The EuroBiotech Journal
REVIEW
Plant Biotechnology

Effect of *Glycyrrhiza glabra* L. on Broiler Growth Performance, Slaughter and Carcass Characteristics, Blood biochemistry, and Hematological Parameters: A Systematic Review

Selim Esen [1,*], Andrea Prete [2], Gerardo Centoducati [2], Maximilian Lackner [3,*], Valiollah Palangi [4], Cemil Tölü [5]

Abstract

In this systematic review, 79 research articles focusing on the impact of *Glycyrrhiza glabra* L. (licorice) supplementation in broilers were meticulously examined, assessing growth performance, slaughter and carcass traits, and blood parameters. Out of these, 12 studies met the predefined criteria. Licorice supplementation, particularly in the absence of specific dietary constraints, signifi-cantly improved feed consumption, body weight gain, and feed conversion efficiency in broilers. The addition of licorice influ-enced slaughter and carcass traits, increasing the dressing percentage, although results varied based on dosage and form of supplementation. Effects on abdominal fat and spleen weights were inconsistent, while liver, heart, and gizzard weights gen-erally increased. Licorice supplementation affected blood biochemistry, showing varied impacts on markers like glucose, cho-lesterol, and triglycerides. Notably, licorice exhibited potential antioxidant properties by reducing malondialdehyde levels, in-dicating decreased oxidative stress. The review highlighted diverse outcomes across growth performance, slaughter traits, car-cass parameters, and blood biochemistry due to licorice supplementation. Variability in dosage, form, and administration methods underscored the need for standardized protocols. Future research should concentrate on uncovering underlying mechanisms, expanding geographical diversity, and exploring interactions with other feed additives, especially in antibiotic-free diets. Despite its promise, further investigation is necessary to optimize licorice's role in poultry production.

Keywords: broiler; licorice; growth performance; carcass traits; biochemical parameters

Introduction

The poultry sector plays a crucial role in meeting the growing demand for animal protein, and various strategies have been implemented to increase profitability in poultry production [1,2]. Among these strategies, dietary modifications stand out as a powerful tool significantly impacting productivity [3,4]. These modifications are vital for the development, health, and overall well-being of broilers, making them of great importance to the poultry industry and consumers alike [5]. Consequently, research continues to focus on identifying safe and sustainable nutritional supplements to enhance broiler production efficiency and product quality. One supplement that has gained particular attention for its potential to improve broiler performance and health is *Glycyrrhiza glabra* L., more commonly known as licorice [6–8].

Glycyrrhiza glabra L., a herbaceous perennial plant from the Leguminosae family, is native to Europe and Asia and has a long history, spanning over 4000 years, of use in medicinal and nutritional applications [9]. The active compounds present in licorice extract (LE), primarily triterpene saponins (including glycyrrhizin, glycyrrhetinic acid, and licoric acid) and flavonoids (such as liquiritin, formononetin, and isoflavonoids), are recognized for their numerous health benefits. These include anti-inflammatory, antioxidant, immunomodulatory, and antimicrobial properties [4,10]. Such characteristics have led researchers to explore its potential applications in the poultry industry.

Previous research has extensively detailed the chemical composition of licorice [11,12], its structural properties [13], and its beneficial effects on poultry production [3,14]. This systematic review focuses on existing studies regarding *Glycyrrhiza glabra* L. supplementation in broilers, including an in-depth analysis of study designs, methodologies, and

[1] Balikesir Directorate of Provincial Agriculture and Forestry, Republic of Türkiye Ministry of Agriculture and Forestry, Balikesir 10470, Türkiye; selim_esen01@hotmail.com (S.E)
[2] Department of Veterinary Medicine, University of Bari Aldo Moro, 70010, Valenzano, Italy; andrea.prete@uniba.it (A.P.); Gerardo.centoducati@uniba.it (G.C.)
[3] Department of Industrial Engineering, University of Applied Sciences Technikum Wien, Hoechstaedtplatz 6, 1200 Vienna, Austria; maximilian.lackner@technikum-wien.at (M.L)
[4] Visiting Researcher at Department of Life Sciences, Western Caspian University, Baku, Azerbaijan; valiollah.palangi@yahoo.com
[5] Department of Animal Science, Faculty of Agriculture, Çanakkale Onsekiz Mart University, Çanakkale 17100, Türkiye; cemiltolu@comu.edu.tr (C.T.)

