Impacts of dietary supplementation of *Boswellia serrata* on growth, nutrients digestibility, immunity, antioxidant status, carcase traits and caecum microbiota of broilers

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**ABSTRACT**

This study evaluated the effect of *Boswellia serrata*, (BS) on growth performance, carcase traits, antioxidant and immune responses, digestive enzymes and caecum microbiota of broiler chickens. A total of 120 one-day-old Ross 308 chicks were randomly allotted into four treatment groups, each of five replicates. The 1st group was fed on a basal diet only and served as control. The 2nd, 3rd and 4th groups were fed the basal diet plus 0.5, 1 and 1.5 g BS/Kg diet, respectively. Body weight (BW) at 42 days old and daily body weight gain (DBWG) during (1–42 days) was linearly (<0.0001) enhanced with high BS levels compare with the control. The addition of BS to diets linearly and quadratic decreased feed intake, improved feed conversion ratio and digestion coefficients for diet ingredients, and most carcase traits compared to the control. The different levels of BS in chicks’ diets linearly increased globulin, total antioxidant capacity (TAC), superoxide dismutase (SOD) and digestive enzymes (amylase and lipase). While, the total cholesterol (TC), low-density lipoprotein (LDL) and malondialdehyde (MDA) were linearly and quadratic reduced in all experimental groups than the control. Total bacteria, total fungi and *E. coli* were linearly reduced in broiler chicks fed the diet supplemented with BS compared with control. It could be concluded that adding BS to broiler diets positively promoted performance, carcase traits, blood measurements, digestive enzymes, immunity organs, antioxidant parameters and caecal microorganisms.

**HIGHLIGHTS**

- Phytobiotics have a beneficial influence on poultry.
- *Boswellia serrata* contains a lot of active ingredients.
- It is expected to affect performance and health positively.

**Introduction**

Herbs and medicinal plants were used a long time ago because of their low side effects and they contain a lot of useful compounds as mentioned in the WHO recommendations (Kumar and Kumar 2010; Abd El-Hack and Alagawany 2015; Gado et al. 2019; Khafaga et al. 2019; Batıha et al. 2020). Using herbal medicine advanced in recent years, especially in developing countries, due to scientific evidence on using herbs to treat infection (Dhilhuydy and Patients 2003; Ashour et al. 2014; Ashour, Bin-Jumah et al. 2020; Ashour, El-Kholy et al. 2020; Abo Ghanima et al. 2020). Many research’s earlier showed that growth performance and carcase were significantly influenced in broilers-fed diets containing herbs (Arif et al. 2019). The beneficial effects of phytobiotic in poultry nutrition are not involved in progress in health status. Still, extended to enhance the performance, feed conversion rates and coefficients of diet nutrients, the phytobiotics increase the bioavailability of feed minerals (Alfaig et al. 2013; Taha et al. 2019).

Consumers request safe, high-quality food so that producers should give extra care to production-quality food steps to give extra care to production-quality food steps to give extra care to production steps in the poultry industry linked with the quality of poultry nutrition. Phytobiotics have a beneficial influence on the palatability and nutritional value of meat and safe for consumers’ health (Jh et al. 2014). *Boswellia serrata* contains many active ingredients used as feed additives for poultry EURFA (EURFA 2015). *Boswellia* is cultivated in many countries (Africa, Arabian countries, Pakistan and India); it has known as frankincense,
olibanum, salaiuggal, loban or kundur (Afsharypuor and Rahmany 2005). *Boswellia* contains several Triterpentinoids of the lupane, ursane, oleanean and tirucallane skeletal types Badria et al. (2003) also, Individual terpentinoids included lupeol, beta boswellic acid, 11-keto and acetyl beta boswellic acid, acetyl alpha boswellic acid and 3 o xo and 3 hydroxytriaclic acids. It is hypothesised that the use of *Boswellia serrata* in poultry diets is expected to positively affect performance and health. Thus, this study aimed to investigate the effects *Boswellia serrata* on growth performance, carcass traits, blood biochemistries, antioxidant and immune measurements, digestive enzymes and caecum microbiota of broiler chickens.

