<0.001

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: DOFP, dried okra fruit powder; SEM, standard error of mean; TBA, thiobarbituric acid.

the immune system (Ashour et al., 2014). The effects of DOFP on immune parameters, such as lysozymes and IgM, are listed in Table 5. Lysozymes and IgM were significantly higher ($P < 0.05$) in groups supplemented with DOFP than in the control group. Hence, DOFP supplementation may enhance the immune system by increasing the lysozymes and IgM values.

Technological and Sensorial Qualities

Meat pH pH is a common factor affecting meat quality parameters, such as tenderness, juiciness, color, water-holding capacity, and shelf life. Broiler meat pH is a reflection of preslaughter glycogen in the muscle and the conversion rate of glycogen into lactic acid after slaughter (Nasir et al., 2017). Table 6 shows the effects of different DOFP levels on the pH of broiler meat samples after storage at -20°C for 3 mo. The pH values of the samples ranged from 6.31 to 5.90 at time zero and from 5.76 to 5.40 after 3 mo of freezing. This indicates that freezing the meat significantly decreases its pH value ($P < 0.05$). However, no significant differences were observed in the pH values of meat under different treatments. Leygonie et al. (2012) confirmed that during proper freezing storage of broiler breast meat, pH decreases with time. This can be attributed to glycogenolysis, water loss due to associated soluble substances, and accumulation of acidic products, which is usually intensified during the thawing process, (Akhtar et al., 2013). In addition, denaturation of proteins may lead to the release of hydrogen ions (Leygonie et al., 2011).

TBA Test Thiobarbituric acid reactive substances assay is one of the most widely used methods for measuring the oxidative rancidity of food. The effects of DOFP addition on the oxidative stability of broiler meat stored under freezing condition is shown in Table 7. There was an increase in Thiobarbituric acid reactive substance in all the samples during freezing storage. However, oxidative rancidity was less in broiler meat supplemented with DOFP than in untreated control samples, throughout the storage period. The major factor affecting the meat sensorial characteristics is lipid oxidation during storage (Muhlisin et al., 2016).

Meat Color Meat color is an important assessment criterion and is considered to be one of the most important factors influencing consumers' acceptance of meat and meat products (Adeyemi and Sazili, 2014). The effect of DOFP supplementation on the color of broiler meat stored under freezing conditions is shown in Table 8. The results show that the L^* values decrease with time in the storage, which might be caused by a decrease in the water-holding capacity, resulting in lower surface light reflectivity (Hughes et al., 2014). Similarly, the a^* value of the samples also decreased with storage time. This reduction in the red color intensity during storage could be a result of the interdependence of color and lipid oxidation in meats (Benli, 2016). The changes in the b^* value can be attributed to the formation of MetMb and the increase in lipid oxidation (Xiong, 2000). Undesirable changes in color parameters and sensorial properties of meat during storage are caused by the compounds produced during oxidative degradation of lipids (Nam et al., 2001; Gok et al., 2008).

Meat Microbiology

The microbiological quality of meat products is dependent on several factors, such as raw material and storage period. Data presented in Table 9 show the microbiological properties of the broiler samples supplemented with different DOFP levels, after storage at -20°C for 3 mo. Different broiler samples were analyzed for total bacterial, psychrophilic bacterial, and yeast and mold counts. The total bacterial count of the samples ranged from 3.70 to 3.78 log CFU/g at time zero. It was noted that the total bacterial counts of all the samples (at time

Table 8. Meat color of broilers under different levels of DOFP supplementation after storage.