***Corresponding authors:**
selim_esen01@hotmail.com (S.E.)
maximilian.lackner@technikum-wien.at (M.L.)

DOI: 10.2478/ebtj-2025-0006

potential biases. Specifically, the primary goal of this review is to thoroughly assess the effects of *Glycyrrhiza glabra* L. supplementation on broilers, covering three main aspects:

i) To improve broiler management practices and gain an in-depth understanding of the effects of *Glycyrrhiza glabra* L. supplementation on growth performance, this review will meticulously examine its impact on feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR), which are key performance indicators.

ii) To assess the influence of *Glycyrrhiza glabra* L. on broiler slaughter and carcass characteristics, providing insights into potential advancements in meat production.

iii) To evaluate the effects of *Glycyrrhiza glabra* L. supplementation on broiler physiology and overall health by monitoring their blood biochemistry and hematological parameters.

These insights will be invaluable for poultry producers, veterinarians, and researchers committed to the sustainable enhancement of broiler production while upholding animal welfare standards and ensuring product quality.

Materials-Methods

Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses methodology (PRISMA), we conducted a systematic literature review to gather the most up-to-date information about the effects of Licorice Extract (LE) on growth performance, slaughtering and carcass characteristics, as well as blood biochemistry and hematological parameters in broilers [15]. To achieve our proposed objective, we followed a series of steps, including search, selection, eligibility, and inclusion of studies, along with the analysis and extraction of relevant information.

2.1. Systematic review of the literature

To identify relevant articles, we conducted a systematic search of the Web of Science, Scopus, and PubMed databases, which are among the most important global scientific literature databases. Given the specific focus of this study, we employed multiple search terms (Table 1) to retrieve as many relevant publications as possible. To ensure a comprehensive search, we utilized Boolean operators (AND, OR, and NOT) along with wildcard truncations (" ") to account for various word and phrase forms, ultimately returning papers that were pertinent to the study.

2.2. Used systematic approach to selecting and organizing studies

This systematic review exclusively included studies that investigated the impact of licorice extract (LE) on broiler growth performance, slaughter and carcass characteristics, and blood biochemistry and hematology. We focused on peer-reviewed experimental articles published in English, up to July 2023, following predefined inclusion and exclusion criteria. The search across the Web of Science, Scopus, and PubMed databases resulted in 35, 31, and 13 results, respectively. After importing *the* data into Mendeley® software, duplicates were identified and eliminated. The selection process, guided by the PRISMA methodology (see Figure 1), involved a four-step screening process [15]. Additionally, this study did not impose additional restrictions such as publication dates, sample sizes, or journal quality, aiming to provide a more comprehensive overview of the existing literature.

2.3. The process of extracting and manipulating information

Microsoft Excel® was employed for the extraction and organization of relevant data from the selected studies. The spreadsheet included details such as study identification, authorship, publication year and journal, country and region, strain, sex, management conditions (housing temperature and lighting cycle), basal diet, experimental design, treatment groups, and study objectives. This approach facilitated a comprehensive and structured analysis of the information obtained from the chosen studies.

Results and Discussion

3.1. Overview of included studies

An overview of the selected studies in this systematic review is presented in Table 2, including authorship, publication year, country and region, strain, sex, housing conditions (including temperature and lighting cycle), basal diets, experimental design, treatment groups, and study objectives. The twelve selected studies spanned the years from 2005 to 2023, reflecting the increasing interest in alternative feed additives. This period coincides with the emergence of *Glycyrrhiza glabra* L. as a novel addition, especially in light of the prohibition of antibiotics as growth promoters in poultry production [16,17].

Table 2 indicates that the research was predominantly carried out in Asian nations, where *Glycyrrhiza glabra* L. is indigenous. Specifically, four studies were conducted in Iraq, another four in Iran, three in Egypt, and one in Pakistan. The Ross-308

Table 1. Search terminology employed in this systematic review investigation.

