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Effects of Arugula Leaves Extract on Blood Biochemical Parameters in Broiler Chickens

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ABSTRACT

Arugula leaves contain abundant flavonoids, glycosides, and other bioactive substances, along with essential minerals such as calcium and potassium, which are commonly used as medicinal herbs in Iraq. The bioactive substances present in arugula leaves can positively influence the biochemical parameters in broiler chickens. The present study aimed to examine the effects of the cold-water extract of arugula leaves (*Eruca sativa*) on the blood biochemical parameters of broiler chickens when added to drinking water. One hundred forty-four broiler chickens with an initial weight of 44 g were randomly allocated to four treatment groups and reared for 35 days. Each treatment contained 36 chickens, with three replications of 12 chickens each. The first treatment group served as the control and did not receive any additional supplements (T1). In the second treatment group, arugula leaf extract was provided in drinking water at a concentration of 50 mg/ml per liter (T2), in the third treatment group, the concentration of arugula leaf extract was 100 mg/ml per liter (T3), and in the fourth treatment group, the concentration of arugula leaf extract was 150 mg/ml per liter (T4). Broiler chickens supplemented with arugula leaf extract indicated a significant reduction in serum levels of glutamic pyruvic transaminase (GPT), glutamic oxaloacetic transaminase (GOT), thyroid hormones, urea, and creatinine compared to the control group. There was a significant increase in red blood cell count, hemoglobin, and packed cell volume in T3 compared to the control group. Additionally, the serum levels of total protein, albumin, and globulin were significantly elevated compared to those in T1. Group T3 demonstrated a significant increase in the concentration of high-density lipoprotein (HDL) and a significant decrease in the concentrations of triglycerides, cholesterol, low-density lipoprotein, and very low-density lipoprotein compared to the control group. The present findings indicated that administering 100 mg/ml of arugula leaf extract improved blood parameters, including liver enzyme activity, thyroid hormone levels, serum proteins (albumin, globulin, and total protein), and HDL concentrations in broiler chickens.

Keywords: Arugula, Broiler chicken, Liver enzyme, Lipoprotein, Thyroid hormone

INTRODUCTION

The excessive and improper use of antibiotics in poultry production has raised significant health and safety concerns, prompting scientists to investigate natural alternatives, such as medicinal plants, that can enhance performance while reducing reliance on pharmaceutical medicines (Azizi et al., 2024). Herbs and spices are rich sources of secondary metabolites that exhibit noticeable biological effects, underscoring their potential as natural resources with a wide range of bioactive properties (Abd El-Hack et al., 2022; Al-Sulivany et al., 2024). The increasing misuse of antibiotics has led to the emergence of antimicrobial resistance, posing a significant threat to human and animal health. Consequently, scientists are actively exploring plant-based alternatives to enhance animal performance and health without contributing to antibiotic resistance (Obianwuna et al., 2024). Medicinal plants such as hot red pepper, arugula, and phyto-biotics are increasingly vital to the global animal production business, due to their natural chemical compounds. These chemical compounds have a major impact on both human and animal physiological performance (Abd El-Hack et al., 2022; Al-Sulivany et al., 2024; Obianwuna et al., 2024). Arugula (*Eruca sativa*) is a leafy vegetable recognized for its ability to boost the immune system, as it is rich in vitamins and minerals that help protect the body

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against diseases (Al-Sulivany et al., 2024). Arugula leaves are among the most prominent medicinal plants, known for their therapeutic and beneficial properties (Stanojković-Sebić et al., 2024). Arugula leaves include biologically active compounds such as beta-carotene, vitamins E and C, and other nutrients (Al-Sulivany et al., 2024). This medicinal plant offers several benefits for broiler chickens, including appetite stimulation, improved food digestion, enhanced immunity, greater gut microflora regulation, and antioxidant and antibacterial properties (Abd El-Hack et al., 2022). Furthermore, arugula leaves are rich in nutrients, such as calcium and potassium, and contain glycosides and other active components, such as flavonoids, which are important bioactive elements that have significant impacts on the production traits in chickens (Lehmood et al., 2026). The antioxidants, fiber, and potassium in arugula help regulate blood pressure, improve digestive health, and protect the body from free-radical damage. Supplementation with arugula leaf extract has been shown to significantly increase blood parameters, including red blood cell (RBC) and hemoglobin (Hb), as well as liver enzymes, such as glutamic pyruvic transaminase (GPT), glutamic oxaloacetic transaminase (GOT), thyroid hormones, and serum lipids, thereby supporting the growth and health of broiler chickens (Lehmood et al., 2026). According to Amal et al. (2023), arugula leaf supplementation led to higher blood calcium, protein, and activity, and lower glucose and cholesterol levels in roosters. Supplementing broiler chickens' diet with arugula oil led to enhanced growth, according to the findings of Hanafi et al. (2010) on growth performance. While arugula leaf extracts provide numerous benefits and diverse applications for humans and animals, their specific impact on biochemical blood parameters in chickens remains poorly studied. Therefore, the present study aimed to investigate the effects of the cold-water extract of arugula leaves on specific blood indicators in broiler chickens.