Items	Meat color after storing for:											
	Time zero			1 mo			2 mo			3 mo		
	L^*	a^*	b^*	L^*	a^*	b^*	L^*	a^*	b^*	L^*	a^*	b^*
DOFP (g/kg diet)												
0.0	59.10 ^a	9.90 ^a	15.26 ^a	56.22 ^a	9.68 ^b	13.12 ^a	51.69 ^a	8.68 ^b	10.80 ^a	49.34 ^a	8.35	10.97 ^a
1.0	49.51 ^c	11.04 ^a	13.87 ^b	48.96 ^b	10.66 ^a	12.39 ^{a,b}	47.70 ^c	9.99 ^a	10.21 ^{a,b}	45.07 ^c	8.84	8.08 ^b
2.0	50.98 ^b	9.78 ^b	12.07 ^b	49.74 ^b	9.51 ^a	10.62 ^c	49.10 ^b	7.75 ^b	9.54 ^b	48.52 ^{a,b}	8.04	8.88 ^b
3.0	51.01 ^b	10.64 ^{a,b}	13.37 ^c	50.58 ^b	9.73 ^a	11.84 ^b	49.51 ^b	8.80	9.90 ^b	47.11 ^b	8.29 ^b	8.56 ^b
SEM	1.25	0.22	0.35	0.77	0.22	0.29	0.45	0.34	0.17	0.54	0.16	0.37
<i>P</i> value	<0.001	0.002	<0.001	<0.001	0.041	<0.001	<0.001	<0.001	<0.001	0.002	0.221	0.002

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: a^* , yellowness; b^* , redness; DOFP, dried okra fruit powder; L^* , lightness; SEM, standard error of mean.

Table 9. Meat microbiology of broilers under different levels of DOFP supplementation after storage.

Items	Log total bacterial count			Yeasts and molds			Psychrophilic bacteria		
	1 mo	2 mo	3 mo	1 mo	2 mo	3 mo	1 mo	2 mo	3 mo
DOFP (g/kg diet)									
0.0	3.78	3.85 ^b	3.90 ^b	2.93	2.96 ^a	2.99 ^b	2.85	2.91 ^b	2.94 ^c
1.0	3.73	3.79 ^b	3.84 ^c	2.85	2.94 ^b	2.96 ^c	2.83	2.86 ^a	2.88 ^a
2.0	3.75	3.82 ^b	3.87 ^b	2.89	2.90 ^a	2.92 ^{a,b}	2.84	2.88 ^a	2.90 ^b
3.0	3.75	3.80 ^a	3.86 ^a	2.36	2.40 ^a	2.63 ^a	2.73	2.80 ^b	2.82 ^b
SEM	0.01	0.01	0.01	0.10	0.01	0.01	0.10	0.01	0.02
<i>P</i> value	0.158	0.04	0.02	0.096	0.003	<0.000	0.080	<0.000	<0.000

Different letters within one column are significantly different ($P < 0.05$).

Abbreviations: DOFP, dried okra fruit powder; SEM, standard error of mean.

zero) were similar. The total bacterial count of the control sample showed a gradual but remarkable increase with storage time. Similarly, broiler samples treated with different DOFP levels also showed an increase in total bacterial counts over time; however, the rate of increase was lower than that observed in the control sample.

Similar results were observed for other microorganisms, where counts of yeast, mold, and psychrophilic bacteria increased in all the treated broiler samples, but at a slower rate than in the control samples. This might be due to the antimicrobial effects of DOFP, especially at higher concentrations. The phytochemicals present in okra confer it with antioxidant, antiulcer, anticancer, antimicrobial, hypoglycemic, hypolipidemic, and antidiabetic properties (Andràs et al., 2005; Umamaheswari et al., 2008; Mahadevan et al., 2009; Chaudhari et al., 2011).

CONCLUSIONS

In conclusion, this study shows that DOFP can be used as a natural supplement in broiler diets for improving their growth performance (the low level 1 g/kg diet). In addition, the increasing level can reduce abdominal fat, blood creatinine, and urea, while stimulating the humoral immune responses. Furthermore, it is a safe and cheap way to improve the technological and sensorial qualities of stored chicken meat products.

ACKNOWLEDGEMENTS

This research was funded by the Deanship of Scientific Research, at Princess Nourah Bint Abdulrahman University, through the Fast-track Research Funding Program.

Conflict of Interest Statement: The authors did not provide a conflict of interest statement.