**Material and methods**

**Design and diets**

A total of 120 chicks of one-day-old Ross 308 were randomly allotted into four treatment groups, each of five replicates (each of six birds). Chicks had nearly equal average initial body weight of all treated groups. The first group was fed on basal diet only and served as control. The second, third and fourth groups were fed the basal diet plus a 0.5, 1 and 1.5 g BS/Kg diet. According to NRC (1994), the basal diet was formulated to cover the nutritional requirements from 1–42 days of age (Table 1). *Boswellia serrata* was bought from the botanicals, spices and herpes market. *Boswellia* was gently mixed with a portion of the basal diet then, mixed with all the experimental diets. All chicks were reared under the same managerial and healthy conditions. Diet and water were provided *ad libitum* and daylight except an hour was preserved during the whole experimental period. Chicks were individually weighed at 1, 14, 28 and 42 days of age. Feed consumption was listed weekly until marketing age on a replicate basis. Consequently, feed conversion (g feed/g gain) and body weight gain were estimated during each experimental period (1–14, 14–28, 28–42 and 1–42 days of age).

**Blood parameters**

At the end of the experiment, ten birds from each group were chosen randomly, weighed and slaughtered to obtain blood samples. Blood samples were collected into tubes with EDTA to determine the possible impact of treatments on some blood constituents. The tubes were closed with a rubber stopper and gently shacked to mix the anticoagulant with the blood to estimate haematology, including white blood cells (WBCs) count (×103/mm³), lymphocyte (%), Monocytes (%) and Heterocytes (%) (Stokosf et al. 1983).

Plasma was isolated by centrifugation of the whole blood at 3000×g for 20 minutes. According to the Biuret method, the total protein (g/dL) was colorimetrically estimated (Weichseibaum 1946). The condensation of albumin (g/dL) was estimated calorimetrically (Wise 1965). Globulin values (g/dL) were studied by subtraction of albumin values of total protein concentration. Triglycerides and total cholesterol were estimated as recommended by Allain et al. (1974). Serum cholesterol was colorimetrically determined according to the following reactions:

- cholesterol ester + \( H_2O \xrightarrow{\text{cholesterol esterase}} \) cholesterol + fatty acids
- Cholesterol ester + \( \text{H}_2\text{O} \xrightarrow{\text{cholesterol oxidase}} \text{cholesten-3 one} + \text{H}_2\text{O} \)
- \( 2\text{H}_2\text{O}_2 \xrightarrow{\text{phenol peroxidase}} \text{red quinon + 4H}_2\text{O} \)

The obtained colour was spectrophotometrically measured at wavelength of 500 mm using cuvette depth 1 cm.

| Ingredients                  | Starter (1–14 day) | Grower (14–28 day) | Finisher (28–42 day) |
|------------------------------|--------------------|--------------------|----------------------|
| Yellow corn                  | 57.00              | 61.40              | 65.74                |
| Soybean meal (48%)           | 35                 | 30                 | 25                   |
| Corn gluten meal             | 2.5                | 2.5                | 2.5                  |
| Limestone                    | 1.89               | 1.96               | 1.96                 |
| Dicalcium phosphate          | 1.9                | 1.8                | 1.6                  |
| Sodium chloride              | 0.25               | 0.25               | 0.25                 |
| DL-Met                       | 0.20               | 0.15               | 0.13                 |
| L-Lys HCl                    | 0.15               | 0.13               | 0.01                 |
| Oil                          | 0.8                | 1.5                | 2.5                  |
| Sodium bicarbonate           | 0.01               | 0.01               | 0.01                 |
| Broiler vitamin-mineral premixa | 0.3               | 0.3                | 0.3                  |
| Total                        | 100                | 100                | 100                  |

Calculated analysisa

| DM %                         | 87.5               | 86.73              | 85.92                |
| Crude protein (CP %)         | 23.2               | 21.0               | 19.0                 |
| Metabolie energy (k cal/kg)  | 2950               | 3020               | 3125                 |
| Ether extract (EE %)         | 3.44               | 4.25               | 5.33                 |
| Crude fibre (CF %)           | 2.42               | 2.36               | 2.30                 |
| Ash                          | 2.76               | 2.55               | 2.34                 |
| Ca                           | 1.20               | 1.18               | 1.12                 |
| Available phosphorus         | 0.50               | 0.47               | 0.43                 |
| Lys                          | 1.39               | 1.22               | 1.00                 |
| Met                          | 0.60               | 0.53               | 0.48                 |
| Met + cys                    | 0.97               | 0.87               | 0.79                 |

aBroiler vitamin-mineral premixa Provided the following per 1.5 kg: vitamin A, 12,000,000 IU; vitamin D3, 3000,000 IU; vitamin E, 40,000 mg; vitamin K, 3000 mg; pantothenic acid, 12,000 mg; B1, 2000 mg; B2, 6000 mg; B6, 5000 mg; B12 20 mg; niacin, 45,000 mg; biotin, 75 mg and folic acid 2000 mg. Mineral premix Provided the following per 1.5 kg: I 1000 mg; Mn, 100,000 mg; Cu, 10,000 mg; Zn, 60,000 mg; Se, 200 mg; Fe, 30,000 mg; choline 260000 mg. Cobalt 100 mg.

bCalculated according to NRC (1994).
The concentration of cholesterol was calculated using the following formula:

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\text{Concentration of cholesterol (mg/dl)} = \frac{A \text{ sample}}{A \text{ standard}} \times n
\]

Where: \(A\) = Absorbance, \(n\) = standard concentration of enzymes.