MATERIALS AND METHODS

Ethical approval

The study at Al-Qasim Green University was approved by the Ethics Commission in September and October 2024 (Agri No. 01, 7, 24).

Study location and duration

The current investigation was conducted in the chicken hall of North Babylon Field in Iraq over a 35-day period, from September 9, 2024, to October 13, 2024.

Preparation of arugula leaf extract

A cold-water extract of arugula leaves was prepared using fresh leaves obtained from the local market in North Babylon, Iraq, and carefully cleaned before extraction, as described by Harborne (1998). Arugula leaves powder (10 gm) was mixed with cold distilled water (200 mL) for 15 minutes on a magnetic stirrer, then the covered solution was left for 24 hours to allow for thorough extraction and prevent contamination. The solution was filtered several times using filter paper and centrifuged at 3000 revolutions/minutes for ten minutes to obtain dry residuals, which were kept in small glass bottles, tightly closed, and stored in a refrigerator at 4°C until further analysis.

Animals

A total of 144 Ross 308 broiler chickens at one day of age (91 male:53 female), each weighing 44 g at birth, were raised for 35 days. The chickens were obtained from farms in Babylon, Iraq, then kept in a room under the same environmental conditions, including identical temperature control (25-35 °C) and *ad libitum* feeding. The animals were housed in metal cages. Each cage measured 100 cm in length, 70 cm in height, and 80 cm in width and contained 12 chickens. The temperature was maintained at 33.5°C for the first week, then gradually lowered by 2°C per week from the second week through the fifth week, reaching approximately 25.5°C. Between days 8 and 35, the lighting program included one hour of darkness and twenty-three hours of illumination. At seven days of age, the broiler chickens received Newcastle and avian influenza vaccines (Compamix, USA) through drinking water. No mortality was observed during the trial. The chemical analysis and composition of the diet are presented in Table 1 (NRC, 1994).

Study design

The chickens were divided into four groups, each consisting of three replicates, with 12 chickens per replicate, for a total of 36 chickens.

The first group was the control group which did not receive any arugula supplementation (T1), the second group received the arugula leaf extract at 50 mg/ml per liter through drinking water (T2), the third group received the arugula leaf extract at 100 mg/ml per liter through drinking water (T3), and the fourth treatment group received the arugula leaf extract at 150 mg/ml per liter through drinking water (T4).

Table 1. Chemical and nutritional contents of diets for broiler chickens

Ingredient percentage	(1-21 days) Starter	(22-35 days) Grower
Corn grain	50	55
Wheat	12	12
Soybean (48%)	29	25.5
*Protein additives (40%)	5	3
Plant oil	2	3
Limestone	1	0.5
NaCl	0.2	0.2
Methionine	0.1	0.1
Premix (29%)	0.5	0.5
L – Lysine	0.2	0.2
Total	100	100
Calculated chemical composition		
Protein (%)	22.34	20.21
Metabolizable energy (Kcal. Kg-1)	3074	3170.5
Calorie: Protein ratio	137.60	156.87
Ether extract (%)	5.02	5.94
Fibre (%)	3.45	3.26
Calcium (%)	0.71	0.42
Available Phosphorus (%)	0.30	0.24
Lysine (%)	1.25	1.11
Methionine + Cysteine (%)	0.83	0.75

The premix was supplemented to the diets at 0.5% and contained a mixture of essential vitamins and minerals to support optimal growth. Each kilogram of the premix contained vitamin A (12,000 IU), Vit E (10 mg), vitamin D_3 (2,200 IU), vitamin K_3 (2 mg), B1 (1.8 mg), B_2 (6.6 mg), B_6 (3.0 mg), and B_{12} (0.015 mg). It also included niacin 30 mg, folic acid 1 mg, pantothenic acid 10 mg, and biotin 0.05 mg. Furthermore, premix complete minerals, such as 50 mg of iron, 60 mg of manganese, 60 mg of zinc, 5 mg of copper, 1 mg of iodine, and 0.2 mg of selenium, along with 100 mg of antioxidant compounds. * The protein feed additive (Biobardin, protein content 45%) contains fish meal.

Parameters

At 35 days of age, 5 mL of blood was collected from the wing vein (brachial vein) of two chickens per replicate with anticoagulant (EDTA) for hematological test, and for serum, a tube without anticoagulant. The serum was used to determine liver enzymes, such as GOT and GPT, using an enzymatic colorimetric method with a commercial diagnostic reagent kit (Randox Laboratories Ltd., UK). Biochemical indicators, such as urea and creatinine, were analyzed in a private laboratory using commercially available diagnostic kits, according to the manufacturer's instructions (Reitman and Frankel, 1957). Serum proteins, including albumin, globulin, and total protein, were measured using an electrochemiluminescence immunoassay method with a COBAS e411 automated machine analyzer (Roche Company, Germany) to measure serum levels of thyroid-stimulating hormone (TSH), triglycerides (TG), high-density lipoprotein (HDL), very low-density lipoprotein (VLDL), thyroxine (T_4), triiodothyronine (T_3), and total cholesterol (TC). The micro-hematocrit method was used to measure the hematological parameters, including the Hb, RBC, and packed cell volume (PCV; Reitman and Frankel, 1957).

