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# Effects of Echinacea purpurea extract in drinking water on growth performance, carcass characteristics, blood biochemistry, meat quality, and cecal microbiota in broiler chickens

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SUMMARY

This study explored the potential of Echinacea purpurea extract (**EPE**) as a natural additive in broiler production, focusing on its effects when added to drinking water. The experiment was conducted using a completely randomized design; a total of 210 Ross 308 broiler chicks were divided into three groups: a control group receiving water without EPE supplementation (**CTRL**), and two treatment groups supplemented with EPE at concentrations of 3.0 mL/L (**T1**) and 6.0 mL/L (**T2**). The trial monitored a varied range of parameters, involving growth performance, feed utilization, carcass composition, blood biochemical markers, meat quality traits, cecal microbiota composition, and economic efficiency. Results showed that birds receiving EPE had significantly ($P \leq 0.05$) improved live body weight (**LBW**), body weight gain (**BWG**), lower feed intake (**FI**), better feed conversion ratio (**FCR**), and more favorable water-to-feed intake (**W/F** ratio). Carcass assessments revealed increased liver and total giblets weights. Blood analysis indicated improved ($P \leq 0.05$) liver and kidney functions, healthier lipid profiles, higher antioxidant enzyme activity (GPx, GSTs, and GSH), lower MDA levels, and elevated levels of IgG and IgM antibodies. In terms of meat quality, EPE supplementation contributed to more stable pH, improved color parameters, and meat water retention traits, and reduced bacterial contamination. Microbial analysis of cecal content showed a substantial ($P \leq 0.001$) reduction in harmful bacteria accompanied by an increase in beneficial Lactobacillus species. The chickens that received 3 ml/L of EPE (T1) had the highest total return (**EGP**) compared to other treatments and the untreated group. All of the results in the existing study point to the convergence of the physiological and microbiological improvements brought forth by EPE, which advances both product quality and broilers' performance, and also produces obvious economic benefits.

**Primary Audience**: Nutritionists, poultry keepers, researchers, and feedmills.

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## Description of Problem

The poultry industry, including both large-scale production and smallholder systems, continues to face global challenges such as limited feed resources, disease outbreaks, suboptimal breeding practices, and inadequate regulatory frameworks—all of which can negatively affect productivity and animal wellbeing (Kamal et al., 2025).

While the use of artificial growth promoters, e.g., antibiotics, has brought tangible benefits to poultry's health and performance, their overuse has raised serious public health concerns due to the emergence of antibiotic-resistant bacteria. Poultry can transmit these resistant pathogens to humans, posing risks to food safety and public health (Muhammad et al., 2020; Zheng et al., 2025). As a result, attention has shifted toward finding safer, natural alternatives to synthetic chemotherapeutics. Among the most promising options are medicinal herbs and their bioactive constituents, many of which have long-standing applications in traditional medicine for both humans and animals.

Herbal plants are rich in bioactive substances such as flavonoids, polyphenols, terpenoids, and alkaloids, which possess diverse biological properties, including antimicrobial, anti-inflammatory, antiviral, antioxidant, as well as immunomodulatory effects (Elsherbeni et al., 2025). One such plant, Echinacea purpurea (commonly known as purple coneflower), has gained increasing interest due to its broad pharmacological activities. Its leaves are particularly rich in trace elements, e.g., copper, zinc, nickel, and magnesium, and the plant contains numerous bioactive compounds, like caffeic acid derivatives, alkylamides, glycoproteins, and polysaccharides (Tinkov et al., 2025; Elnesr et al., 2025; Awortwe et al., 2021; Ren et al., 2023).

Historically, E. purpurea has been used for the treatment of bacterial and virus-related infections, as well as for its "anti-toxin" properties in cases of snake venom or blood poisoning. It has also been traditionally applied in managing conditions such as nasopharyngeal inflammation, tonsillitis, non-healing superficial wounds, and regular infections of the urinary and respiratory tracts (Barnes et al., 2005). More recently, supplementation with Echinacea in poultry diets was linked to improved growth performance, enhanced immune response, lower feed conversion ratios (FCR), and enhanced digestive system integrity and antioxidant grade (Rady et al., 2023; Wang et al., 2024). In addition, Echinacea supplementation also enhanced immunological response, increased antibody titers, and changed intestinal immunity in broilers vaccinated against avian influenza (Zhang et al., 2023). Also, broilers treated with *E. purpurea* displayed an improvement in health status and a decreased mortality rate when challenged with *E. coli* (Hassan et al., 2022). Further studies similarly stated that Echinacea supplementation enhanced broilers' growth performance traits, immune activity, and overall economic efficiency (**EE**) in broilers reared under intensive systems (Mohamed & Hanafy, 2025).

Based on this background, the existing study was designed to assess the effects of *Echinacea purpurea* extract (EPE) added to drinking water on broiler performance. The investigation focused on its impact on growth, feed efficiency, carcass traits, blood biochemical markers, meat quality, and changes in specific caecal bacterial groups to identify a natural strategy for promoting productivity and producing safer poultry products without relying on synthetic antibiotics.

## Materials and methods

### *Ethical statement*

The experiment took place in the Poultry Research Farm, Department of Poultry, Agriculture Faculty, Zagazig University, Egypt. The experiments were authorized by the Ethics Committee of the Poultry Department, Agriculture Faculty, Zagazig University, and carried out following the Institutional Animal Care and Use Committee (**IACUC-2025**) guidelines.

### *Echinacea solution formulation*

The Echinacea was obtained from 2 M Group - a commercial firm- which is located in the 10th of Ramadan region of Sharqi, Egypt. To create aqueous Echinacea solutions, 250 g of mashed ripe Echinacea were soaked in one liter of extraction solvent (water-ethanol). The solutions are kept at ambient temperature for no less than one day (24 hrs) before sifting them. Filter sheets marked Whatman No. 42 (Hawach Scientific Co., Ltd., Xi'an, China) were used. The delivery of Echinacea powder extract (EPE) in the chicks' drinking water began when they were 5 days old and was sustained till they were 34 days old. Throughout this time, the remedy was implemented in their water.

### *Sample preparation*

200 milliliters of 70 % methanol and 10 grams of Echinacea powder (**EP**) were mixed, agitated for a period of 3 hours, then filtered through filtering papers (Whatman No. 2). An evaporator (A BuCHI water bath B-480) was employed for methanol extraction from the extract at 45°C and under vacuum. The extract was then lyophilized employing a freeze-dryer (Thermoelectron Corporation-Heto Power Dry LL 300 Freeze Dryer). The resultant extract was stored at 20°C until it was employed in additional analyses (Ashour et al., 2020).

### *Assessing total phenolic compounds (TPCs)*

The TPCs of the methanolic extract (1 g/mL) taken from all samples were analyzed using the Folin-Ciocalteu test. Gallic acid (**Ga**) was utilized (a standard phenolic element) with various doses (10-1000 mg/mL) to generate the standard curve [y ¼ 0.001x þ 0.0563 ($R^2$ ¼ 0.9792)], wherein y and x represent Ga absorbance and concentration in mg/mL, respectively. 1 mL of every sample (standard Ga), 2 mL of $Na_2\ CO_3$ 7.5 %, and 3 mL of diluted Folin-Ciocalteu were combined and incubated in the dark at 25°C for a period of thirty minutes. At last, at 760 nm, the mixture absorbance was measured with a spectrophotometer (JENWAY 6405 UV/Vis, U.K.) (Abdel-Shafi et al., 2019).