High-intensity lipoprotein, HDL; (Warnick et al. 2001), low-intensity lipoprotein (LDL); (Friedewald et al. 1972) and liver enzymes activity; alanine-aminotransferase (ALT) and aspartate-aminotransferase (AST) (Reitman and Frankel 1957). Amylase activity was estimated (Somogyi 1960). Lipase action was examined by the technique (Tietz et al. 1966). Protease activity was measured (Lynn and Clevette-Radford 1984). Total antioxidant capacity (TAC) was determined according to Koracevic et al. (2001), superoxide dismutase (SOD) level was determined spectrophotometrically (Nishikimi et al. 1972), malondialdehyde (MDA) (Uchiyama and Mihara 1978). Gama Immunoglobulin (IgG) was dissolved by ELISA technique (Bianchi et al. 1995).

**Digestibility coefficients**

At the study’s termination, five birds per each group were used in digestibility trials to obtain the apparent digestion coefficients of each dietary nutrient and calculate the experimental diets’ nutritional values. Birds individually settled in a metallic cage and fed their respective trail diets. The preliminary period continued for three days and the collection period extended to five days in which excreta were quantitatively collected every 24 hours and daily intake was recorded. The excreta were cleanout from feathers and diet, then weighed and dried in an oven at 70°C for thirty-six hours. At the end samples were ground and placed in screw _top_ glasses till analysis. The direct analysis of diets and excreta was executed according to AOAC (2006). Faecal nitrogen was estimated as the procedure (Jakobsen et al. 1960). Nutritive values were calculated as total digestible nutrients (TDN) and metabolisable energy (ME) TDN, according to Titus (1960).

**Carcass characteristics**

At 42 days, ten birds per group were chosen, randomly fasted overnight and weighted, slaughtered. After that, birds were scalped, de-feathered and carcasses were removed. The heart, gizzard, liver, spleen, thymus and bursa were excised and weighed. The carcase characteristics were a carcase, giblets (liver, heart and gizzard) and dressing (dressed percentage = carcase weight inclusion giblets weight/a live weight × 100). 

**Microbiology traits**

Caecum digesta samples were taken of each broiler chick as fresh digesta 1 g of the middle portion from the caecum and hold in bottles with a CO₂ current and transport into the laboratory to estimate bacterial counts (Xia et al. 2004; Alagawany et al. 2018).

**Statistical analysis**

Data were statically analysed by using the GLM procedure of SAS (package program, 2008). The linear and quadratic effects of bile acids level were assessed using orthogonal polynomials. Results are reported as means. A _p_-value of less than .05 was considered statistically significant.

**Results and discussion**

**Growth performance**

The growth performance is clarified in Table 2. The different levels of *Boswellia serrata* (BS) linearly (_p_ < .0001) increased LBW at 42 days old and DBWG during 28–42 and 1–42 days old, respectively. The highest overall BW and DBWG values (_p_ < .0001) were noted in BS 1.0 and 1.5 g/kg diets compared to the control and other groups. Chicks that received different levels of BS diets linearly (_p_ = .0019), quadratically (_p_ = .0185) and quadratically (_p_ = .0173) consumed less feed than the control throughout 14–28, 13–28 and 1–42 days of age, respectively. Chicks fed a diet supplemented with BS at different levels (0.5, 1.0 and 1.5 g/kg) had linearly (_p_ = .0019, .0010 and <.0001, respectively) improved FCR than the control throughout 14–28, 13–28 and 1–42 days of age, respectively. While values were quadratically (_p_ = .0152 and .0020, respectively) improved during 14–28 and 1–42 days of age, respectively. However, chicks received 1.0 g BS/kg recorded the best FCR than control and other groups.