Statistical analysis

Statistical software (SPSS) was used to analyze the data using one-way ANOVA. The Duncan test was used to compare the means between the groups (Duncan, 1955). The Findings were considered statistically significant when the p-value was less than 0.05.

RESULTS AND DISCUSSION

The lowest GPT concentration was recorded in T3 (56.771 U/L), indicating a marked reduction compared to the control group (83.259 U/L; $p < 0.05$). The present GOT results were reported sequentially as T1 (36.080), T2 (24.640), T3 (20.053), and T4 (23.100) U/L. The observed reduction in liver enzymes could be due to the abundant natural antioxidants found in plant secondary metabolites (Table 2).

Table 2. Influence of arugula leaf extract on liver enzymes in broiler chickens aged 35 days

Treatments	GPT (U/L)	GOT (U/L)
T1	$83.259^a \pm 3.025$	$36.080^a \pm 1.243$
T2	$70.917^b \pm 1.859$	$24.640^b \pm 1.364$
T3	$56.771^c \pm 3.432$	$20.053^c \pm 0.759$
T4	$75.020^b \pm 0.792$	$23.100^b \pm 0.777$
Significant	*	*

^{a,b,c}Means in each column with distinct superscript letters are statistically different at 5% significance level. GPT: G: Glutamate P: Pyruvate T: Transaminase, GOT: G: Glutamate O: Oxaloacetate T: Transaminase. T1: Control with no additions, T2, T3, and T4: Addition of the aqueous extract of arugula leaf at 50, 100, and 150 ml/liter/drinking water, respectively. *: $p < 0.05$.

These secondary metabolites include polyphenols such as phenolic acids and flavonoids, as well as carotenoids, all of which are important in preventing liver disease (Abou Seif, 2016). Arugula leaves and seeds are rich in antioxidants, which are vital for neutralizing free radicals (Hanna and Al-Salhie, 2024). These antioxidants protect the body from oxidative damage by sustaining or boosting antioxidant molecules and enzymes (Al-Sulivany et al., 2024). This process protects cells and tissues, thereby promoting overall health and well-being (Jabari et al., 2024). Arugula contains many healthy substances, including glucosinolates, vitamins A, C, and K, thiamine, riboflavin, niacin, vitamin B-6 (pyridoxine), pantothenic acid, and minerals such as calcium, copper, iron, magnesium, manganese, phosphorus, selenium, and zinc. These nutrients have strong antioxidant properties, effectively scavenging free radicals and reducing oxidative stress, which contributes to notably lower liver enzyme levels that are crucial for liver health and preventing liver diseases (Al-Sulivany et al., 2024). In contrast to the present results, Razooqi et al. (2014) found that administering four different levels of arugula seed oil to broiler chickens did not demonstrate any remarkable differences compared to the control group. While increased GPT and GOT activities in treatments with arugula seeds might suggest hepatic stress or potential damage, this elevation could also indicate an adaptive response, suggesting that the bioactive compounds and antioxidant properties of arugula seeds can enhance liver cell metabolic efficiency. Hanna and Al-Salhie (2024) indicated that arugula extract contributed to lowering GPT and GOT levels, emphasizing that the effect of arugula may differ depending on the plant part, form of supplementation, and dosage.

Table 3. Influence of cold-water extract of the arugula leaves on metabolic processes in broiler chickens aged 35 days

Treatments	Creatinine (mg/dl)	Urea (mg/dl)
T1	0.585[a] ± 0.003	21.150[a] ± 0.020
T2	0.297[c] ± 0.006	16.479[c] ± 0.015
T3	0.396[b] ± 0.004	18.072[b] ± 0.024
T4	0.405[b] ± 0.009	18.846[b] ± 0.024
Significant	*	*

[a,b,c] Means in each column with distinct superscript letters are statistically different at 5% significance level. T1: Control with no additions, T2, T3, and T4: Addition of the aqueous extract of arugula leaf at 50, 100, and 150 ml/liter/drinking water, respectively. *: $p < 0.05$.

The present results indicated that there was a significant decrease in creatinine levels in T2 (0.297 mg/dL), T3 (0.396 mg/dL), and T4 (0.405 mg/dL) compared to the control group (0.585 mg/dL; $p < 0.05$). In addition, a significant decrease in the urea concentration was observed in T2 (16.479 mg/dL), T3 (18.072 mg/dL), and T4 (18.846 mg/dL) compared to the control group (21.150 mg/dL; $p < 0.05$; Table 3). The evaluation of creatinine and urea levels served as a reliable diagnostic indicator of kidney function, as these compounds are metabolic byproducts that are reabsorbed in the renal tubules. The lower creatinine and urea concentrations observed in the groups supplemented with arugula extract, compared to the control group, indicated proper renal function and suggested that arugula supplementation supported kidney function (Al-Okbi et al., 2014). The current results are consistent with those of Hameed et al. (2026), who reported reductions in creatinine and urea levels in rats that were supplemented with arugula leaf extract, which had protective effects against oxidative stress. This protective effect contributed to improving kidney function by reducing the oxidative damage caused by free radicals. The observed improvement in creatinine and urea levels can be attributed to the nephron-protective and diuretic properties of arugula. By protecting renal cells from structural and functional impairment and simultaneously boosting the kidneys' filtration and urine excretion capacity, arugula effectively lowers metabolic waste accumulation and promotes overall renal health (Elgazar and AboRaya, 2013). The active ingredients in arugula, such as flavonoids and vitamin E, have antioxidant properties that are essential for reducing the production of free radicals, which decreases oxidative stress and helps preserve the integrity of the cells. This protective mechanism favored glucose utilization for energy over protein breakdown, thereby reducing muscle protein degradation and limiting nitrogenous waste production. Consequently, serum creatinine and urea levels decreased, indicating improved kidney function and a more balanced metabolic state (Hameed et al., 2026).