Acronym	Search string
Animals	("poultry" OR "broilers" OR "chicken")
Additives	("*Glycyrrhiza glabra*" OR "Liquorice" OR "Licorice")
Output	("performance" OR "growth performance" OR “biochemical parameters" OR "blood indices" OR "antioxidants capacity" OR "carcass" OR “meat” OR “meat quality”)

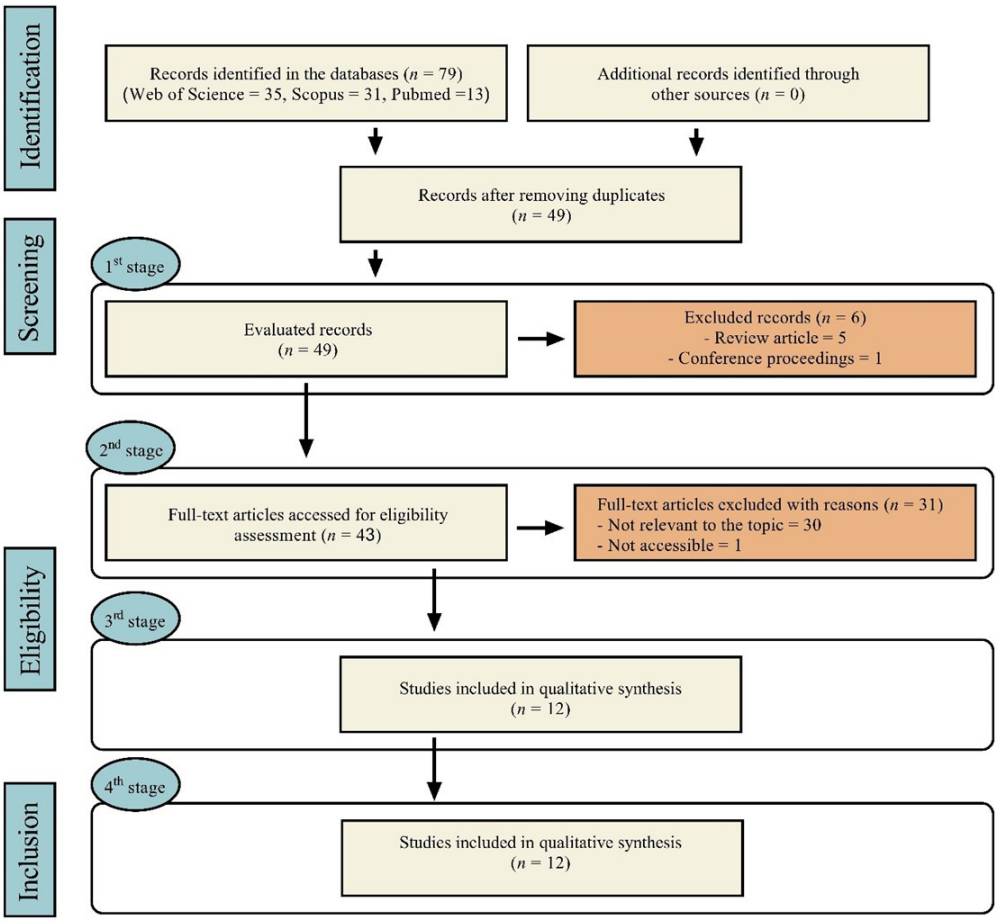

Figure 1. An overview of selecting and searching for relevant articles within the PRISMA guideline

strain was the primary choice in most studies, with Cobb used in two, Fawbro in one, and Arian in one. Eight studies did not specify the sex of the chicks, while two mentioned using male chicks, and the remaining two used mixed-sex chicks. Additionally, lighting cycle information was not provided in four studies, and five studies lacked details regarding housing temperature conditions.

In these studies, it was reported that a basal diet primarily composed of maize and soybean meal was utilized. Two studies incorporated a basal diet consisting of wheat and soybean meal. Moreover, one study employed a commercial broiler ration, and another study lacked information about the basal diet. *Glycyrrhiza glabra* L. was added to the basal diet in nine studies, while three studies introduced it into drinking water. In two studies, *Glycyrrhiza glabra* L. was used in the form of essential oil (LEO), either within the base diet or added to drinking water. The remaining studies utilized it as an extract (LE). Additionally, in two studies, *Glycyrrhiza glabra* L. was incorporated into diets contaminated with aflatoxin as an alternative to antibiotics.