### *Total flavonoids estimation*

The extract's total flavonoid (**TF**) content should be 1000 mg/mL. Quercetin was employed as a standard phenolic substance at various levels (10-1000 mg/mL) to generate a standard curve [y ¼ 0.0012x þ 0.008 ($R^2$ ¼ 0.944)], where x represents the quercetin concentration in mg/mL and y represents absorbance. 1 ml of 20 g/L AlCl3 ethanol was combined with 1 ml of quercetin extract. A spectrophotometer to evaluate the color absorbance at 420 nm according to the methods of Abdel-Shafi et al. (2019).

### *Estimating antioxidant activity*

The capability of the EP to scavenge 2,2-diphenyl-1-picrylhydrazyl (**DPPH**) was utilized to measure the antioxidant efficacy of the extract. 1 mL of every sample was blended with 3 mL of methanolic-DPPH solution, and after thirty minutes of incubation process the absorbance at 520 nm (DPPH-assay) was measured with a spectrophotometer. The extract condensing that scavenges fifty percent of the ABTS and DPPH radicals ($SC_{50}$) was determined (Abdel-Hamid et al., 2017).

### *Birds, diets, and design*

We used a completely randomized approach to assign 210 broiler chicks (Ross 308 strain) at 5 days old, with equal live body weight (LBW), to 3 experimental groups. Each was subdivided into seven replicates (10 unsexed chicks/replicate). As the control group (CTRL), we offered the 1$^{st}$ group only water to drink. In contrast, EPE was added to each liter of drinking water (municipal water) in quantities of 3.0 mL

(T1) and 6.0 mL (T2). This supplementation was given three times per week (every other day) for the duration of the 34 days of the birds' age.

The chicks spent the first three days of their life in an open house at 33°C and subsequently reduced gradually until they reached 24°C by the 5$^{th}$ week of age. When the chicks arrived, they had been placed on a continuous illumination scheme that included 23h light/1 h darkness. The nutritional demands of the Ross 308 Broiler Nutrition Specifications (Aviagen Inc., 2019) were considered while establishing the basal diets (pellet form), Table 1. The basal diet was provided in 2 periods: the starter diet (days 5–21) and the finisher diet (days 22–34). The vaccination program was as follows: chicks received the Hitchner vaccine at seven days of age, the Lasota vaccine at 21 and 35 days of age, and the Gumboro vaccine at 14 and 28 days of age. Each chick was grown under identical sanitary, management, and environmental conditions. All chicks were reared in wire-floor battery cages (1.0 × 1.0 × 0.50 $m^3$/replicate) provided with individual feeders and nipple-type drinkers. To ensure strict separation among treatment groups, each treatment was assigned a distinct nipple drinking line.

### *Data collection*

For all the experimental groups, during the 34-day study period, water intake was recorded once daily/replicate by comparing the amount of water given to the amount of water left in the drinkers after 24 hours. The ratio of water/feed (W/F ratio) was evaluated during the experimental period. To determine the LBW, individually, all birds were weighed at the ages of 5, 21, and 34 days. Moreover, we calculated the daily body weight gain (BWG) at periods of 5-21, 22-34, and 5-34 days. The average FI was estimated, and the FCR was calculated according to the following equation: FCR = FI / BWG.

### *Carcass characteristics*

Seven birds per treatment (one/replicate) were taken randomly for carcass traits at the end of the experiment (34 days of age). As described by Battula et al. (2008) and Abd El-Hack et al. (2017), following a 12-hour fast with unrestricted access to water, the birds were weighed and slaughtered in line with Islamic procedures by cutting the jugular vein with a sharp knife. Once they had completely bled (about 2 to 3 minutes), the birds were scalded in hot water (60 ± 2°C) for 45 seconds and then defeathered mechanically using a rotary picker. The carcasses were properly cleaned with potable water. Following a 15-minute chill in an ice-water bath (2–4°C), the dressed carcasses were left to drip-dry at room temperature. Following butchering, the carcasses were divided into standard parts (breast, thighs, drumsticks, wings, back, neck, and giblets), and each part was weighed separately. Every weight was stated as a percentage of the birds' live body weight as well as in grams.

**Table 1**
Composition and quantitative examination of the foundational diet.

| Items | Starter (5 – 21 days) | Finisher (22 – 34 days) |
|---|---|---|
| Ingredients ( %) | | |
| Soybean meal (44 %) | 33.50 | 28.75 |
| Yellow corn | 55.45 | 58.7 |
| Corn germ (60 %) | 5.50 | 5.50 |
| Dicalcium phosphate | 1.93 | 2.00 |
| Limestone | 1.08 | 0.95 |
| Premix[1] | 0.30 | 0.30 |
| L-lysine | 0.14 | 0.0 |
| Salt | 0.30 | 0.30 |
| DL-methionine | 0.0 | 0.0 |
| Soybean oil | 1.80 | 3.50 |
| Calculated analysis[2] | | |
| CP % | 23.03 | 21.05 |
| ME (Kcal/kg) | 2968.67 | 3109.68 |
| Calcium % | 0.98 | 0.94 |
| Available phosphorus % | 0.45 | 0.45 |
| DL-methionine % | 0.79 | 0.74 |
| L-lysine % | 1.3 | 1.04 |
| Potassium % | 0.54 | 0.52 |

[1] Minerals and vitamins premix manufactured by Multi Vita Animal Nutrition® (Tenth of Ramadan City, Sharkia Governorate, Egypt) provides vitamin A 12000 IU, vitamin D3 2500 IU, vitamin E 20 mg, vitamin K3 2 mg, vitamin B1 2 mg, vitamin B2 5 mg, vitamin B6 2 mg, vitamin B12 0.05 ug, niacin 30 mg, biotin 0.05 ug, folic acid 1 mg, pantothenic acid 10 mg, manganese 60 mg, zinc 50 mg, iron 40 mg, copper 10 mg, iodine 0.6 mg, selenium 0.3 mg per 1 kg diet. DL-methionine (manufactured by Evonik Industries, Essen, Germany) contains 99 % methionine. Lysine = lysine hydrochloride (Evonik Industries) and contains 70 % Lysine. CP, crude protein; ME, Metabolizable energy.

[2] Calculated according to Ross 308 Broiler Nutrition Specifications (Aviagen, 2019).

*Calculated according to NRC 1994.

### *Blood biochemical parameters*

During slaughtering processes, in non-heparinized tubes, blood samples were collected, then centrifuged at 5000 revolutions/minute for 15 minutes at 4°C. The resulting serum was kept at -20 degrees Celsius until it was ready for biochemical analysis. Commercial diagnostic kits from Bio Diagnostic Co. (Giza, Egypt) were employed to determine the serum concentrations of immunological functions (IgG, IgM), total protein, albumin, ALT, AST, Triglycerides, LDL, HDL, Cholesterol, creatinine, and urea. The activities of multiple oxidative status markers, such as malondialdehyde (MDA), glutathione peroxidase (GPx), glutathione-S-transferase (GST), and glutathione reduced (GSH), were assessed in line with a recent publication (Abd El-Hack et al., 2017).

### *Meat quality*

Three samples of breast fillet were prepared and then cut into small pieces (3 cm). The meat samples' color indices, including lightness (L), redness (a), and yellowness (b), were estimated (AMSA, 2012). Through the HANNA pH meter (Woonsocket, USA), the breast meat samples' pH values were evaluated; samples were stored for 1, 5, 10, and 15 days before their pH was measured. About 5 g of muscle samples were cooked in an aluminum pan placed in an electric oven (heated up to 200°C) for 15 minutes, or until the oven temperature reached about 80°C. The cooking loss % was determined by estimating the changes between cooked and raw meat sample weights, calculated as a percentage of the uncooked meat sample after thirty minutes of cooling at 15°C. The holding capacity of water (WHC) was measured as described by Huff-Lonergan and Lonergan (2005).