The current results indicated that the levels of T_3 hormone had significantly decreased in T2 (0.738 pmol/L), T3 (0.603 pmol/L), and T4 (0.882 pmol/L) compared to the control group (1.188 pmol/L; $p < 0.05$). A significant reduction in T_4 hormone concentration was observed in T2 (17.820 pmol/L), T3 (14.472 pmol/L), and T4 (16.695 pmol/L) compared to the control group (21.870 pmol/L; $p < 0.05$). The TSH hormone level was significantly decreased in T2 (0.711 mlu/L), T3 (0.576 mlu/L), and T4 (0.792 mlu/L) compared to the control group (1.080 mlu/L; $p < 0.05$; Table 4). The decrease in thyroid hormone concentrations aligns with the findings of Dhibi et al. (2018), highlighting that arugula leaf extract effectively regulates T_3, T_4, and TSH levels. The present results indicated that the plant extract might have improved thyroid hormone production by activating TSH receptors on thyroid cells. This activation stimulated adenylate cyclase, increased cAMP production, and enhanced thyroid enzymatic activity. Conversely, the reduction in thyroid hormone levels could be linked to the antioxidant compounds of arugula, such as saponins and flavonoids, which inhibited lipid peroxidation and thereby reduced T_3 and T_4 hormone secretion. Moreover, flavonoids contribute to lowering oxidative stress by neutralizing free radicals and enhancing antioxidant defenses, particularly glutathione, thereby ensuring sufficient iodine availability for thyroid hormone synthesis (Kumar and Pandey, 2013). The decrease in TSH levels resulted from a negative feedback mechanism that suppressed TSH secretion from the anterior pituitary gland (Brady et al., 2025). Lower T_4 hormone levels influenced the anterior lobe of the pituitary gland, resulting in decreased TSH secretion from thyrotrope cells. Furthermore, decreased T_4 can affect hypothalamic cells, leading to reduced TRH release and, consequently, lower TSH secretion (Shani, 2019).

Table 4. Influence of cold-water extract of the arugula leaves on thyroid hormones in broiler chickens aged 35 days

Treatments	Triiodothyronine (pMol/l)	Thyroxine (pMol/l)	Thyroid-stimulating hormone (mlu/l)
T1	$1.188^a \pm 0.018$	$21.870^a \pm 1.017$	$1.080^a \pm 0.045$
T2	$0.738^c \pm 0.009$	$17.820^b \pm 0.576$	$0.711^c \pm 0.018$
T3	$0.603^d \pm 0.036$	$14.472^c \pm 0.657$	$0.576^d \pm 0.009$
T4	$0.882^b \pm 0.027$	$16.695^b \pm 0.396$	$0.792^b \pm 0.009$
Significant	*	*	*

[a,b,c,d] Means in each column with distinct superscript letters are statistically different at 5% significance level. T1: Control with no additions, T2, T3, and T4: Addition of the aqueous extract of arugula leaf at 50, 100, and 150 ml/liter/drinking water, respectively. *: $p < 0.05$. Mlu/l: Milli-international units per liter.

Table 5. Influence of cold-water extract of the arugula leaves on blood parameters in broiler chickens aged 35 days

Treatments	RBCs (x106/mm3)	HB (g/dl)	PCV (%)
T1	$2.538^c \pm 0.099$	$9.189^b \pm 0.090$	$26.316^c \pm 0.162$
T2	$2.970^b \pm 0.045$	$9.630^{ab} \pm 0.072$	$28.773^a \pm 0.072$
T3	$3.609^a \pm 0.090$	$10.206^a \pm 0.099$	$28.296^a \pm 0.135$
T4	$2.790^b \pm 0.054$	$9.990^{ab} \pm 0.345$	$27.900^b \pm 0.054$
Significant	*	*	*

[a,b,c] Means in each column with distinct superscript letters are statistically different at 5% significance level. PCV: Packed cell volume, HB: Hemoglobin, RBCs: Red blood cells ($\times 10^6/mm^3$). T1: Control with no additions, T2, T3, and T4: Addition of the aqueous extract of arugula leaf at 50, 100, and 150 ml/liter/drinking water, respectively. *: $p < 0.05$.