3.2. Effect of *Glycyrrhiza glabra* L. supplementation on growth performance

Out of the twelve selected studies, ten focused on growth performance characteristics, with only six of them implementing a separate diet for chicks during the starter period. As depicted in Table 3, the incorporation of Licorice Extract (LE) in the diet of broiler chicks during the starter period led to improvements in Feed Intake (FI) and Body Weight Gain (BWG), except in one study [28]. Additionally, it resulted in a reduction in Feed Conversion Ratio (FCR) by 0.01-0.10%. The optimal dosage for these effects was found to be two grams of LE per kilogram of diet. Conversely, when LEO was introduced into the diet at equivalent levels to LE, it did not elicit the same positive response from the chicks.

In two distinct studies (Beski et al.[20]; Iqbal et al.[17]), the favorable outcomes were observed when LE was added to the drinking water of broiler chicks, as opposed to directly incorporating LE and LEO into their diet. Particularly noteworthy was a study where licorice root powder was infused into the drinking water through a three-hour boiling process at 80 °C [17], yielding superior outcomes compared to another study where licorice root powder was simply added to the water and subsequently filtered [20]. However, it has been established that this extraction method has minimal impact on reducing FCR. On the contrary, a reduction in FCR is observed when

Reference	Place	Strain	Sex	Housing temperature	Lighting cycle	Basal diet	Experimental design	Treatments	Purpose
Al-Daraji et al. [18]	IQ	Fawbro	NS	NS	NS	[1]Commercial broiler ration containing 22.7% CP and 2867.4 kcal/kg ME were used in the starter phase (1-21 d) and commercial broiler ration containing 20.6% CP and 2867.4 kcal/kg ME were used in the finisher phase (22-49 d).	A CR design was used to allocate 900 three-week-old chicks into 6 experimental groups in 3 replications, with 50 chicks in each group.	[2, 3] Diets were treated as follows: CON diets with zero supplements, diets contaminated with 2 mg AF/kg diet, diets contaminated with 2 mg AF/kg diet+mold killer, diets contaminated with 2 mg AF/kg diet + 0.15, 0.30 or 0.45 g LE/kg diet.	To suppress the effect of AF on the production performance of broiler chickens.
Sedghi et al. [19]	Mashhad, IR	Ross-308	Male	Started out at 30-32°C, decreased by 2.5°C/w to 20-22°C, and remained constant between the d 28 and 49.	24 h for 1-3 d, 23:1 h for 4-49 d	Maize-soybean meal-based diets with 2 different RDAA ratios (95 and 100%) were used in 3 different phases (starter 1-14 d, grower 15-35 d, and finisher 36-49 d)	A CR design was used to allocate 600 day-old birds into 10 experimental groups in 5 replications, with 12 birds in each group.	[4] Diets were subdivided into 5 categories: CON diets with zero supplements, and diets supplemented with 2.0 g prebiotic/kg and 0.5, 1.0 or 2.0 g LE/kg diet.	To evaluate dietary supplementation of LE and prebiotic on PER, BM, FD and DOS of broiler chickens fed diets containing different levels of digestible amino acids.