### *Determination of aerobic plate count (APC)*

The aerobic plate count (**APC**), additionally referred to as the total viable count (**TVC**). After removing any apparent fat and connective tissue, breast samples were labeled separately and put into sterile plastic bags. The samples were kept at 4°C and transported to the lab on crushed ice (0-5°C) for assays performed through 24 hours of slaughter processes. The overall microbial burden of broiler meat samples (breast muscles) was estimated using the total viable count (TVC). The FDA Bacteriological Analytical Manual (FDA, 2025) and ISO (2013) both define the standard plate count method that was employed. First, 90 milliliters of sterile buffered peptone water were aseptically filled with ten grams of each sample. A 1:10 (w/v) dilution was then produced by homogenizing the mixture for one minute utilizing a stomacher (Bag-Mixer 400, Interscience, France). Then, using the same diluent, ten-fold serial dilutions ($10^{-1}$ to $10^{-6}$) were made. The pour-plate method was then used to inoculate Plate Count Agar (PCA; Merck, Germany) with one-milliliter aliquots of the corresponding dilutions. For 48–72 hours, the plates were incubated aerobically at 30±1°C. Plates producing 30–300 colonies were chosen for counting after incubation. The findings were presented as colony-forming units (CFU/g) per gram of sample. Before statistical analysis, the collected results were transformed into logarithmic form ($\log_{10}$ CFU/g) (Jay, 2002).

*Microbial count in cecal samples*

After the birds were slaughtered, their cecum was removed for microbiological analysis. To assess the makeup of gut microbiota and the impact of dietary interventions on intestinal health, the microbial count in broiler chicken caecal samples was measured. Caecal contents were aseptically collected into sterile containers as soon as the birds were slaughtered, then sent to the lab for microbiological investigation on ice. To create serial tenfold dilutions, one gram of caecal sample was homogenized in nine milliliters of sterile 0.1 % peptone water. Placing suitable dilutions on Plate Count Agar (PCA) and incubation aerobically at 37°C for 24 to 48 hours was how the total bacterial count (TBC) was determined (ISO 4833-1:2013). On de Man, Rogosa, and Sharpe (MRS) agar incubated anaerobically at 37°C for 48 hours, *Lactobacillus* were counted (Vásquez et al., 2019). After heating aliquots to 80°C for 10 minutes to remove vegetative cells, plating on Nutrient Agar, and incubating at 37°C for 24 hours, the number of *Bacillus spp*. was measured (Hernández-Patlán et al., 2019). Violet Red Bile Agar (VRBA) was used to isolate coliforms, and Eosin Methylene Blue (EMB) agar was used to identify *E. coli* during a 24-hour incubation period at 37°C (APHA, 2017). To detect *Salmonella*, samples were streaked onto Xylose Lysine Deoxycholate (XLD) agar for isolation and biochemical confirmation after being pre-enriched in buffered peptone water (37°C, 18–24 hours) and selectively enriched in Rappaport–Vassiliadis broth (42°C, 24 hours) (ISO 6579-1:2017). The colony-forming units (CFU) of the microbial populations were expressed as log10 per gram of caecal material. The microbial balance and intestinal health status of broiler chickens are reflected in this culture-dependent method, which offers a trustworthy evaluation of both helpful and harmful bacterial populations.

*Economic efficiency*

The birds were fed a basal diet priced at 20 Egyptian pounds (EGP) per kilogram. The additive cost (EPE) was calculated based on a price of 120 EGP per liter, being 0.00, 0.36, and 0.72 EGP/L of drinking water for the control group (CTRL), T1 (3.0 mL EPE/L), and T2 (6.0 mL EPE/L) groups, respectively. Other constant costs were ignored because they were consistent. The following equations were used to assess economic evaluation (Hamouda et al., 2025; Farag & Hanafy, 2025):

$$\text{Economic efficiency (EE) (\%)} = (\text{Net revenue} / \text{Total cost}) \times 100$$

$$\text{Relative economic efficiency (\%)} = (\text{EE of treatment} / \text{EE of control}) \times 100$$

Where:

$$\text{Net revenue (EGP)} = \text{Total return} - - \text{Total cost}$$

$$\text{Total return (EGP)} = \text{Final live body weight (kg)} \times \text{price per kg live weight}$$

$$\text{Total cost (EGP)} = \text{Feed cost} + \text{additive cost}$$

*Statistical Analysis*

The data were submitted to one-way ANOVA with a totally randomized design using SPSS (SPSS, 2019). The test of post-hoc Duncan (Duncan, 1955) was employed to examine average differences, and statistical significance was determined at a level of $P<0.05$. Next, we utilized the following statistical framework:

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

Where $Y_{ij}$ = observed value of the concerned treatment, $\mu$ = observed mean for the concerned treatment, $T_i$ treatment effect, and $e_{ij}$ = the error related to individual observation.

## Results and discussion

*EPE bioactive components*

Natural herbs, including *Echinacea purpurea, Rosmarinus officinalis*, and *Artemisia ordosica*, have been demonstrated in recent research to have preventative and therapeutic benefits on oxidative stress-related disorders (Ashraf et al., 2024). Flavonoids, alkylamides, glycoproteins, polysaccharides, and phenolic compounds, including caffeic acid derivatives (e.g., caffeic acid, chicoric acid, caftaric acid, chlorogenic acid, and echinacoside), are the most important constituents of EP (Burlou-Nagy et al., 2022; Ren et al., 2023). Moreover, low SC50 levels are indicative of high antioxidant activity (Osman et al., 2019). The EPE's DPPH activity, total phenolic (TP), and total flavonoid (TF) contents are shown in Table 2. The extract's TP content was 18.57mg GAE per gram, while its TF content was 6.43mg QE. With SC50 values of 13.00, 21.66, 40.67, and 79.00 mg/ml at concentrations of 100, 250, 500, and 1000 mg/mL, respectively, the DPPH radical scavenging activity rose in a dose-dependent manner. Plants contain several phenolic compounds as secondary metabolites, and their levels can serve as a crucial indicator of antioxidant potential. As is known, aggregation of polyphenols enhances the antioxidant potential of coffee and other foods (Acidri et al., 2020). In order to reduce cell damage and prevent lipid oxidation, the active compounds of EP use an antioxidant mechanism that involves direct reactions with free radicals, like hydroxyl (OH) radicals, hydrogen peroxide, and superoxide anion radicals (Lee et al., 2013; Selamoğlu et al., 2025).

*Performance traits*

The growth performance traits, such as LBW, BWG, FI, FCR, water consumption, and water/feed ratio, of Ross 308 broilers were delineated in Table 3. There was a substantial ($P \leq 0.05$) difference observed between treatments in Broilers' LBW, BWG, FI, FCR, and water/feed ratio in response to echinacea extract addition to drinking water, except for initial LBW (LBW5), and BWG during (22-34 days). In comparison to the control group, the highest final LBW and average BWG were recorded in the group that received 6 ml EPE/liter; however, the lowest values of average FI were obtained from groups treated with 3 ml and 6 ml EPE/liter. The finest values of average FCR were obtained from the group treated with 6 ml EPE/liter, followed by the group treated with 3 ml EPE/liter. In addition, the EPE supplementation resulted in a noteworthy ($P \leq 0.05$) rise in water /feed ratio; the highest scores were obtained from T1 (3 ml EPE/L), followed by T2 (6 ml EPE/L).