The present work showed advantages of dietary enriched with *Boswellia S* on the LBW and BWG of broiler chickens, the same trend obtained by Al-Yasiry et al. (2017) who cleared that chicks fed diets supplemented with (3, 4, or 5%) of *Boswellia serrata* had a favourable impact on broiler growth attitude; this finding is regular with prior finds by Kiczorowska et al. (2016). Also, Al-Yasiry et al. (2017) found that
the addition of BS at 2.0–2.5% in diets enhanced the broiler growth than control chickens. Similarly, Ismail et al. (2019) indicated that LBW and BWG were improved in growing rabbits fed diets enriched with BS. The improvement in LBW and BWG by BS may be due to stimulating the ability to digestible nutrients and absorption by some active compounds (such as boswellic acid) (2016). Also, the improvement of growth by BS supplementation in broiler diet may be due to boswellic acid in BS which reducing nutrients consumption such as energy and protein by microbial in the host for subclinical infection, consequently improve growth enhance and decrease the ammonia production and also, excretion of immune intercessor (Dibner and Buttin 2002; Chevrier et al. 2005). Our results revealed that the use of 1.0 g/kg diet of Boswellia significantly reduced feed intake and improve feed efficiency. These results disagree with the finding by Tabatabaei et al. (2012), who reported that birds fed diet contained 0.5% BS had the poorest FCR comparative with control birds within the grower interval. On the other hand, our results harmonise with previous findings, which clarified that dietary enriched with some plant extracts improved growth performance and FCR in broiler chickens (Bampidis et al. 2005; Griggs and Jacob 2005).

Table 2. Growth performance of broiler chicks affected by different levels of Boswellia serrata.

| Boswellia serrata levels (g/kg diet) | p value |
|--------------------------------------|---------|
|                                      | 0       | 0.5   | 1.0   | 1.5   | SEM | Linear | Quadratic |
| Live body weight (g)                 |         |       |       |       |     |        |           |
| 1-14                                 | 0.0171  | 0.0141| 0.0127| 0.0141| .0037| .0001  | .0012     |
| 14-28                                | 0.0159  | 0.0139| 0.0127| 0.0141| .0037| .0001  | .0012     |
| 28-42                                | 0.0171  | 0.0141| 0.0127| 0.0141| .0037| .0001  | .0012     |
| Daily feed intake (g/day)            |         |       |       |       |     |        |           |
| 1-14                                 | 0.0171  | 0.0141| 0.0127| 0.0141| .0037| .0001  | .0012     |
| 14-28                                | 0.0159  | 0.0139| 0.0127| 0.0141| .0037| .0001  | .0012     |
| 28-42                                | 0.0171  | 0.0141| 0.0127| 0.0141| .0037| .0001  | .0012     |

Means within the same row with different common superscripts differ significantly.

Table 3. Digestion coefficient and nutritive values affected by different levels of Boswellia serrata.

| Boswellia serrata levels (g/kg diet) | p Value |
|--------------------------------------|---------|
|                                      | 0       | 0.5   | 1.0   | 1.5   | SEM | Linear | Quadratic |
| DM                                   | 0.0001  | 0.0001| 0.0001| 0.0001| .0001| .0001  | .0001     |
| OM                                   | 0.0001  | 0.0001| 0.0001| 0.0001| .0001| .0001  | .0001     |
| CP                                   | 0.0001  | 0.0001| 0.0001| 0.0001| .0001| .0001  | .0001     |
| FE                                   | 0.0001  | 0.0001| 0.0001| 0.0001| .0001| .0001  | .0001     |
| NFE                                  | 0.0001  | 0.0001| 0.0001| 0.0001| .0001| .0001  | .0001     |
| TDN                                  | 0.0001  | 0.0001| 0.0001| 0.0001| .0001| .0001  | .0001     |
| ME                                   | 0.0001  | 0.0001| 0.0001| 0.0001| .0001| .0001  | .0001     |

Means within the same row with different common superscripts differ significantly.

Data presented in Table 3 show that chicks received diets containing 0.5, 1.0, or 1.5 g BS/kg diet had a linearly and quadratically higher digestion coefficient for crude protein (CP). While, values of ether extract (EE) and crude fibre (CF) were linearly (p < .0001) reduced than the control. A quadratic enhances the digestion coefficients of dry matter (DM) and the nutritional values (TDN and ME) in the chicks fed a diet supplemented with different BS/kg levels compared to control.