Beski et al. [20]	Duhok, IQ	Ross-308	NS	Started out at 33 °C fort he first 5 d, gradually decreased by 0.5°C/d to 23°C, and remained constant between the d 25 and 35.	24 h for 1 d, 23:1 h for 2-35 d	[5] Wheat-soybean meal-based diets were used in 3 different phases (starter 1-10 d, grower 11-24 d, and finisher 25-35 d)	A CR design was used to allocate 160 day-old birds into 4 experimental groups in 4 replications, with 10 birds in each group.	[6] The aqueous form of LE was used as drinking water throughout the experiment. Treatments used in the experiment were: CON drinking water with zero LE, drinking water supplemented with 0.50, 0.70 or 0.90 g LE/L.	To elucidate the impact of administering aqueous LE through drinking water on the PER, CC, and intestinal histomorphology of broiler chickens.
Rashidi et al. [21]	Ahvaz, IR	Ross-308	Mixed	Started out at 30-33°C, decreased by 2.5°C/w to 22-24°C, and remained constant between the d 28 and 42.	24 h for 1-3 d, 23:1 h for 4-42 d	[7] Maize-soybean meal-based diets were used in 2 different phases (starter 1-21 d, grower 22-42 d)	A CR design was used to allocate 336 day-old birds into 5 experimental groups in 4 replications.	[8] A SD-based experimental group was created. Treatments were as follows: PC (12 birds/m^2, or 0.08 m^2 FS for each bird), NC (18 birds/m^2, or 0.05 m^2 FS for each bird), NC + 0.5 g/LE kg; NC + 0.2 g/probiotic kg; NC + 0.5 g/LE kg + 0.2 g/probiotic kg diet.	To investigate the effects of LE and probiotic, alone and in combination, on PER, BP, CC, droppings and welfare- related parameters of broiler chickens at high SD
Ibrahim et al. [22]	Zagazig, EG	Ross-308	Male	Started out at 32-34 °C for the first 3 d, decreased by 3.0 °C/w to 24°C, and remained constant at the end of the experiment.	24 h for 1-3 d, 23:1 h for 4-35 d	[9] Wheat-soybean meal-based diets were used in 2 different phases (starter 1-20 d, grower to finisher 21-35 d)	A CR design was used to allocate 500 day-old birds into 5 experimental groups in 10 replications, with 10 birds in each group.	Diets were treated as follows: CON diets with zero supplements, diets supplemented with 0.25, 0.50, 1.0 or 2.0 g LE/kg diet.	To evaluate the efficacy of LE on PER, gene expression (occludin, JAM-2, FABP-6, GLP-2, TLR-4, and MUC-2 genes), and resistance to *Campylobacter jejuni* infection in broiler chickens.
Ibrahim et al. [23]	Kirkuk, IQ	Ross-308	NS	NS	NS	[7]Maize-soybean meal-based diets were used in 2 different phases (starter 1-21 d, grower 22-35 d)	A CR design was used to allocate 120 day-old birds into 5 experimental groups in 3 replications, with 8 birds in each group.	Diets were treated as follows: CON diets with zero supplements, diets supplemented with 0.50, 1.0, 1.5 or 2.0 g LE/kg diet.	To investigate the effects of LE on BP and istestinal microflora of broiler chickens
Iqbal et al. [17]	Faisalabad, PK	Cobb	NS	NS	NS	The composition of the basal diet was not provided; however, the study employed two distinct diets for the starter phase (1-21 d) and the grower phase (22-35 d).	A CR design was used to allocate 180 day-old birds into 6 experimental groups in 3 replications, with 10 birds in each group.	[10,11] Treatments were as follows: PC (diet + antibiotic), NC (diet without antibiotic), diet supplemented with 10, 15, 20 or 25 mL/L LE.	