Our findings exhibited that the addition of EPE at a level of 6.0 mL/Liter of drinking water resulted in a significant increase in LBW and BWG compared to other treatments. Also, our findings harmony with Seifi et al. (2018), who noted that, in quails, EPE addition at a dose of 0.50 mL/ Liter of drinking water enhanced their FCR. Further, Hashem et al. (2020) and Bagno et al. (2021) reported that the inclusion of EP in

**Table 2**
Total bioactive components of the methanolic extract samples acquired from echinacea.

| Items | **Tp** (mg GAE $g^{-1}$ extract) | **TF** (mg QE $g^{-1}$ extract) | **DPPH** activity (SC50; mg $mL^{-1}$) | | | |
|---|---|---|---|---|---|---|
| | | | 100 | 250 | 500 | 1000 |
| Methanolic echinacea extract | 18.57 | 6.43 | 13.00 | 21.66 | 40.67 | 79.00 |

TP: Total phenolic; TF: total flavonoid; DPPH: 2,2-diphenyl1-picryl-hydrazyl-hydrate.

**Table 3**
Broilers' LBW, BWG, FI, FCR, WC, and water/feed ratio in response to echinacea extract addition to drinking water.

| Items | Control | *Echinacea purpurea* extract levels (mL/L drinking water) | | *P*-value |
|---|---|---|---|---|
| | | 3 mL | 6 mL | |
| Live body weight (g) | | | | |
| LBW 5 | 129.7 ± 1.036 | 130.3 ± 2.358 | 130.1 ± 2.166 | 0.829 |
| LBW 21 | 885.1 ± 18.31[b] | 923.3 ± 16.57[a] | 921.6 ± 38.05[a] | 0.022 |
| LBW 34 | 1990.1 ± 76.58[b] | 2061.8 ± 84.92[ab] | 2124.1 ± 93.75[a] | 0.029 |
| Body weight gain (g/day) | | | | |
| BWG 5-21 | 47.22 ± 1.156[b] | 49.56 ± 1.040[a] | 49.47 ± 2.350[a] | 0.023 |
| BWG 22-34 | 85.00 ± 5.660 | 87.57 ± 6.862 | 92.50 ± 7.890 | 0.144 |
| BWG 5-34 | 64.15 ± 2.623[b] | 66.60 ± 2.962[ab] | 68.76 ± 3.215[a] | 0.030 |
| Feed intake (g/day) | | | | |
| FI 5-21 | 60.49 ± 2.201[a] | 60.31 ± 1.982[a] | 57.31 ± 1.586[b] | 0.011 |
| FI 22-34 | 152.4 ± 8.866[a] | 133.4 ± 4.555[b] | 140.7 ± 7.301[b] | <0.001 |
| FI 5-34 | 101.7 ± 4.367[a] | 93.06 ± 2.118[b] | 94.69 ± 2.674[b] | <0.001 |
| Feed conversion ratio | | | | |
| FCR 5-21 | 1.281 ± 0.065[a] | 1.217 ± 0.041[b] | 1.158 ± 0.055[b] | 0.003 |
| FCR 22-34 | 1.793 ± 0.164[a] | 1.532 ± 0.136[b] | 1.521 ± 0.139[b] | 0.003 |
| FCR 5-34 | 1.585 ± 0.110[a] | 1.397 ± 0.067[b] | 1.377 ± 0.076[b] | <0.001 |
| Water consumption (mL/day) | | | | |
| WC 5-21 | 154.4 ± 7.942 | 161.0 ± 6.528 | 157.7 ± 5.522 | 0.211 |
| WC 22-34 | 369.0 ± 32.49 | 399.1 ± 33.54 | 416.4 ± 59.53 | 0.151 |
| WC 5-34 | 250.6 ± 17.75 | 267.7 ± 16.54 | 273.7 ± 26.83 | 0.129 |
| Water/Feed ratio | | | | |
| W/F ratio 5-21 | 2.552 ± 0.055[c] | 2.670 ± 0.065[b] | 2.752 ± 0.043[a] | <0.001 |
| W/F ratio 22-34 | 2.424 ± 0.189[b] | 2.993 ± 0.239[a] | 2.952 ± 0.327[a] | 0.001 |
| W/F ratio 5-34 | 2.465 ± 0.141[b] | 2.877 ± 0.162[a] | 2.887 ± 0.230[a] | <0.001 |

[a,b,c] Means with different letters in the row represent significant differences at $P \leq 0.05$.

broilers' diet increased their BWG. Similarly, Farag and Hanafy (2025) found that the addition of 0.5, 1.0, and 1.5 % *Echinacea purpurea*/kg diet pointedly (p<0.05) increased broilers' LBW, BWG, and FI, with an improvement in FCR values compared to the CTRL. The benefit of utilizing Echinacea is that it increases the height of intestinal villi, which improves nutrition absorption and increases LBW (Rady et al., 2023). Additionally, phytogenic feed additives often contain bioactive components, including flavonoids, alkaloids, and phenolic composites, which can alter the immune system and increase digestive enzyme secretion (Singh and Gaikwad, 2020; Ikusika et al., 2025).

Even though the EPE-treated broilers showed lower FI, their increased LBW and FCR indicate that *Echinacea purpurea* enhanced nutrient absorption and digestive efficiency rather than directly increasing appetite (Krauze, 2021). Additionally, as shown in our study, EPE additions, especially at a dose of 6.0 mL, significantly increased the W/F ratio. Compared to the untreated group, the W/F ratio ranged from 2.7 to 3.3 in EPE treatments in the current study, which was greater than the recommended value (1.8) under commercial sectors (Aviagen-EPI 2017). Analogous to our findings, Ashour et al. (2025) noted that inclusion of EPE in broilers' diets at levels of 1.0, 2.0, and 3.0 $cm^{3}$/Liter resulted in an insignificant increase in W/F ratio during periods 5-21 days and 22-35 days of birds' old. The differences in water-to-food (W/F) ratios may be attributed to variations in the used drinking systems, ambient temperature, and the required amounts of water for biological processes in the bird's body. Conversely, Lee et al. (2012) and Nosrati et al. (2017) observed that adding EP at 2.50cc $L^{-1}$ for 4 days after broilers' vaccination had no impact on their growth performance traits.

### Carcass traits

Table 4 reveals how the Ross 308 broilers' carcass traits were affected by EPE supplementation. Only absolute weights of liver and total giblets were significantly increased ($P$ = 0.031 and 0.030, respectively) by adding 6 mL of EPE to broilers' drinking water. In addition, this group exhibited ($P > 0.05$) the maximum values of most carcass traits (g), compared to the control group (CTRL) and the T1 group. However, the highest abdominal fat ($P > 0.05$) was obtained from broilers of the T1 group.