The highest value of the digestion coefficient of CP, EE, CF and nutritional values (TDN and ME) were observed with chicks given 1.0 g BS/kg diet compared with broiler chicks received 0.5 or 1.5 g BS/kg and control. It is worth to note that the high digestion coefficient of nutrients and nutritional values were observed in chicks’ group diet inclusion 0.5 or 1.0 g BS/kg diet. The BS impact is linked with high sucking, which raises the produce enzymes of digestion and enhances growth, morphology of intestinal villi, and lowers the fast of material transit (Panda et al. 2009). Healthy gut and morphology lead to improving the availability of nutrients and enhancing organic matter digestibility of diet (AI-Yasiry et al. 2017). Similarly, the positive effect of Boswellia serrata on the gut was previously observed (Kiczorowska et al. 2016). In this context, Rao et al. (2001) stated that a feeding diet enriched with Boswellia improved appetite and enhanced flowing the digestive juices, consequence enhancement digestion pathway and absorption. Qurishi et al. (2010) confirmed that boswellic acid stimulates these secretions of pancreatic enzymes, consequently enhances protein and energy digestibility and reduces endogenous nitrogen and ammonia wastage. Dzubak et al. (2006) demonstrated that boswellic acid had an inducing effect on liver functions.
Besides, Khalaji et al. (2011) reported that villi length and crypt depth were enhanced to improve nutrient absorption when plant extracts were used in feeding. Results are in agreement with Kiczorowska et al. (2016). They found that dietary Boswellia resin at the levels of 2.0 and 2.5% increase the digestibility of organic matter and dry matter and an upward trend in energy digestibility of broiler chicks compared to the control group.

**Carcasse traits**

The impacts of diets enriched with *Boswellia serrata* on the carcasse measurements of chickens are illustrated in Table 4. Most carcasse measurements were affected by BS’s addition, except the percentages of carcasse and dressing that were not impacted (p > .05) by BS diet. The different BS levels linearly (p = .0081 and .0080, respectively) enhanced liver and heart relative weights, respectively compared to the control. While, a quadratic (p = .0207 and .0142, respectively) increases were observed in relative weights of gizzard and giblets respectively compared to the control. Likely, Al-Yasiry et al. (2017) concluded that chickens fed on diet contained 2.0–2.5% *Boswellia serrata* improved (p < .05) carcasse quality compared with non-treated chickens. In contrast, Ismail et al. (2019), in growing rabbits, showed that the most traits of carcasse and edible organs insignificantly affected in group fed diet enriched with BS than control. The previous studies also proposed that carcasse characteristics were not influenced by natural feed additives such as (cinnamon, ginger extracts, pepper, *Echinacea angustifolia* and oil thyme) when supplemented to diet (Costa et al. 2011; Abdelnour et al. 2018).

**Protein and lipid fractions**

The impacts of dietary plus *Boswellia* S. on plasma metabolites of broiler chicks are stated in Table 5. The influence of BS was detected in albumin, globulin, A/G ratio, TC, HDL, and LDL while, plasma TP and TG the changes were insignificant (p > .05). The overall BS levels supplementation linearly reduced (p = .0147) blood albumin values. Globulin concentration was linearly (p = .0248) increased as compared to the control group. A/G ratio was linearly and quadratically lower than the control. Moreover, BS at 0.5, 1.0 and 1.5 g/kg linearly and quadratically reduced TC and LDL values compared to the control group. Triglycerides and HDL values were linearly and quadratically enhanced in broilers fed diet plus BS. Whereas, levels of 1.0 and 1.5 g BS/kg produced higher HDL concentration than that of the other treatment groups. Proteins of plasma are good changeful checking the nutritional and health case of the immune functions and enzymatic, which have multifunction in the body (Al-Yasiry et al. 2017).

Our finding showed an increase in globulin values and this agent responsible for good health. In

### Table 4. Relative weights of carcasse traits as affected by different levels of *Boswellia serrata*.

| Items      | Boswellia serrata levels (g/kg diet) | SEM | p Value       |
|------------|--------------------------------------|-----|---------------|
|            | 0         | 0.5 | 1.0 | 1.5 | Linear | Quadratic |
| Carcase (%)| 63.23     | 65.86 | 63.47 | 64.43 | 1.069 | .8178 | .4912 |
| Liver (%)  | 2.55      | 2.72  | 2.58  | 3.17  | 0.088 | .0081 | .0910 |
| Heart (%)  | 0.52      | 0.61  | 0.53  | 0.71  | 0.030 | .0080 | .1761 |
| Gizzard (%)| 3.46      | 3.46  | 2.87  | 3.51  | 0.091 | .3932 | .0207 |
| Giblets (%)| 6.53      | 6.80  | 5.97  | 7.39  | 0.180 | .0671 | .0142 |
| Dressing (%)| 69.76  | 72.66 | 69.44 | 71.82 | 1.097 | .6050 | .0665 |

Means within the same row with different common superscripts differ significantly.