Rashidi et al. [24]	Ilam, IR	Ross-308	NS	NS	NS	[12] Maize-soybean meal-based diets were used in 3 different phases (starter 1-11 d, grower 12-24 d, and finisher 25-42 d)	A CR design was used to allocate 504 day-old birds into 7 experimental groups in 6 replications, with 12 birds in each group.	[13,14] Diets were treated as follows: CON diets with zero supplements or AF B_1, diets contaminated with 0.5 mg AF B_1/kg diet, diets contaminated with 0.5 mg AF B_1/kg diet + 3 or 6 g LE/kg, diets contaminated with 0.5 mg AF B_1/kg diet + 0.5 g probiotic/kg diet, diets contaminated with 0.5 mg AF B_1/kg diet + 1.0 g toxin binder/kg diet, diets contaminated with 0.5 mg AF B_1/kg diet + 5 g PLB/kg diet.	To assess the protective effect of the probiotic, toxin binder, PLB, and LE on broilers against AF B_1, and to contrast the efficacy of PBL, probiotic, and toxin binder with LE by evaluating PER, CC, AT, serum biochemical attributes, liver enzyme activities, hepatocyte pathology, and antioxidant status.
Geravand et al. [16]	Tehran, IR	Arian	NS	Started out at 32-34°C, decreased by 3.5°C/w to 22-24°C	23:1 h for 1-42 d	Maize-soybean meal-based diets were used in 3 different phases (starter 1-14 d, grower 15-28 d, and finisher 29-42 d)	A CR design was used to allocate 625 day-old birds into 5 experimental groups in 5 replications, with 25 birds in each group.	[15,16,17] Diets were treated as follows: CON diets with zero supplements, diets supplemented with 0.15 g antibiotic/kg diet, diets supplemented with 0.10 g probiotic/kg diet diets supplemented with 0.20 or 0.40 g LEO/kg diet,	To investigate the effects of LE, as a substitute for antibiotics, on PER, BP, ascites sensitivity and ileal microbiota of broiler chickens.
Abo-Samaha et al. [6]	Alexandria, EG	Cobb500	NS	Started out at 32°C, decreased by 3.5°C/w to 24°C	23:1 h for 1-42 d	[7] Maize-soybean meal-based diets were used in 3 different phases (starter 1-14 d, grower 15-28 d, and finisher 29-42 d)	A CR design was used to allocate 180 one-week-old chicks into 3 experimental groups in 3 replications, with 20 birds in each group.	[6]The aqueous form of LE was used as drinking water throughout the experiment. Treatments used in the experiment were: CON drinking water with zero LE, drinking water supplemented with 0.40 or 0.80 g LE/L.	To characterize the impact of administering aqueous LE through drinking water on the PER, CC, BP, and intestinal histopathology and gene expression of broiler chickens.
Dheyauldeen Salahdin et al. [7]	Anbar-Ramadi, IQ	Ross-308	NS	Started out at 33°C, decreased by 2.5°C/w to 24°C, and remained constant between the d 28 and 42.	23:1 h for 1-42 d	[7] Maize-soybean meal-based diets were used in 3 different phases (starter 1-10 d, grower 11-28 d, and finisher 29-42 d)	A CR design was used to allocate 160 day-old birds into 4 experimental groups in 4 replications, with 10 birds in each group.	[18] Diets were treated as follows: CON diets with zero supplements, diets supplemented with 1.0, 2.0 or 3.0 g LEO/kg diet.	To investigate the effectiveness of LEO as a potential substitute for chemical antibiotics on PER, CC, BP of broiler chickens.
Toson et al. [8]	El-Minia, EG	Ross-308	Mixed	NS	23:1 h for 1-35 d	[10] Maize-soybean meal-based diets were used in 2 different phases (starter 1-21 d, grower 22-35 d)	A CR design was used to allocate 320 day-old birds into 4 experimental groups in 8 replications, with 10 birds in each group.	Diets were treated as follows: CON diets with zero supplements, diets supplemented with 1.0, 2.0 or 3.0 g LE/kg diet.	To investigate the effects of LE on PER, BP, CC and antioxidative capacity of broiler chickens

[1] The periods given as weeks are converted to days for the purpose of standardization. [2] The unit given as mg/kg has been converted to g/kg for the purpose of standardization. [3] The production of aflatoxin was achieved by growing *Aspergillus flavus* on rice. [4] The Fermacto was utilized as a prebiotic. [5] A comprehensive table of the experimental diet composition is not included. [6] An aqueous LE was produced by mixing licorice root powder with water. [7] The diets were prepared based on NRC [25] recommendations. [8] *Bacillus subtilis* DSM 17299 was used as a probiotic at a rate of 4×10^9 cfu/g per gram. [9] The diets were prepared based on Ross catalog recommendations [26]. [10] There was no mention of the specific antibiotic used or its dosage. [11] An LE was prepared by boiling 50 g of licorice root powder for 3 h at 80 °C with one liter of water. [12] The diets were prepared based on Ross catalog recommendations [27] . [13] AF was generated through the fermentation of rice grains using an *Aspergillus parasiticus* PTCC-5286 culture, with subsequent quantification of its AF B1 content. [14] Protexin, utilized as a probiotic, consists of 9 bacterial strains and contains a bacterial count of 2×10^9 cfu per gram. [15] Protexin, utilized as a probiotic, consists of 7 bacterial and 2 yeast strains [16] A premix mixture of 10% avilamycin was used as an antibiotic. [17] A commercially available LEO was used (Zard Band Pharmaceutical Co., Tehran, Iran). [18] An essential oil extracted from licorice root was used. CON: control, CP: crude protein, ME: metabolizable energy, LE: licorice extract, PER: performance, BM: blood metabolites, BP: blood parameters, FD: fat digestibility, DOS: digestive organ size, RDAA: recommended digestible amino acid, NS: not specified, AF: aflatoxins, PLB: poultry litter biochar, PC: positive control, NC: negative control, FS: floor space, SD: stocking density, LEO: licorice essential oil.