Carcass attributes in broiler chickens are the physical and chemical properties of the bird after it has been slaughtered. These factors are very important for judging the quality of the meat, the amount of meat it produces, and what customers want. In our study, the addition of EPE significantly affected liver and total giblets (heart, liver, and gizzard) weights only, especially at a level of 6.0 mL, which exhibited the highest pre-slaughter weight, carcass, carcass %, and liver weights. Findings obtained are nearly from Awad et al. (2020), who noted that, as compared to the CTRL group, the proportion of abdominal fat decreased with all EP levels added to the diet; nevertheless, the eviscerated carcass % and total edible meat increased with the addition of EP at levels of

**Table 4**
Absolute and relative carcass weights (g) in response to echinacea extract addition to broilers' drinking water.

| Items | Control | *Echinacea purpurea* extract levels (mL/L drinking water) | | *P*-value |
|---|---|---|---|---|
| | | 3 mL | 6 mL | |
| Pre-slaughter weight (g) | 2003.3 ± 81.60 | 2070.2 ± 115.1 | 2105.0 ± 104.1 | 0.190 |
| Carcass (g) | 1400.8 ± 43.69 | 1452.0 ± 66.10 | 1466.0 ± 70.20 | 0.139 |
| Carcass ( %) | 69.95 ± 0.934 | 70.18 ± 1.231 | 69.65 ± 0.867 | 0.633 |
| Liver (g) | 46.53 ± 3.249[b] | 50.66 ± 4.528[ab] | 52.10 ± 3.185[a] | 0.031 |
| Liver ( %) | 2.324 ± 0.151 | 2.446 ± 0.144 | 2.479 ± 0.172 | 0.175 |
| Heart (g) | 8.600 ± 0.574 | 9.071 ± 0.535 | 9.086 ± 0.430 | 0.164 |
| Heart ( %) | 0.429 ± 0.022 | 0.438 ± 0.019 | 0.432 ± 0.024 | 0.723 |
| Gizzard (g) | 28.67 ± 1.134 | 29.36 ± 1.614 | 30.01 ± 1.659 | 0.266 |
| Gizzard ( %) | 1.431 ± 0.017 | 1.418 ± 0.013 | 1.426 ± 0.017 | 0.310 |
| T. giblets (g) | 83.80 ± 4.206[b] | 89.09 ± 6.192[ab] | 91.20 ± 3.926[a] | 0.030 |
| T. giblets ( %) | 4.184 ± 0.162 | 4.302 ± 0.147 | 4.337 ± 0.176 | 0.209 |
| Dressing (g) | 1484.6 ± 45.93 | 1541.1 ± 71.55 | 1557.2 ± 73.12 | 0.117 |
| Dressing ( %) | 74.14 ± 0.906 | 74.48 ± 1.250 | 73.99 ± 0.998 | 0.677 |
| Abdominal fat (g) | 8.043 ± 1.107 | 8.386 ± 0.930 | 8.286 ± 1.108 | 0.823 |
| Abdominal fat ( %) | 0.401 ± 0.054 | 0.407 ± 0.052 | 0.395 ± 0.062 | 0.934 |

[a,b] Means with different letters in the row represent significant differences at $P \leq 0.05$

0.50 and 0.75 %.

Moreover, Rady et al. (2023) discovered that incorporating 1 % Echinacea per kilogram of broilers' diet increased the thymus % and bursa % weights, while concurrently reducing the liver % and spleen % weights. According to Atay (2023), the addition of pharmaceutical and aromatic plant-based powders to broilers' diet enhances BWG, FI, and FCR. These herbs also have a considerable influence on carcass yield, colors of thigh and breast, besides wings, thigh, spleen, heart, and bursa weights, which improve performance and carcass metrics. In a previous study by Farag and Hanafy (2025) noted that the addition of EP in broiler diets at levels of 0.50, 1.0, and 1.50 % considerably enhanced carcass %, heart % weights, and intestine length, while markedly reducing the abdominal fat %, when compared to the CTRL group. Except for the gizzard, spleen, besides abdominal fat weights, there were noticeable variations in carcass characteristics, whereas the level of 3.0 $Cm^3$ EPE had a larger proportion of carcass parts and less abdominal fat as noted by Ashour et al. (2025). Additionally, Przybylski et al. (2016) and Elnesr et al. (2025) suggest that EPE may protect intestinal cells, increase antioxidant activity, boost alkaline phosphatase (ALP) activity, protein metabolism, and optimize dietary fiber conversion and digestion. According to Lee et al. (2013), these elements could also increase the efficiency of broiler carcass traits.

*Blood biochemical parameters*

Blood parameters, including liver and kidney functions, protein fraction, lipid profile, immunoglobulins, as well as antioxidant enzymes, reflect the nutritional and health status of birds. As illustrated in Table 5, EPE addition at a level of 6.0 mL displayed the lowest value ($P < 0.001$) of AST activity when compared to other treatments, while ALT activity was insignificantly ($P = 0.191$) affected by EPE treatments. Regarding kidney functions, only the urea levels were affected meaningfully ($P < 0.001$) by all EPE treatments; the lowest urea and creatinine ($P = 0.951$) values were detected from the T2 group. As shown in our study, the highest dose of EPE (6.0 mL) increased total protein ($P = 0.022$), compared with the control group. Also, albumin levels increased significantly ($P = 0.005$) in EPE-treated groups; nevertheless, the maximum globulin levels ($P = 0.379$) appeared in the T2 group. Furthermore, an improvement in broilers' lipid profile following the EPE addition, which was evident in a decrease in TC ($P = 0.005$), TG ($P < 0.001$), LDL ($P = 0.007$), and VLDL ($P < 0.001$) levels, accompanied by increased HDL levels ($P < 0.001$). The T2 group recorded the highest level of HDL and the lowest TG, TC, and VLDL levels, while the lowest LDL levels were recorded in the T1 group, compared to the broilers of the CTRL group.(Table 6).

In addition, dietary supplementation of EPE through drinking water significantly enhanced both antioxidant status and immune responses in broilers. Birds supplemented with 6 mL/L showed a marked increase in GPx activity ($P = 0.001$) compared with the control and 3 mL/L groups. Similarly, GST and GSH levels were significantly elevated in the treated groups ($P < 0.001$), with the highest values observed at 3 mL/L. In contrast, MDA concentrations were significantly reduced in both echinacea-supplemented groups relative to the control ($P = 0.021$), indicating improved protection against lipid peroxidation. Regarding immune function, supplementation with EPE resulted in progressive increases in IgG and IgM concentrations ($P < 0.001$), with the greatest values recorded at 6 mL/L.

Blood is essential for the internal environment because it facilitates the movement of numerous metabolites throughout the body. To some extent, biochemical indicators may shed light on the body's metabolic processes. In the existing study, drinking water supplemented with EPE generally improved most serum biomarkers. This improvement was reflected in increased levels of ALT, AST, Tpr, Alb, HDL, and immunoglobulins (IgG and IgM). Additionally, there was a tangible reduction in urea, Cho, Tri, and LDL levels. Furthermore, the antioxidant status was also improved, as evidenced by a decline in MDA level and an upsurge in GPx, GSTs, and GSH levels. The obtained results are similar to those of Rady et al. (2023), who discovered that administering Echinacea at a 1 % level caused an increase in Tpr, Alb, and globulin in the blood for broiler chicks.