### Table 5. Total protein, its fractions and lipid profile parameters as affected by different levels of *Boswellia serrata*.

| Items       | Boswellia serrata levels (g/kg diet) | SEM | p Value       |
|------------|--------------------------------------|-----|---------------|
|            | 0         | 0.5 | 1.0 | 1.5 | Linear | Quadratic |
| Total Protein (g/dL) | 3.92  | 3.84  | 4.02  | 3.94  | 0.176 | .8078 | 1.0000 |
| Alb (g/dL)  | 3.00      | 2.01  | 2.38  | 2.08  | 0.169 | .0147 | .0850 |
| Glob (g/dL) | 0.92      | 1.83  | 1.64  | 1.86  | 0.175 | .2468 | .1475 |
| A/G (%)     | 3.35      | 1.12  | 1.68  | 1.13  | 0.289 | .0038 | .0388 |
| Total Cholesterol (mg/dL) | 65.37 | 51.07 | 50.06 | 52.32 | 2.13  | .0060 | .0091 |
| Triglycerides (g/dL) | 45.38 | 61.36 | 59.7  | 48.06 | 4.385 | .7629 | .0164 |
| HDL (mg/dL) | 18.55 | 18.77 | 22.27 | 28.59 | 0.866 | <.0001| .0101 |
| LDL (mg/ dL) | 37.75 | 20.04 | 15.85 | 14.13 | 2.02  | <.0001| .0064 |

Means within the same row with different common superscripts differ significantly.

Alb = Albumin, Glob = Globulin, HDL = High-density lipoprotein and LDL = low density lipoprotein.
contrast, higher globulin concentrations are a worthy index of produce anti-bodies and immunological response (Scanes 2015). The findings in Table 5 cleared that a significant reduction in the TC and LDL content in chickens fed with BS diet. Besides, it has been indicated that the addition B. serrata by 0.5, 1.0, or 1.5 g/kg significantly reduced levels than control chicks. In agreement with our findings by Abd El-Hack, Mahgoub et al. (2018) and Abdelnour et al. (2018), the addition of phytogenic additives to the diet due to reduced blood lipids. Several plant sterols inhibit the intestinal absorption of dietary cholesterol (Akamatsu et al. 2004).

The same trend was obtained by Ismail et al. (2019) in growing rabbits treated by BS. Furthermore, the addition of medicinal plants or flavouring in rabbit diets could be backing enzymes efficiency participate in cholesterol processing into bile acids, which due to lowering the cholesterol level of rabbit carcass (Abdelnour et al. 2018). Our findings also agree with Ravi et al. (2005), who reported that HDL values were increased in rats treated with BS extract. They added that this increase in HDL shows the cardioprotective effect of BS extract.

**Liver and kidney functions**

For liver and kidney functions, ALT and AST were quadratically \( p = .0040 \) and .0485, respectively) increased compared to the control group. Total bilirubin was linearly higher than the control. While, direct bilirubin, creatinine and uric acid were not affected by dietary *Boswellia serrata* (Table 6). The liver plays a major role in the body, so the enzymes of the liver are an effective index of the healthy case of broiler chicks fed *Boswellia S.* According to our result, it was proposed that quick metabolisation of secondary cracks in the liver of medicinal plants may because impairment of its job, therefore, enhance liver enzyme values (AST and ALT) (Abdelnour et al. 2018). On the contrary, liver enzyme concentrations reduced significantly but within the normal values in broilers fed diet plus 3 to 5% of *B. serrata* (Al-Yasiry et al. 2017). *Boswellia S.* has natural flavonoids and polyphenols; these compounds were due to have strong hepatoprotective effects (Akamatsu et al. 2004).

**Relative lymphoid organs, some immune measurements and oxidative parameters**

The comparative weight of thymus gland was linearly \( p = .0004 \) and quadratically \( p = .0390 \) increased in birds fed diet plus BS. The relative weight of spleen linearly \( p = .0416 \) enhanced in BS groups than the control group (Table 7). It is worth noting that the highest comparative weights of thymus and spleen were recorded in birds fed diets supplemented with 1.5 g/kg diet. In contrast, BS supplementation to broiler diet numerically increased the relative weight of bursa compared with the untreated birds. In the current study, WBCs, monocytes % and lymphocytes % were insignificantly impacted by the *Boswellia* trail. While, heterocyst % was quadratically \( p = .0063 \) reduced in birds fed diet plus BS compared to the control (Table 7).

Regrettably, there has been no other available regarding the impacts on bird’s immunity of *Boswellia* to our better. While Al-Yasiry et al. (2017) observed that bursa weight values were \( p < .5 \) higher in chickens given drinking water enriched with 3 g BS/L water and pursue in impact (2 g BS/L water) comparative to the control. Camarda et al. (2007) noted that *Boswellia* has an antifungal effect, also antimicrobial (Rajendra et al. 2013), Anti-Inflammatory (Siddiqui 2011), Antioxidant activates (Frank and Unger 2006) and immune-modulatory (Frank and Unger 2006) broiler have more resistance against disease with the larger synthesis of immune globulins with larger bursa of Fabricius (Yamamoto and Glick 1982) and rising antibody titres in chicks having a higher weight of bursas (Sadler and Glick 1962).