REFERENCES

Abd El-Hack, M. E., and M. Alagawany. 2015. Performance, egg quality, blood profile, immune function, and antioxidant enzyme activities in laying hens fed diets with thyme powder. *J. Anim. Feed Sci.* 24:127–133.

Abd El-Hack, M. E., M. Alagawany, M. R. Farag, R. Tiwari, K. Karthik, K. Dhama, J. Zorriehzahra, and M. Adel. 2016. Beneficial impacts of thymol essential oil on health and production of animals, fish and poultry: a review. *J. Essen. Oil Res.* 28:365–382.

Abd El-Hack, M. E., E. A. Ashour, G. M. Elaraby, A. O. Osman, and M. Arif. 2018a. Influences of dietary supplementation of peanut skin powder (*Arachis Hypogaea*) on growth performance, carcass traits, blood chemistry, antioxidant activity and meat quality of broilers. *Anim. Prod. Sci.* 58:965–972.

Abd El-Hack, M. E., S. A. Mahgoub, M. M. Hussein, and I. M. Saadeldin. 2018b. Improving growth performance and health status of meat-type quail by supplementing the diet with black cumin cold-pressed oil as a natural alternative for antibiotics. *Environ. Sci. Poll. Res.* 25:1157–1167.

Abd El-Hack, M. E., S. A. Abdelnour, A. E. Abd El-Moneim, M. Arif, A. Khafaga, H. Shaheen, D. Samak, and A. A. Swelum. 2019. Putative impacts of phytochemical additives to ameliorate lead toxicity in animal feed. *Environ. Sci. Poll. Res.* 26.

Adeyemi, K. D., and A. Q. Sazili. 2014. Efficacy of carcass electrical stimulation in meat quality enhancement: a review. *Asian-Australas J. Anim. Sci.* 27:447–456.

Akhtar, S., M. I. Khan, and F. Faiz. 2013. Effect of thawing on frozen meat quality: a comprehensive review. *Pak. J. Food Sci.* 23:198–211.

Alagawany, M. M., M. R. Farag, K. Dhama, M. E. Abd El-Hack, R. Tiwari, and G. M. Alam. 2015a. Mechanisms and beneficial applications of resveratrol as feed additive in animal and poultry nutrition: a review. *Inter. J. Pharmacol.* 11:213–221.

Alagawany, M., M. E. Abd El-Hack, M. R. Farag, R. Tiwari, and K. Dhama. 2015b. Biological effects and modes of action of carvacrol in animal and poultry production and health - a review. *Adv. Anim. Vet. Sci.* 3:73–84.

Alagawany, M., S. S. Elnesr, M. R. Farag, M. E. Abd El-Hack, A. F. Khafaga, A. E. Taha, R. Tiwari, M. I. Yatoo, P. Bhatt, G. Marappan, and K. Dhama. 2019. Use of licorice (*Glycyrrhiza glabra*) herb as a feed additive in poultry: current knowledge and future prospects. *Animals* 9:536.

Andràs, D. C., B. Simàndi, F. Orsi, C. Lambrou, D. Missopolinou-Tatala, C. Panayiotou, J. Damoskos, and F. Doleschall. 2005. Supercritical carbon dioxide extraction of Okra (*Abelmoschus esculentus* L.) seeds. *J. Sci. Food Agric.* 85:1415–1419.

APHA. 1992. American Public Health Association. *AJPH* 87:1–6.

Arif, M., Z. Hayat, M. E. Abd El-Hack, M. Saeed, H. M. Imran, A. N. Alowaimier, and A. A. Swelum. 2019. Impacts of supplementing broiler diets with a powder mixture of black cumin, Moringa and chicory seeds. *S. Afr. J. Anim. Sci.* 49:564–572.

Ashour, E. A., M. Alagawany, F. M. Reda, and M. E. Abd El-Hack. 2014. Effect of supplementation of *Yucca Schidigera* extract to growing rabbit diets on growth performance, carcass characteristics, serum biochemistry and liver oxidative status. *Asian J. Anim. Vet. Adv.* 9:732–742.