Additionally, the improved lipid profile in the current study was confirmed by Rahimi et al. (2011) and Nosrati et al. (2017), who claimed that the addition of EP resulted in a noteworthy increase in serum HDL levels as well as a decrease in Cho and LDL. According to Sharifi et al. (2013), one probable explanation for this is that probiotics have anti-atherosclerotic properties. Also, the reduction in triglyceride levels in the blood increases the amount of HDL cholesterol by inhibiting 3-hydroxy-3-methylglutaryl reductase coenzyme A (HMG-CoA), a vital enzyme in cholesterol production. Obtained findings were also

**Table 5**
Blood indices in response to echinacea extract addition to broilers' drinking water.

| Items | Control | *Echinacea purpurea* extract levels (mL/L drinking water) | | *P*-value |
|---|---|---|---|---|
| | | 3 mL | 6 mL | |
| Liver function | | | | |
| ALT (IU/L) | 11.01 ± 0.234 | 11.21 ± 0.177 | 11.10 ± 0.173 | 0.191 |
| AST (IU/L) | 141.6 ± 1.984[a] | 142.2 ± 1.670[a] | 134.1 ± 4.308[b] | <0.001 |
| Kidney function | | | | |
| Urea (mg/dL) | 5.430 ± 0.597[a] | 4.157 ± 0.091[b] | 3.743 ± 0.204[c] | <0.001 |
| Creatinine (mg/dL) | 0.629 ± 0.023 | 0.626 ± 0.023 | 0.624 ± 0.030 | 0.951 |
| Protein fraction | | | | |
| Total protein (mg/dL) | 6.213 ± 0.071[b] | 6.334 ± 0.168[ab] | 6.423 ± 0.124[a] | 0.022 |
| Albumin (mg/dL) | 3.017 ± 0.053[b] | 3.136 ± 0.043[a] | 3.126 ± 0.090[a] | 0.005 |
| Globulin (mg/dL) | 3.196 ± 0.080 | 3.199 ± 0.177 | 3.297 ± 0.175 | 0.379 |
| A/G ratio | 0.945 ± 0.035 | 0.983 ± 0.062 | 0.951 ± 0.068 | 0.418 |
| Lipid profile | | | | |
| TG (mg/dL) | 141.5 ± 0.887[a] | 115.5 ± 11.07[b] | 99.50 ± 6.368[c] | <0.001 |
| TC (mg/dL) | 211.9 ± 4.789[a] | 205.7 ± 2.967[b] | 204.9 ± 3.110[b] | 0.005 |
| HDL (mg/dL) | 49.17 ± 1.779[b] | 55.00 ± 2.097[a] | 55.73 ± 1.135[a] | <0.001 |
| LDL (mg/dL) | 134.4 ± 4.963[a] | 127.6 ± 2.979[b] | 129.3 ± 2.440[b] | 0.007 |
| VLDL (mg/dL) | 28.30 ± 0.177[a] | 23.09 ± 2.213[b] | 19.90 ± 1.274[c] | <0.001 |
| Antioxidant parameters | | | | |
| GPx (nmol /mL) | 164.2 ± 2.775[b] | 164.1 ± 1.574[b] | 170.1 ± 3.579[a] | 0.001 |
| GST (nmol /mL) | 4.589 ± 0.174[c] | 5.864 ± 0.126[a] | 5.330 ± 0.363[b] | <0.001 |
| GSH (nmol /mL) | 72.81 ± 1.303[c] | 81.89 ± 2.079[a] | 79.04 ± 0.431[b] | <0.001 |
| MDA (nmol /mL) | 4.373 ± 0.771[a] | 3.651 ± 0.284[b] | 3.583 ± 0.398[b] | 0.021 |
| Immunoglobulins | | | | |
| IgG (mg/dL) | 210.7 ± 7.997[c] | 233.5 ± 6.713[b] | 244.6 ± 6.900[a] | <0.001 |
| IgM (mg/dL) | 18.07 ± 0.287[c] | 18.90 ± 0.586[b] | 19.69 ± 0.313[a] | <0.001 |

[a,b,c] Means with different letters in the row represent significant differences at $P \leq 0.05$.

ALT: alanine transaminase; AST: aspartate transaminase; A/G ratio: Albumin/globulin ratio; TG: triglycerides; TC: total cholesterol; HDL: high-density lipoproteins; LDL: low-density lipoproteins; VLDL: very low-density lipoproteins; GPx: Glutathione peroxidase; GST: Glutathione-S-Transferase; GSH: Reduced glutathione; MDA: Malondialdehyde; IgG: Immunoglobulin G; IgM: Immunoglobulin M.

**Table 6**
Meat quality in response to echinacea extract addition to broilers' drinking water.

| Items | Control | *Echinacea purpurea* extract levels (mL/L drinking water) | | *P*-value |
|---|---|---|---|---|
| | | 3 mL | 6 mL | |
| pH | | | | |
| Day 0 pH | 6.480 ± 0.075 | 6.444 ± 0.037 | 6.393 ± 0.135 | 0.231 |
| Day 5 pH | 6.681 ± 0.120[a] | 6.210 ± 0.073[c] | 6.331 ± 0.053[b] | <0.001 |
| Day 10 pH | 6.783 ± 0.255[a] | 6.620 ± 0.147[a] | 6.376 ± 0.130[b] | 0.003 |
| Day 15 pH | 7.220 ± 0.290[a] | 6.494 ± 0.157[b] | 7.161 ± 0.375[a] | <0.001 |
| WHC | 62.05 ± 5.870[b] | 73.20 ± 9.681[a] | 60.15 ± 9.883[b] | 0.024 |
| Purge | 4.447 ± 0.672[b] | 5.633 ± 0.578[a] | 6.314 ± 1.237[a] | 0.003 |
| Cooking loss | 34.39 ± 1.119[a] | 29.42 ± 1.347[b] | 35.62 ± 3.155[a] | <0.001 |
| Color parameters | | | | |
| Lightness ($L^*$) | 37.89 ± 3.581[b] | 42.71 ± 2.149[a] | 44.35 ± 2.935[a] | 0.002 |
| Redness ($a^*$) | 14.95 ± 0.852[a] | 10.87 ± 1.484[b] | 9.589 ± 2.171[b] | <0.001 |
| Yellowness ($b^*$) | 21.33 ± 0.784[b] | 23.81 ± 0.957[a] | 24.56 ± 1.706[a] | <0.001 |
| Aerobic Plate Count (APC) | | | | |
| Day 1 APC | 4.960 ± 0.149[b] | 5.626 ± 0.231[a] | 4.734 ± 0.365[b] | <0.001 |
| Day 10 APC | 6.583 ± 0.277[a] | 5.670 ± 0.388[b] | 5.644 ± 0.348[b] | <0.001 |
| Day 15 APC | 7.029 ± 0.177[a] | 6.551 ± 0.281[b] | 6.666 ± 0.200[b] | 0.002 |

[a,b,c] Means with different letters in the row represent significant differences at $P \leq 0.05$.
WHC: Water holding capacity

confirmed in a study by Farag and Hanafy (2025), who reported that dietary EP supplementation showed substantial modifications ($p < 0.05$) in levels of total protein, albumin, and globulin. Birds fed EP-supplemented diets exhibited substantially higher ($p < 0.05$) Tpr and globulin levels compared to broilers of the control group. When compared to other treatments, 0.50 and 1.0 % EP boosted blood Alb levels considerably; the same authors reported that a substantial reduction in serum Tri, Chol, and LDL levels was detected, whereas HDL were augmented as a result of EP addition to broiler diets. Moreover, there was a noteworthy upsurge in TAC and GPx concentrations with a reduction in MDA levels. In contrast, El-Sayed Wahdan et al. (2018) and Abd-Allah et al. (2018) observed that the ALT and AST levels in serum were unaltered after EP supplementation.

Antioxidants are substances that delay or prevent lipid oxidation; when included in poultry diets, they help reduce rancidity, suppress the formation of harmful oxidation products, and retain nutritional content. As clarified in the existing study, EPE treatment improved both antioxidant and immune status. Similarly, Lee et al. (2012) and Zhang et al. (2025) discovered inclusion of EP in the broilers' diet caused an increase in SOD levels. Further, Abd-Allah et al. (2018) noted that the inclusion of *Echinacea purpurea* in broilers improved GSH levels with a reduction in MDA levels. MDA levels were significantly lower in the groups who got Echinacea and nucleotide supplements, according to Rady et al. (2023). Soybean isoflavone, a natural extract included in the diet, has been found to boost plasma TEAC, SOD, and CAT enzyme activity while decreasing peroxidation of lipids in broilers (Jiang et al. 2007; Ahmed et al., 2024). Moreover, herbal plants are high in antioxidants (such as polyphenols, organosulfur compounds, and flavonoids); these chemicals' antioxidant qualities have been demonstrated and may be related to a decrease in oxidative stress, as evidenced by improved antioxidant enzyme activity (Ibrahim et al., 2018; Ismail et al., 2021; Mubeen et al., 2025), as confirmed in the current study.