**Table 6.** Liver and kidney functions as affected by different levels of *Boswellia serrata*.

| Items               | Boswellia serrata levels (g / kg diet) | p Value       |
|---------------------|----------------------------------------|---------------|
|                    | 0           | 0.5       | 1.0       | 1.5       | SEM   | Linear | Quadratic |
| Liver function      |             |           |           |           |       |        |           |
| ALT (u/L)           | 4.73        | 7.89      | 8.10      | 5.62      | 1.126 | .5914  | .0404     |
| AST (u/L)           | 178.77      | 212.21    | 221.18    | 205.49    | 9.633 | .1037  | .0485     |
| Total bilirubin (mg/dL) | 0.52    | 0.44      | 0.59      | 0.63      | 0.036 | .0236  | .1677     |
| Direct bilirubin (mg/dL) | 0.10    | 0.13      | 0.14      | 0.13      | 0.009 | .0767  | .1434     |
| Kidney function     |             |           |           |           |       |        |           |
| Creatinine (mg/dL)  | 0.68        | 0.73      | 0.71      | 0.60      | 0.047 | .2748  | .1515     |
| Uric acid (mg/dL)   | 5.69        | 4.94      | 5.34      | 4.78      | 0.493 | .3922  | .8718     |

Means within the same row with different common superscripts differ significantly.

ALT: Alanine-aminotransferase; AST: Aspartate-aminotransferase.
Data in Table 7 showed that Gama immunoglobulin (IgG) was linearly and quadratically enhanced. While, SOD and TAC values were linearly improved in broilers fed diet plus *Boswellia* compared to control birds. Also, MDA was linearly improved than the control. Our finding partially agreed with Ismail et al. (2019) who found that WBCs and lymphocytes were slightly reduced than control groups in most groups fed diet plus *Boswellia serrata*. The anti-oxidant action of plant extractor or its secondary cracks is sincerely linked with its polyphenols’ content, reflecting the efficient bioactive compounds that, having anti-oxidant activity (Abd El-Hack, Ashour et al. 2018). Phenolic compounds enhance the protein and energy efficiency by reducing the host with microbials on nutrients and endogenous nitrogen damage by decreasing subclinical infections and immune intercessors secretion and lowering ammonia production (Chevrier et al. 2005).

### Digestive enzymes

Digestive enzymes (amylase and lipase) values were quadratically ($p \leq .0001$ and .0002, respectively) higher in BS chicks than control while protease enzyme was linearly and quadratically decreased with grading BS levels as shown in Table 8. The impact of BS is linked with elevation absorption, which induced digestive enzymes releasing, consequently improving performance, the morphology of intestinal villi, and detracting material crossing’s rapidity (Panda et al. 2009). Similarly, the positive impact of *Boswellia* S on the gut was previously observed (Kiczorowska et al. 2016). The intestine’s healthy structure and functions are also due to improving nutrients availability and enhancing the organic matter digestibility of diet (Al-Yasiry et al. 2017).

### Bacteriology

Adding BS to broiler diets led to significant ($p < .01$) differences in microbial population’s content of caecum (Table 9). It was cleared that chicks fed diet plus 0.5, 1.0, or 1.5 g/kg BS linearly reduced ($p = .0012$ and $p < .0001$, respectively) total bacterial count (TBC) and *E. coli* when compared to control chicks. While total fungi were linearly and quadratically reduced in treated chicks with BS compared to the control. Chicks received *Boswellia* S at different levels numerically recorded the lowest *Salmonella enteritidis* PT4 count compared to the control. Chick's caecum content of microbial kinds influenced by BS, in the present study, dietary BS resulted in appearance lowering. Raise BS level from 0.5 to 1.5 g/kg in the diet lowered the count of *E. coli*, total bacterial and *S. enteritidis* spp. in

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### Table 7. Relative weight of lymphoid organs, some immune parameters, and oxidative parameters of broiler chicks as affected by different levels of *Boswellia serrata*.