Benli, H. 2016. Consumer attitudes toward storing and thawing chicken and effects of the common thawing practices on some quality characteristics of frozen chicken. *Asian-Australas J. Anim. Sci.* 29:100–108.

Biswas, A., M. Ahmed, V. K. Bharti, and S. B. Singh. 2011. Effect of antioxidants on physio-biochemical and hematological parameters

- in broiler chicken at high altitude. *Asian-Australas J. Anim. Sci.* 24:246–249.
- Cabuk, M., M. Bozkurt, A. Alcicek, Y. Akbas, and K. Kucukyilmaz. 2006. Effect of a herbal essential oil mixture on growth and internal organ weight of broilers from young and old breeder flocks. *S. Afr. J. Anim. Sci.* 36:135–141.
- Cardoso, V. S., C. A. R. De-Lima, M. E. F. De-Lima, L. E. G. Dorneles, and M. G. M. Danelli. 2012. Piperine as a phyto-genic additive in broiler diets. *Pesq. Agrop. Bras* 47:489–496.
- Chaudhari, Y., E. P. Kumar, M. Badhe, R. H. Mody, and B. A. Vamshikrishna. 2011. An evaluation of antibacterial activity of *Abelmoschus esculentus* on clinically isolated infection disease causing bacteria pathogen from hospital. *Inter. J. Pharm. Phyto-pharmacol. Res.* 1:107–111.
- Cho, J. H., H. J. Kim, and I. H. Kim. 2014. Effects of phyto-genic feed additive on growth performance, digestibility, blood metabolites, intestinal microbiota, meat color and relative organ weight after oral challenge with *Clostridium perfringens* in broilers. *Livest. Sci.* 160:82–88.
- Feng, G. M., and X. H. Xu. 1984. *Flora of China*, Vol. 49. China Scientific Press, Beijing, China.
- Fernández-Ginés, J. M., J. Fernández-López, E. Sayas-Barberá, and J. A. Pérez-Alvarez. 2005. Meat products as functional foods: a review. *J. Food Sci.* 70:37–43.
- Fotina, A. A., V. I. Fisinin, and P. F. Surai. 2013. Recent developments in usage of natural antioxidants to improve chicken meat production and quality. *Bulg. J. Agric. Sci.* 19:889–896.
- Gado, A. R., H. F. Ellakany, A. R. Elbestawy, M. E. Abd El-Hack, A. F. Khafaga, A. E. Taha, M. Arif, and S. A. Mahgoub. 2019. Herbal medicine additives as powerful agents to control and prevent avian influenza virus in poultry—a review. *Ann. Anim. Sci.* 19.
- Gok, V., E. Obuz, and L. Akkaya. 2008. Effect of packaging method and storage time on the chemical, microbiological, and sensory properties of Turkish pastirma – a dry cured beef product. *Meat Sci.* 80:335–344.
- Hatano, T., H. Kagawa, T. Yasuhara, and T. Okuda. 1988. Two new flavonoids and other constituents in licorice root: their relative astringency and radical scavenging effects. *Chem. Pharm. Bull.* 36:2090–2097.
- Hughes, J. M., S. K. Oiseth, P. P. Purslow, and R. D. Warner. 2014. A structural approach to understanding the interactions between colour, water-holding capacity and tenderness. *Meat Sci.* 98: 520–532.
- HunterLab. 1983. *The Science and Technology of Appearance Measurement*. Hunter Associates Laboratory, Reston, VA.
- Hussein, M. M., M. E. Abd El-Hack, S. A. Mahgoub, I. M. Saadeldin, and A. A. Swelum. 2018. Effects of clove (*Syzygium aromaticum*) oil on quail growth, carcass traits, blood components, meat quality, and intestinal microbiota. *Poult. Sci.* 98:319–329.
- Kanatt, S. R., R. Chander, and A. Sharma. 2010. Antioxidant and antimicrobial activity of pomegranate peel extract improves the shelf life of chicken products. *Inter. J. Food Sci. Technol.* 45: 216–222.