Also, immunoglobulins, including IgG, IgA, and IgM, are critical elements of the immune response, and their concentrations are positively correlated with an individual's immune capability. The obtained findings are in line with those published by Ashour et al. (2025), who noted that diets containing EPE at levels of 1, 2, and 3 $cm^3$/ Liter produced greater IgM and IgG concentrations, lower MDA levels, and higher SOD activity. The addition of EP at a dose of 0.25 %/ kg of broilers' diet insignificantly increased IgM and IgG levels compared to the other treatments (Nazari et al., 2024). Additionally, polysaccharides are a principal bioactive component in *Echinacea purpurea* that enhances gut microbiota and increases the quantity of helpful bacteria (Wei et al., 2024). Talazadeh et al. (2016) showed that the immediate impact of probiotics (the beneficial bacteria) on enhancing immunological activity may be attributed to the activation of the lymphatic system, while the secondary impact might result from alterations in the microbial composition of the intestinal lumen. Too, probiotics create short-chain fatty acids (SCFAs); by stimulating the production of adenosine triphosphate (ATP) and fatty acid content in B cells, SCFAs can accelerate B cell stimulation, differentiation, and antibody formation; this enhances the release of IgA and IgM (Amu et al., 2010; Kim et al., 2016). Numerous compounds, including polysaccharides and cichoric acid, a derivative of caffeic acid, indicate that Echinacea has an impact on the immune system (Tolouei et al., 2017). In addition, several studies found that herbal medicine's polysaccharide components mostly boost the immune system by specifically increasing serum levels of TNF-α, IFN-γ, and IL-2 (Liu et al., 2022; Nam et al., 2022).

*Meat quality*

Supplementation of broilers' drinking water with EPE significantly influenced several meat quality parameters. Regarding pH, no differences were observed on day 0 ($P = 0.231$), but significant variations appeared during storage. EPE-treated groups showed lower pH values at day 5 ($P < 0.001$) and day 10 ($P = 0.003$) compared with the control, while on day 15, the 3 mL/L group maintained a lower pH than the control and 6 mL/L group ($P < 0.001$). Water-holding capacity was significantly enhanced at 3 mL/L ($P = 0.024$), whereas purge losses increased in both treated groups ($P = 0.003$), and cooking loss was reduced only at 3 mL/L but elevated again at 6 mL/L ($P < 0.001$). Meat color was also affected, as lightness ($L^*$) and yellowness ($b^*$) values were significantly higher in supplemented groups ($P = 0.002$ and $P < 0.001$, respectively), whereas redness ($a^*$) decreased markedly with EPE ($P < 0.001$). In terms of APC, birds receiving 3 mL/L exhibited higher APC on day 1 ($P < 0.001$), but by days 10 and 15, both EPE-supplemented groups displayed significantly lower APC counts than the control ($P < 0.001$ and $P = 0.002$, respectively), suggesting improved meat preservation during storage.

Meat quality varies depending on the experiment period, broiler breed, and slaughter methods. EPE treatments had improved most of the meat quality traits, as displayed in the existing study. Battula et al. (2008) and Debut et al. (2003) indicated that the normal pH value of broilers' meat after 15 minutes of slaughter ranges between 6.3 and 6.6. Moreover, the current study exhibited that EPE with different levels achieved pH values in this range, which indicates no problem in meat quality related to the tested additives. The inclusion of EP juice at a level of 0.250 ml/kg of BW $^{0.75}$ for three days (1-3d, 13-15d, and 25-27d of broiler age) resulted in insignificant differences in meat colour ($L^*$, $a^*$, and $b^*$ values), electrical conductivity, and shear force values, whereas this treatment showed considerably ($P < 0.05$) reduced grill losses (Nasir & Grashorn, 2010).

The $L^*$ value correlates with the brightness of tissues and drip loss rates. The $a^*$ value is influenced by muscle hemoglobin and myoglobin concentrations. The $b^*$ value represents the deposit of fat between meat muscles. When broilers' diets provided with 0.10, 0.50, 1 and 2 g of EP powder/kg diet increased pH values, the thigh and breast drip loss was significantly ($P < 0.05$) reduced, while, WHC values meaningfully ($P < 0.05$) increased; in addition colour values of meat ($L^*$, $a^*$, and $b^*$) were affected by EP powder additions; the $L^*$ value was lesser in birds fed diets with 2.0 % EP, whereas the highest $b^*$ values ($P < 0.01$) were observed in 0.50, 1.0 and 2.0 % EP groups, when compared to untreated group. The antioxidant effects of EP were reported, with echinacoside and caffeic acid identified as potent scavengers of free radicals such as superoxide and hydroxyl radicals. Consequently, *Echinacea purpurea* supplementation in the diet could enhance meat quality by reducing lipid peroxidation and enhancing the oxidative status in male broilers (Lee et al., 2013; Akbari et al., 2025). Otherwise, EPE inclusion in broilers' drinking water at doses of 0.1, 0.2, and 0.6 g/L improved $L^*$ values of thigh and breast muscles, enhanced shear force and value of pH, and decreased water and drip loss ratios (Shen et al., 2020). An earlier study by Jiang et al. (2007) demonstrated that adding soybean isoflavone (ISF), a high antioxidant, to broilers' diets can improve meat quality traits and reduce lipid peroxidation. Additionally, elevated oxidative status in poultry resulted in improved WHC and pH advancement after slaughter (Young et al., 2003).

Also, EP antioxidants, including chicoric acid, might decrease drip loss rates by inhibiting hyaluronidase, reducing free radicals, and enhancing the integrity of cell membranes and permeability (Dogan et al., 2014; Ahmadi, 2024). Additionally, a higher pH may also lead to a greater WHC and a lower rate of drip loss, which could account for E. purpurea's notable ability to lower water loss rates (Shen et al., 2020). Generally, supplementing with plant-based antioxidants decreased MDA formation and drip loss because of a better oxidative state, which protected against stress-induced increases in lipid oxidation; likewise, improvements in water holding capacity (WHC) and pH development in post-mortem muscle were attributed to an enhanced oxidative status in the chickens (Carvalho et al., 2019; Petcu et al., 2023), which is confirmed in the present study.

### *Microbial analysis in broiler cecum*

Supplementation of broilers' drinking water with EPE markedly modulated the cecal microbial population (Table 7). Total bacterial count (TBC) was significantly reduced in both treated groups compared with the control ($P < 0.001$). Beneficial bacteria, particularly Lactobacilli, increased progressively with supplementation, showing the highest counts at 6 mL/L ($P < 0.001$), whereas Bacillus counts were not significantly affected ($P = 0.626$). In contrast, potentially harmful bacteria were suppressed, as coliforms ($P < 0.001$), *E. coli* ($P = 0.001$), and *Salmonella* ($P < 0.001$) were significantly lower in both echinacea groups relative to the control.