Table 6. Influence of arugula leaf extract on serum protein profiles in broiler chickens aged 35 days

Treatments	Total protein (g/dl)	Albumin (g/dl)	Globulin (g/dl)
T1	$4.356^c \pm 0.055$	$2.387^b \pm 0.132$	$1.969^c \pm 0.055$
T2	$5.489^b \pm 0.222$	$3.366^a \pm 0.033$	$2.123^b \pm 0.044$
T3	$6.094^a \pm 0.253$	$3.817^a \pm 0.187$	$2.277^a \pm 0.044$
T4	$5.929^a \pm 0.198$	$3.630^a \pm 0.178$	$2.299^a \pm 0.022$
Significant	*	*	*

[a,b,c] Means in each column with distinct superscript letters are statistically different at 5% significance level. T1: Control with no additions, T2, T3, and T4: Addition of the aqueous extract of arugula leaf at 50, 100, and 150 ml/liter/drinking water, respectively. *: $p < 0.05$.

Table 7. Influence of cold-water extract of the arugula leaves on the lipid profile in broiler chickens aged 35 days

Treatments	TC mg/dl	TG mg/dl	LDL mg/dl	HDL mg/dl	VLDL mg/dl
T1	$128.700^a \pm 2.574$	$111.760^a \pm 0.132$	$91.828^a \pm 3.069$	$63.679^d \pm 1.716$	$22.352^a \pm 0.594$
T2	$116.600^b \pm 3.597$	$92.400^b \pm 0.033$	$70.730^b \pm 7.106$	$75.592^b \pm 0.999$	$18.480^b \pm 0.555$
T3	$96.140^c \pm 2.981$	$78.540^c \pm 3.432$	$57.475^c \pm 1.881$	$85.723^a \pm 1.969$	$15.620^c \pm 0.264$
T4	$121.000^b \pm 4.356$	$99.660^b \pm 0.178$	$77.572^b \pm 3.773$	$70.730^c \pm 1.584$	$19.932^b \pm 0.814$
Significant	*	*	*	*	*

[a,b,c,d] Means in each column with distinct superscript letters are statistically different at 5% significance level. TC: Cholesterol, TG: Triglycerides, LDL: Low-density lipoprotein, HDL: High-density lipoprotein, VLDL: Very low-density lipoprotein. T1: Control with no additions, T2, T3, and T4: Addition of the aqueous extract of arugula leaf at 50, 100, and 150 ml/liter/drinking water, respectively. *: $p < 0.05$.

A significant increase in RBCs was observed in Group T3 (3.609 × 10^6/mm^3) compared to the control group (2.538 × 10^6/mm^3; $p < 0.05$; Table 5). There was a significant increase in Hb concentration in Group T3 (10.206 g/dL) compared to the control group (9.189 g/dL; $p < 0.05$). Additionally, a significant increase in PCV was observed in Group T3 (28.296%) compared to the control group (26.316 %; $p < 0.05$). The increase in hematological parameters might be attributed to the presence of antagonists. The oxidative carotenoids preserved in arugula help mitigate the harmful effects of free radicals, thereby protecting cell membranes and lipids (Al-Sulivany et al., 2024). Free radicals can damage lipids and cell membranes, potentially leading to increased levels of RBC, Hb, and PCV. Antioxidants such as carotenoids mitigate the cellular damage, helping to maintain a healthy physiological balance (Komeroski et al., 2023). Haemoglobin and PCV increases might be due to the iron and essential vitamins found in arugula. These vitamins include B12, Niacin (B3), B6, B2, and B1, all of which are essential for the biosynthesis of Hb in the body. Iron and the aforementioned vitamins support RBC and Hb production, thereby contributing to the overall increase in Hb and PCV, ensuring the efficient transport of oxygen throughout the body (Al-Sulivany et al., 2024).

Arugula leaf extract administration increased the concentrations of albumin, globulin, and total protein in serum in the current investigation (Table 6). The present results indicated a significant increase in the serum total protein concentration in T3 (6.094 g/dL) and T4 (5.929 g/dL) compared to the control group, which had an average total protein concentration of 4.356 g/dL ($p < 0.05$). A significant increase in albumin concentration was observed in T2 (3.366 g/dL), T3 (3.817 g/dL), and T4 (3.630 g/dL) compared to the control group (2.387 g/dL, $p < 0.05$). A significant increase in globulin concentration was noted in T3 (2.277 g/dL) and T4 (2.299 g/dL) compared to the control group (1.969 g/dL; $p < 0.05$). These findings are consistent with those reported by Meligi and Hassan (2017). Arugula treatment mitigated the adverse effects of abamectin, likely due to its antimicrobial properties, as evidenced by improvements in biochemical indicators such as albumin, globulin, and total protein (Khalil et al., 2015). Including arugula in the diet enhanced overall performance and improved several physiological parameters, specifically boosting the total protein, albumin, and globulin levels. The current results indicate that arugula may be effective in enhancing metabolic efficiency and promoting greater health. Additionally, the rich nutrient profile of arugula, which includes antioxidants, vitamins, and minerals, contributed to its beneficial effects on physiological responses (Lehmood et al., 2026). An increase in protein levels was observed following arugula extract treatment, highlighting its protective role against liver damage. The high antioxidant content of arugula was responsible for its protective effects, which helped mitigate oxidative stress and promote liver health. Consistent with the present findings, Dhibi et al. (2018) observed that arugula oil might improve the general function of chicken liver cells, increase protein production in an injured liver, and encourage the regeneration of liver tissues. Furthermore, Abou El-Maaty et al. (2021) reported that incorporating rocket seeds into the chicken diet improved blood plasma components, particularly the total protein content.