- Khafaga, A. F., and A. E. Bayad. 2016a. Ginkgo biloba extract attenuates hematological disorders, oxidative stress and nephrotoxicity induced by single or repeated injection cycles of cisplatin in rats: physiological and pathological studies. *Asian J. Anim. Sci.* 10:235–246.
- Khafaga, A. F., and A. E. Bayad. 2016b. Impact of Ginkgo biloba extract on reproductive toxicity induced by single or repeated injection of cisplatin in adult male rats. *Int. J. Pharmacol.* 12: 340–350.
- Khafaga, A. F., M. E. Abd El-Hack, A. E. Taha, S. S. Elnesr, and M. Alagawany. 2019. The potential modulatory role of herbal additives against Cd toxicity in human, animal and poultry: a review. *Environ. Sci. Poll. Res.* 26:4588–4604.
- Khajuria, A., N. Thusu, and U. Zutshi. 2002. Piperine modulates permeability characteristics of intestine by inducing alterations in membrane dynamics: influence on brush border membrane fluidity, ultrastructure and enzyme kinetics. *Phytomedicine* 9:224–231.
- Kim, J. S., S. L. Ingale, Y. W. Kim, K. H. Kim, S. Sen, M. H. Ryu, J. D. Lohakare, I. K. Kwon, and B. J. Chae. 2011. Effect of supplementation of multi-microbe probiotic product on growth performance, apparent digestibility, cecal microbiota and small intestinal morphology of broilers. *J. Anim. Physiol. Anim. Nutr.* 95:632–641.
- Kishawy, A. T., S. A. Amer, M. E. Abd El-Hack, I. M. Saadeldin, and A. A. Swelum. 2019. The impact of dietary linseed oil and pomegranate peel extract on broiler growth, carcass traits, serum lipid profile, and meat fatty acid, phenol, and flavonoid contents. *Asian-Australas J. Anim. Sci.* 32:1161–1171.
- Kohlert, C., I. van Rensen, R. März, G. Schindler, E. U. Graefe, and M. Veit. 2000. Bioavailability and pharmacokinetics of natural volatile terpenes in animals and humans. *Plan. Méd.* 66:495–505.
- Leygonie, C., T. J. Britz, and L. C. Hoffman. 2011. Oxidative stability of previously frozen ostrich *Muscularis iliofibularis* packaged under different modified atmospheric conditions. *Int. J. Food Sci. Technol.* 46:1171–1178.
- Leygonie, C., T. J. Britz, and L. C. Hoffman. 2012. Impact of freezing and thawing on the quality of meat: review. *Meat Sci.* 91:93–98.
- Liu, G. D., D. J. Wang, G. Y. Hou, and Y. F. Chen. 2007. Effective of pigmentation in chicken vitelline with powdery *Abelmoschus esculentus* additive. *Chin. Agric. Sci. Bull.* (in press).
- Liu, G. D., G. Y. Hou, D. J. Wang, S. J. Lv, X. Y. Zhang, W. P. Sun, and Y. Yang. 2008. Skin pigmentation evaluation in broilers fed different levels of natural okra and synthetic pigments. *J. Appl. Poult. Res.* 17:498–504.
- Mahadevan, N., S. Shivali, and P. Kamboj. 2009. *Hibiscus sabdariffa* Linn. – an overview. *Nat. Product Rad.* 8:77–83.
- Marzoni, M., R. Chiarini, A. Castillo, I. Romboli, M. De Marco, and A. Schiavone. 2014. Effects of dietary natural antioxidant supplementation on broiler chicken and Muscovy duck meat quality. *Anim. Sci. Pap. Rep.* 32:359–368.
- Muhlisin, D. T. U., J. H. Lee, J. H. Choi, and S. K. Lee. 2016. Antioxidant enzyme activity, iron content and lipid oxidation of raw and cooked meat of Korean native chickens and other poultry. *Asian-Australas J. Anim. Sci.* 29:695–701.