| Items          | Boswellia serrata levels (g/kg diet) | SEM | p Value       |
|----------------|--------------------------------------|-----|---------------|
|                | 0         | 0.5   | 1.0   | 1.5         | Linear | Quadratic |
| Thymus %       | 0.28      | 0.38  | 0.32  | 0.58        | 0.030  | .0004     | .0390    |
| Spleen %       | 0.15      | 0.21  | 0.24  | 0.25        | 0.029  | .0416     | .4118    |
| Bursa %        | 0.11      | 0.13  | 0.10  | 0.12        | 0.023  | .8663     | .9608    |
| WBCs ($\times 10^3$ m$^{-1}$) | 26.42 | 26.14 | 24.91 | 27.19       | 1.720  | .0055     | <.0001   |
| Lymph (%)      | 46.96     | 48.39 | 47.21 | 45.78       | 0.792  | .3644     | .0063    |
| Mono (%)       | 6.83      | 8.05  | 5.95  | 7.45        | 0.018  | .8754     | .6924    |
| Hetero (%)     | 63.96     | 53.33 | 52.14 | 60.62       | 1.973  | .3495     | .0063    |
| IgG (nmol/ml)  | 220.17    | 398.50| 309.00| 274.00      | 3.985  | .0055     | <.0001   |
| MDA (nmol/mL)  | 0.25      | 0.25  | 0.24  | 0.15        | 0.020  | .0011     | .5490    |
| SOD (nmol/mL)  | 0.13      | 0.16  | 0.22  | 0.22        | 0.015  | .0018     | .4260    |
| TAC (nmol/mL)  | 0.15      | 0.18  | 0.19  | 0.21        | 0.007  | .0111     | .5490    |

Means within the same row with different common superscripts differ significantly.

WBCS: White blood cells count; Lymph: lymphocyte; Mono: Monocytes; Hetero: Heterocytes; IgG: Gama immunoglobulin; MDA: Malondialdehyde; SOD: Superoxide dismutase; TAC: Total antioxidant capacity.

### Table 8. Digestive enzymes as affected by different levels of *Boswellia serrata*.

| Items     | Boswellia serrata levels (g/kg diet) | SEM | p Value       |
|-----------|--------------------------------------|-----|---------------|
|           | 0         | 0.5   | 1.0   | 1.5         | Linear | Quadratic |
| Amylase (u/L) | 163.50 | 313.00| 192.00| 208.00      | 4.748  | .5864     | <.0001   |
| Lipase (u/L) | 17.26  | 48.79 | 30.52 | 24.66       | 2.973  | .7747     | .0002    |
| Protease (u/L) | 0.25  | 0.32  | 0.17  | 0.14        | 0.006  | <.0001    | <.0001   |

Means within the same row with different common superscripts differ significantly.
the caecum of broiler because of the powerful anti-microbial impact of BS due to the high content of Boswellic acid and polyphenols (Camarda et al. 2007; Kiczorowska et al. 2016).

Chevrier et al. (2005) observed that *Boswellia carterii* extract dampen TH1 cytokines and induced TH2 cytokines in vitro. The plant extracts or their subordination cracks have anti-microbial impacts due to their polyphenols’ content reversing efficient bioactive compounds with anti-microbial and anti-oxidant activity (Abd El-Hack et al. 2018). Polyphenols may modify the pH gradient and the cell membrane of bacterial potential due to *Salmonella* and *E. coli* intracellular ATP content (Alagawany et al. 2018). In the current time, medicinal plants are used as substitution pharmaceutical drugs to prevent Gram-negative bacteria growth.

### Conclusions

Thus, we concluded from our study that *Boswellia serrata* (1 g/kg diet) positively promotes performance and carcass traits, blood measurements, digestive enzymes, immunity organs, antioxidant parameters and caecal microorganism’s content of broiler chickens.

### Ethical approval

All procedures of the current study were followed according to the Directive 2010/63/EU of the European Parliament and the Council of 22 September 2010, on the safety of animals used for scientific purposes. The experimental protocol regarding the care and handling of animals had been approved by the Ethics Committee of the Department of Poultry, Faculty of Agriculture, Zagazig University, Egypt.

### Disclosure statement

The authors declare that there is no conflict of interest associated with the paper. The authors alone are responsible for the content and writing of this article.

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### Table 9. Bacterial content as affected by different levels of *Boswellia serrata*.

| *Boswellia serrata* levels (g/kg diet) | SEM | Linear | Quadratic |
|--------------------------------------|-----|--------|-----------|
| CFU/g | 0 | 0.5 | 1.0 | 1.5 | p Value |
| Total Bacteria | 187.50 | 155.00 | 120.00 | 71.00 | 14.073 .0012 .6513 |
| Total Fungi | 9.50 | 23.50 | 6.50 | 4.00 | 1.083 .0001 <.0001 |
| E. coli | 70.50 | 50.00 | 23.50 | 19.50 | 4.258 <.0001 .1241 |
| Salmonella | 74.67 | 69.00 | 58.00 | 66.01 | 5.729 .1973 .2789 |

Means within the same row with different common superscripts differ significantly. CFU/g: Colony ForUnit/gram.

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