According to the present results, TC concentration was significantly reduced in Group T3 (96.140 mg/dL) compared to the other treatment groups ($p < 0.05$; Table 7). Significant reductions in T2 (116.600 mg/dL) and T4 (121.000 mg/dL) were observed in TC levels in comparison to the control group (128.700 mg/dL; $p < 0.05$). The current results indicated a significant reduction in the TG concentration in Group T3 (78.540 mg/dL) compared to other treatment groups ($p < 0.05$). The TG levels in T2 (92.400 mg/dL) and T4 (99.660 mg/dL) were significantly lower than those of the control group (111.760 mg/dL; $p < 0.05$). There was a significant reduction in LDL concentration in T2 (70.730 mg/dL), T3 (57.475 mg/dL), and T4 (77.572 mg/dL) compared to the control group (91.828 mg/dL; $p < 0.05$). The present results indicated a significant increase in HDL level in Group T3 (85.723 mg/dL) compared to the other treatment groups ($p < 0.05$). The current findings demonstrated that the VLDL concentration significantly decreased in T2 (18.480 mg/dL), T3 (15.620 mg/dL), and T4 (19.932 mg/dL) compared to the control group (22.352; $p < 0.05$). The significant presence of linoleic and linolenic acids and unsaturated fatty acids in arugula oil (approximately 85%) is likely responsible for the observed decrease in lipid levels, as these fatty acids are known to enhance lipid metabolism and reduce hepatic cholesterol production (Alhila et al., 2022). Additionally, diets high in monounsaturated fatty acids (MUFA) can effectively reduce blood cholesterol levels by promoting the removal of LDL from the bloodstream and reducing its production in the liver (Schwingshackl and Hoffmann, 2012). The reduction in serum cholesterol levels with arugula treatment can be attributed to the presence of β-sitosterol, a compound that decreases cholesterol absorption in the intestine and consequently lowers blood cholesterol levels (Al-Sulivany et al., 2024). Flavonoids may lower cholesterol biosynthesis in hepatic cells by inhibiting hydroxymethylglutaryl-CoA (HMG-CoA) reductase, the primary enzyme that catalyzes the conversion of hydroxymethylglutaryl-CoA to mevalonic acid (Alhila et al., 2022). The reduction in TG levels might be attributed to the presence of fibers in arugula, which stimulated the activity of lipoprotein lipase, the enzyme responsible for triglyceride hydrolysis, thereby enhancing the breakdown of triglycerides into free fatty acids and glycerol, and consequently lowering their concentrations in the blood. Additionally, dietary fiber contributed to improved lipid metabolism by delaying intestinal fat absorption, increasing bile acid excretion, and modulating gut microflora, all of which collectively supported the observed decrease in serum TG levels (Komeroski et al., 2023). The lipid-lowering effects of arugula could be related to its phenolic compounds, which are powerful antioxidants with notable radical-scavenging activity. These phenolic compounds can boost antioxidant enzymes and lipoprotein lipase activity, facilitating triglyceride breakdown and removal from plasma, thus improving lipid metabolism and reducing serum TG levels (Lehmood et al., 2026). Arugula is rich in vitamin E, which plays an important role in reducing serum TG levels by preventing lipid oxidation in the liver cell membranes (Hanna and Al-Salhie, 2024). This antioxidant protects liver cells and helps lower blood TG levels. Vitamin E, in particular, plays a crucial role in preventing LDL oxidation by donating hydrogen atoms to free radicals, thereby inhibiting lipid peroxidation and subsequent cell damage (Mehvari et al., 2023).

CONCLUSION

The current results indicated that 100 mg/mL of arugula leaf extract in the broiler chickens' drinking water was the most effective level of supplementation, which improved blood parameters, liver enzymes, thyroid hormone levels, protein, and lipid metabolism. Future studies should consider applying this supplementation strategy to laying hens, with a specific focus on investigating its effects on reproductive hormones and egg production.

DECLARATIONS

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Authors' contributions

Bashar Ahmed Lehmood performed the research, data collection, analysis, and manuscript drafting. The manuscript was reviewed and edited by Tahreer Mohammed Al-Thuwaini and Eelaff Mishaal Mohammed. All authors have read and approved the final edition of the manuscript.

Availability of data and materials

This article contains all the data produced throughout the study. The authors provide further information upon reasonable requests.

Competing interests

No conflicts of interest have been disclosed by the authors.

Ethical considerations

All authors have checked for plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publishing and/or submission, and redundancy. The authors confirm that no AI tools were used for preparing or writing the present study.