- Nam, K. C., S. J. Hur, H. Ismail, and D. U. Ahn. 2001. Lipid oxidation, volatiles, and color changes in irradiated raw turkey breast during frozen storage. *J. Food Sci.* 67:2061–2066.
- Nasir, A., R. Aasima, K. Faneshwar, S. Vijay, and S. Vivek. 2017. Determinants of broiler chicken meat quality and factors affecting them: a review. *J. Food Sci. Technol.* 54:2997–3009.
- NRC, National Research Council. 1994. *Nutrient Requirements of Poultry*. National Academy of Sciences, Washington, D.C.
- Ocak, N., G. Erener, A. K. F. Burak, M. Sungu, A. Altop, and A. Ozmen. 2008. Performance of broilers fed diets supplemented with dry peppermint (*Mentha piperita* L.) or thyme (*Thymus vulgaris* L.) leaves as growth promoter source. *Czech J. Anim. Sci.* 53:69–175.
- Ordonez, A., J. Gomez, and M. Vattuone. 2006. Antioxidant activities of *Sechium edule*(Jacq.) swartz extracts. *Food Chem.* 97:452–458.
- Rao, L. H., L. Yi. Khizar, E. Karangwa, S. Q. Xia, C. C. Jia, and X. M. Zhang. 2011. Effect of ultrafiltration and fining adsorbents on the clarification of green tea. *J. Food Engin.* 102:321–326.
- Saeed, M., M. E. Abd El-Hack, M. Alagawany, M. Naveed, M. A. Arain, M. Arif, R. N. Soomro, M. Kakar, R. Manzoor, R. Tiwari, R. Khandia, A. Munjal, K. Karthik, K. Dhama, H. M. N. Iqbal, and S. Chao. 2017. Phytochemistry, modes of action and beneficial health applications of green tea (*Camellia sinensis*) in humans and animals. *Inter. J. Pharmacol.* 13:698–708.
- Saeed, M., A. A. Kamboh, S. F. Syed, D. Babazadeh, I. Suheryani, M. Umar Shah, I. Kakar, M. Naveed, M. E. Abd El-Hack, M. Alagawany, and S. Chao. 2018. Phytochemistry and beneficial impacts of cinnamon (*Cinnamomum zeylanicum*) as a dietary supplement in poultry diets. *World Poult. Sci. J.* 74:331–346.
- Scheuermann, G. N., A. Cunha Junior, L. Cypriano, and A. M. Gabbi. 2009. Phyto-genic additive as an alternative to growth promoters in broiler chickens. *Ciênc. Rur.* 39:522–527.
- Shewita, R. S., and A. E. Taha. 2018. Influence of dietary supplementation of ginger powder at different levels on growth performance, haematological profiles, slaughter traits and gut morphometry of broiler chickens. *S. Afr. J. Anim. Sci.* 48:997–1008.
- Singleton, V. L., R. Orthofer, and R. M. Lamuela-Raventós. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. *Methods Enzymol.* 299:152–178.

- SPSS. 2008. Statistical Package for the Social Sciences, Release 16. SPSS Inc, Chicago, IL.
- Swain, B. K., and T. S. Johri. 2000. Effects of supplementation of combinations of different levels of selenium and vitamin E on relative weight of some organs and serum enzymes level in broilers. *Indian J. Poult. Sci.* 35:66–69.
- Umamaheswari, A., R. M. Shreevidya, and A. Nuni. 2008. *In vitro* antibacterial activity of *Bougainvillea spectabilis* extracts. *Adv. Biol. Res.* 2:1–5.
- Xiong, Y. L. 2000. Protein oxidation and implications for muscle food quality. Pages 85–111. in *Antioxidants in Muscle Foods: Nutritional Strategies to Improve Quality*. E. Decker, C. Faustman and C. J. Lopez-Bote eds. John Wiley and Sons, New York, NY.
- Zhang, H., G. Qing-feng, W. Ke-bang, L. Xiao-chun, and W. Xue-mei. 2017. Effects of adding okra on growth performance, slaughter performance, meat quality and digestive enzymes activity of Danzhou chickens. *China Anim. Husb. Vet. Med.* 44:425–431.