There is a considerable correlation between exact bacterial species and certain phytogenic feed additives in animal intestines, which results in improved productivity. Natural ingredients can advance poultry welfare and production performance by gut microbiota modification (Lillehoj et al., 2018). The obtained data suggest that the addition of EPE to the drinking water of Ross 308 broilers generally led to a substantial enhancement in caecal bacterial groups. This improvement was characterized by a rise in the beneficial bacteria proliferation and a concurrent inhibition of pathogenic species. This may be linked to supplementing broilers with EP, which enhances intestinal morphology (Rady et al., 2023), which is also consistent with research by Gilani et al. (2021) that found that adding phytobiotics to broilers' diets enhances gut morphology.

Current findings are in harmony with Ebrahimi et al. (2016), who noted that EP pointedly declines the count of pathogenic bacteria (C. *jejuni*) in broilers' caecum. In addition, *Escherichia coli* counts were much lower ($p < 0.05$) in the group that received phytogenic feed additives; moreover, the ileum did not contain any *Escherichia coli* populations (Rashid et al., 2020). In comparison to the CTRL group, the addition of EP (at levels of 0.25 and 0.50 %/kg diet) decreased the amount of *Campylobacter jejuni* and raised the count of Bifidobacterium in *Campylobacter jejuni*-infected broilers (Nazari et al., 2024). The antibacterial features of herbal plants may be related to their abundance in bioactive components (e.g., thymoquinone, flavonoids, alkaloids, as well as volatile oils), and these additives have a stabilizing influence on broilers' gut flora (Aminullah et al., 2025).

**Table 7**
Changes in caecal bacterial groups in response to echinacea extract addition to broilers' drinking water.

| Items | Control | *Echinacea purpurea* extract levels (mL/L drinking water) | | *P*-value |
|---|---|---|---|---|
| | | 3 mL | 6 mL | |
| TBC (Log10 CFU) | 8.808 ± 0.404[a] | 7.699 ± 0.112[b] | 7.943 ± 0.467[b] | <0.001 |
| *Lactobacilli* (Log10 CFU) | 5.673 ± 0.151[c] | 6.366 ± 0.325[b] | 6.792 ± 0.085[a] | <0.001 |
| *Bacillus* (Log10 CFU) | 5.933 ± 0.997 | 5.549 ± 0.525 | 5.630 ± 0.718 | 0.626 |
| Coliforms (Log10 CFU) | 7.672 ± 0.504[a] | 6.239 ± 0.496[b] | 6.015 ± 0.456[b] | <0.001 |
| *E. coli* (Log10 CFU) | 6.876 ± 0.134[a] | 5.530 ± 0.817[b] | 5.790 ± 0.482[b] | 0.001 |
| *Salmonella* (Log10 CFU) | 4.461 ± 0.956[a] | 2.224 ± 0.080[b] | 2.299 ± 0.443[b] | <0.001 |

[a,b,c] Means with different letters in the row represent significant differences at $P \leq 0.05$.
TBC: Total bacterial count.

### *Economic efficiency*

Economic evaluation revealed that EPE supplementation influenced production costs and profitability in broilers (Table 8). Feed cost alone was significantly reduced in both echinacea-treated groups compared with the control ($P < 0.001$), while the combined feed and additive cost showed a slight increase at 6 mL/L ($P = 0.008$), reflecting the higher expense of the supplement at this level. The cost per kilogram of body weight gain was not significantly affected ($P = 0.085$). In terms of returns, both total return and net return tended to increase with supplementation, with the highest values recorded at 6 mL/L ($P = 0.029$ and $P = 0.071$, respectively). Similarly, EE and relative EE improved in echinacea groups compared with the control, particularly at 3 mL/L, although these differences did not reach statistical significance ($P = 0.094$). Overall, echinacea extract supplementation, especially at 3 mL/

**Table 8**
Economic efficiency in response to echinacea extract addition to broilers' drinking water.

| Items | Control | *Echinacea purpurea* extract levels (mL/L drinking water) | | *P*-value |
|---|---|---|---|---|
| | | 3 mL | 6 mL | |
| Feed cost (EGP) | 58.98 ± 2.532[a] | 53.98 ± 1.229[b] | 54.92 ± 1.551[b] | <0.000 |
| Feed + additive cost (EGP) | 58.98 ± 2.532[ab] | 56.77 ± 1.312[b] | 60.63 ± 2.014[a] | 0.008 |
| Feed + additive cost/kg BWG (EGP) | 31.76 ± 2.179 | 29.44 ± 1.391 | 30.47 ± 1.826 | 0.085 |
| Total return (EGP) | 149.3 ± 5.742[b] | 154.6 ± 6.369[ab] | 159.3 ± 7.031[a] | 0.029 |
| Net return (EGP) | 90.28 ± 7.203 | 97.86 ± 6.332 | 98.68 ± 7.362 | 0.071 |
| Economic efficiency % | 153.7 ± 17.99 | 172.5 ± 12.06 | 163.0 ± 14.81 | 0.094 |
| Relative economic efficiency % | 100.0 ± 11.71 | 112.2 ± 7.846 | 106.1 ± 9.641 | 0.094 |

[a,b] Means with different letters in the row represent significant differences at $P \leq 0.05$.

L, was associated with reduced feed cost and improved profitability without markedly increasing production expenses.

As noted in the current study, compared to the CTRL group, the EPE-treated groups' improvements in FCR and LBW resulted in increased EE. The improved growth performance traits produced a net economic benefit, even with the slight additional cost of adding EPE. Studies display that phytogenic feed additives might raise profitability by improving FI and lowering health-related losses and have also found similar results (Rady et al., 2023; Mohamed & Hanafy, 2025). These results suggest that in the commercial broiler sector, EPE supplementation can offer a financially feasible extra.

All of the results in the existing study point to the convergence of the physiological and microbiological improvements brought forth by EPE, which advances both product quality and broilers' performance. EPE aids improve FI and FCR and meat quality by enhancing gut microbiota, immunological response, and antioxidant balance. EPE is placed as a sustainable result of these biological benefits, which also produce obvious economic benefits.

## Conclusions and applications

1. The inclusion of *Echinacea purpurea* extract in drinking water effectively enhances growth performance, carcass yield, and physiological health indicators in Ross 308 broiler chickens.
2. Supplementation at both tested levels (3.0 and 6.0 mL/L) improved metabolic functions, antioxidant status, and immune response, while positively modulating gut and meat microbiota profiles, and from an economic view, the tested level 3 mL EPE/Liter has the best EE and relative EE.
3. These outcomes indicate that EPE serves not only as a functional antioxidant and immunomodulator but also as a potential natural substitute for conventional antibiotics in poultry nutrition.
4. Its application could thus contribute to safer, more sustainable meat production systems that align with consumer health concerns and industry regulatory trends. Further studies are recommended to validate long-term impacts and optimize dosing strategies under varied production settings.

## Consent for publication

Not applicable.

## Data availability

Data will be available upon reasonable request from the corresponding authors.

## CRediT authorship contribution statement

**Zuhair Hamdi:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Elwy A. Ashour:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Conceptualization. **Abdel El-Hakeem M. Nour-Eldeen:** Writing – review & editing, Validation, Supervision, Formal analysis, Data curation. **Islam Sabike:** Writing – review & editing, Visualization, Validation, Methodology, Investigation. **Ali O. Osman:** Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Funding acquisition, Formal analysis. **Samir A. Mahgoub:** Writing – review & editing, Validation, Software, Methodology, Formal analysis. **Ahmed I. Elsherbeni:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Mohamed M. El-Mekkawy:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation. **Mohammad M.H. Khan:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Hanan M. Alharbi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Funding acquisition, Formal analysis. **Khairiah M. Alwutayd:** Writing – review & editing, Writing – original draft, Visualization, Validation, Funding acquisition, Data curation. **Mohamed E. Abd El-Hack:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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