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REFERENCES

Abd El-Hack ME, El-Saadony MT, Elbestawy AR, Gado AR, Nader MM, Saad AM, El-Tahan AM, Taha AE, Salem HM, and El-Tarabily KA (2022). Hot red pepper powder as a safe alternative to antibiotics in organic poultry feed: An updated review. Poultry Science, 101(4): 101684. DOI: https://www.doi.org/10.1016/j.psj.2021.101684

Abou El-Maaty H, Abd El-Aziz MH, El-Diasty MZ, and El-Said EA (2021). Effect of dietary rocket seeds meal and nano-chitosan on performance and related gene expression to growth and lipid profile in broiler chicks. Egyptian Journal of Nutrition and Feeds, 24(1): 139-155. DOI: https://www.doi.org/10.21608/ejnf.2021.139155

Abou Seif HS (2016). Physiological changes due to hepatotoxicity and the protective role of some medicinal plants. Beni-Suef University Journal of Basic and Applied Sciences, 5(2): 134-146. DOI: https://www.doi.org/10.1016/j.bjbas.2016.03.002

Al-Okbi SY, Mohamed DA, Hamed TE, Esmail RS, and Donya SM (2014). Prevention of renal dysfunction by nutraceuticals prepared from oil rich plant foods. Asian Pacific Journal of Tropical Biomedicine, 4(8): 618-626. DOI: https://www.doi.org/10.12980/APJTB.4.2014C1036

Al-Sulivany BS, Ahmed DY, Naif RO, Saleem PM, and Omer EA (2024). Phytochemical profile of *Erucaruca sativa* and its therapeutic potential in disease prevention and treatment. Global Academic Journal of Agriculture and Biosciences, 6(3): 57-64. DOI: https://www.doi.org/10.36348/gajab.2024.v06i03.001

Alhila M, Sulaiman YA, Subuh AM, Habra N, and Alhilal S (2022). *Eruca sativa* mill seeds oil alleviates hyperlipidemia and nonalcoholic fatty liver disease in Syrian hamster. Journal of Animal & Plant Sciences, 32(6): 1552-1561. DOI: https://www.doi.org/10.36899/JAPS.2022.6.0564

Amal M, El-Sahn AA, Iraqi EE, Elprollosy AA, and Farag ME (2023). Effects of supplementation of *Eurca* seeds as nutraceutical feed additive on productivity, antioxidant activity, and yolk cholesterol level of laying hens. Journal of World's Poultry Research, 13(3): 342-351. DOI: https://www.doi.org/10.36380/jwpr.2023.37

Azizi MN, Zahir A, Mahaq O, and Aminullah N (2024). The alternatives of antibiotics in poultry production for reducing antimicrobial resistance. World Veterinary Journal, 14(2): 270-283. DOI: https://www.doi.org/10.54203/scil.2024.wvj34

Brady K, Long JA, Liu HC, and Porter TE (2021). Characterization of hypothalamo–pituitary–thyroid axis gene expression in the hypothalamus, pituitary gland, and ovarian follicles of Turkey hens during the preovulatory surge and in hens with low and high egg production. Poultry Science, 100(4): 100928. DOI: https://www.doi.org/10.1016/j.psj.2020.12.026

Dhibi S, Bouzenna H, Elfeki A, and Hfaiedh N (2018). *Eruca sativa* essential oil protects upon hyperthyroidism induced damages in rat. Medicinal and Aromatic Plants, 7(2): 1000319. DOI: https://www.doi.org/10.4172/2167-0412.1000319

Duncan DB (1955). Multiple range and multiple F-tests. Biometrics, 11: l-42. DOI: http://www.doi.org/10.2307/3001478

Elgazar AF and AboRaya AO (2013). Nephroprotective and diuretic effects of three medicinal herbs against gentamicin-induced nephrotoxicity in male rats. Pakistan Journal of Nutrition, 12(8): 715-722. DOI: https://www.doi.org/10.3923/pjn.2013.715.722

Hameed KI, Jasim MF, Kadhim RS, and Hindi MH (2026). Effect of *Eruca sativa* leaf extract on serum cystatin C levels and renal function markers in experimental rats. Journal of Animal Health and Production, 14(1): 65-71. DOI: https://www.doi.org/10.17582/journal.jahp/2026/14.1.65.71

Hanafi EM, Hegazy EM, Riad RM, and Amer HA (2010). Bio-protective effect of *Eruca sativa* seed oil against the hazardus effect of aflatoxin b1 in male-rabbits. International Journal of Academic Research, 2(2): 67-74. Available at: https://scispace.com/pdf/bioprotective-effect-of-eruca-sativa-seed-oil-against-the-4z7e3s4g9q.pdf

Hanna SJ and Al-Salhie KC (2024). The effect of the alcoholic extract of *Eruca sativa* seeds on some blood biochemical indicators and histological characteristics of liver in broiler chickens exposed to lead acetate poisoning. Basrah Journal of Veterinary Research, 23(3): 13-23. DOI: https://www.doi.org/10.23975/bjvr.2024.150390.1092

Harborne J (1998). Phytochemical methods: A guide to modern techniques of plant analysis. Chapman and Hall. Available at: https://books.google.iq/books?hl=en&lr=&id=2yvqeRtE8CwC&oi=fnd&pg=PR7&dq=Harborne+J+(1998).+Phytochemical+methods:+A+guide+to+modern+techniques+of+plant+analysis.+Chapman+and+Hall.&ots=xBhiQ8NrW2&sig=0hVxImf0Y8mv1d8e7rFJx9ZrLd0&redir_esc=y#v=onepage&q=Harborne%20J%20(1998).%20Phytochemical%20methods%3A%20A%20guide%20to%20modern%20techniques%20of%20plant%20analysis.%20Chapman%20and%20Hall.&f=false

Khalil FF, Mehrim AI, and Refaey MM (2015). Impact of dietary rocket (*Eruca sativa*) leaves or seeds on growth performance, feed utilization, biochemical and physiological responses of *Oreochromis niloticus*, Fingerlings. Asian Journal of Animal Sciences, 9(4): 134-147. DOI: https://www.doi.org/10.3923/ajas.2015.134.147

Komeroski MR, Portal KA, Comiotto J, Klug TV, Flores SH, and Rios AD (2023). Nutritional quality and bioactive compounds of arugula (*Eruca sativa* L.) sprouts and microgreens. International Journal of Food Science and Technology, 58(10): 5089-5096. DOI: https://www.doi.org/10.1111/ijfs.16607

Kumar S and Pandey AK (2013). Chemistry and biological activities of flavonoids: An overview. The Scientific World Journal, 2013(1): 162750. DOI: https://www.doi.org/10.1155/2013/162750

Lehmood B, Mohammed E, Assaf A, Fadhil H, Khlaif LS, and Al-Thuwaini T (2026). Effect of adding the arugula leaf extract to drinking water on the growth performance of broilers. Journal of Livestock Science and Technologies, 14(1): 41-47. DOI: https://www.doi.org/10.22103/jlst.2025.25305.1630

Mehvari F, Imanparast F, Mohaghegh P, Alimoradian A, Khansari N, Ansari Asl B, and Khosrowbeygi A (2023). Protective effects of paraoxonase-1, vitamin E and selenium, and oxidative stress index on the susceptibility of low density lipoprotein to oxidation in diabetic patients with/without coronary artery disease. European Journal of Medical Research, 28(1): 300. DOI: https://www.doi.org/10.1186/s40001-023-01254-9

Meligi NM and Hassan HF (2017). Protective effects of *Eruca sativa* (rocket) on abamectin insecticide toxicity in male albino rats. Environmental Science and Pollution Research, 24(10): 9702-9712. DOI: https://www.doi.org/10.1007/s11356-017-8671-8

Jabari IMN, Salih SA, Hussein RA, and Bapir SH (2024). Effects of adding powdered arugula (*Eruca sativa*) seed on some of physiological and biochemical blood parameters in local male rabbits under oxidative stress. Kirkuk University Journal for Agricultural Sciences, 15(1): 221-226. Available at:

https://iasj.rdd.edu.iq/journals/uploads/2025/05/28/2432bf73423845ac00a0c7c85c45d8e4.pdf

National research council (NRC) (1994). Nutrient requirement of poultry, 9th Revised Edition. National Research Council. National Academy Press, Washington, D. S, USA. Available at: https://books.google.iq/books?hl=en&lr=&id=bbV1FUqRcM0C&oi=fnd&pg=PR11&dq=National+research+council+(NRC)+(1994).+Nutrient+requirement+of+poultry,+9th+Revised+Edition.+National+Research+Council.+National+Academy+Press,+Washington,+D.+S,+USA.&ots=IllNZEesRu&sig=ogE8_-RMQ0-dQRoWJ_GWFMZwR3A&redir_esc=y#v=onepage&q&f=false

Obianwuna UE, Chang X, Oleforuh-Okoleh VU, Onu PN, Zhang H, Qiu K, and Wu S (2024). Phytobiotics in poultry: Revolutionizing broiler chicken nutrition with plant-derived gut health enhancers. Journal of Animal Science and Biotechnology, 15(1): 169. DOI: https://www.doi.org/10.1186/s40104-024-01101-9

Razooqi RH, Shkeer HK, Alwan YO, and Hayder MI (2014). Effect of *Eruca sativa* oil (ESO) on broiler performance and some blood traits. International Journal of Advanced Biological Research, 4(4): 479-482. Available at: http://www.scienceandnature.org/IJABR/IJABR_Vol4(4)2014/IJABR_V4(4)14-16.pdf

Reitman S and Frankel S (1957). A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. American Journal of Clinical Pathology, 28(1): 56-63. DOI: https://www.doi.org/10.1093/ajcp/28.1.56

Schwingshackl L and Hoffmann G (2012). Monounsaturated fatty acids and risk of cardiovascular disease: Synopsis of the evidence available from systematic reviews and meta-analyses. Nutrients, 4(12): 1989-2007. DOI: https://www.doi.org/10.3390/nu4121989

Shani E (2019). Evaluation of the protective effect of *Eruca sativa* seeds powder against oxidative stress and some physiological, histological and productive performance in broilers. Master's Thesis, University of Kerbala, Iraq.

Stanojković-Sebić A, Miladinović V, Stajković-Srbinović O, and Pivić R (2024). Response of arugula to integrated use of biological, inorganic, and organic fertilization. Microorganisms, 12(7): 1334. DOI: https://www.doi.org/10.3390/microorganisms12071334