Table 3. Effect of licorice (*Glycyrrhiza glabra* L.) extract on growth performance parameters in broilers[1,2]

Reference	Dosage	Period	FI (g)	BWG (g)	FCR (g/g)
[3,4] Sedghi et al. [19]	0.5 g LE/kg diet	G	R95: -40 R100: +115	R95: -9 R100: +79	R95: -0.02 R100: -0.03
	1.0 g LE/kg diet		R95: -23 R100: +79	R95: -12 R100: +60	R95: 0 R100: -0.03
	2.0 g LE/kg diet		R95: -76 R100: +90	R95: -16 R100:+47	R95: -0.04 R100: 0
	0.5 g LE/kg diet	F	R95: +33 R100: +32	R95: +19 R100:+4	R95: -0.01 R100: +0.02
	1.0 g LE/kg diet		R95: -36 R100: -110	R95: -11 R100: -44	R95: -0.01 R100: -0.01
	2.0 g LE/kg diet		R95: +36 R100: +151	R95: +11 R100: +67	R95: +0.01 R100: 0
	0.5 g LE/kg diet	T	R95: +103 R100: +305		R95: +0.03 R100: +0.06
	1.0 g LE/kg diet		R95: +62 R100: -165		R95: +0.04 R100: -0.08
	2.0 g LE/kg diet		R95: +110 R100: +279		R95: +0.06 R100: +0.02
Beski et al. [20]	0.5 g LE/L DW	S	-5	+9	-0.07
	0.7 g LE/L DW		-9	+10	-0.06
	0.9 g LE/L DW		+1	+10	-0.03
	0.5 g LE/L DW	G	+40	+16	-0.02
	0.7 g LE/L DW		+42	+7	0
	0.9 g LE/L DW		+5	-17	+0.01
	0.5 g LE/L DW	F	+125	+83	+0.01
	0.7 g LE/L DW		+162	+139	0
	0.9 g LE/L DW		+128	+108	-0.03
	0.5 g LE/L DW	T	+169	+120	0
	0.7 g LE/L DW		+188	+156	+0.01
	0.9 g LE/L DW		+133	+114	0
[5] Rashidi et al. [24]	0.5 g/LE kg diet	S	PC: +54 NC: +63	PC: +62 NC: +40	PC: -0.09 NC: -0.01
		G	PC: +35 NC: +100	PC: +89 NC: +186	PC: -0.10 NC:- 0.18
		T	PC: +78 NC: +154	PC: +151 NC: +228	PC: -0.10 NC: -0.13
Ibrahim et al. [22]	0.25 g LE/kg diet	S	-14	+33	-0.09
	0.50 g LE/kg diet		-74	+23	-0.14
	1.0 g LE/kg diet		-158	+66	-0.32
	2.0 g LE/kg diet		-136	+37	-0.25
	0.25 g LE/kg diet	G-F	-200	+33	-0.19
	0.50 g LE/kg diet		-168	+191	-0.36
	1.0 g LE/kg diet		+114	+451	-0.44
	2.0 g LE/kg diet		+51	+169	-0.19
	0.25 g LE/kg diet	T	-214	+66	-0.15
	0.50 g LE/kg diet		-241	+214	-0.27
	1.0 g LE/kg diet		-43	+517	-0.38
	2.0 g LE/kg diet		-84	+209	-0.20

[6] Iqbal et al. [17]	10 mL LE/L DW	S	PC: +18 NC: +45	PC: +18 NC: +22	PC: -0.01 NC: +0.02
	15 mL LE/L DW		PC: +43 NC: +70	PC: +29 NC: +33	PC: 0 NC: +0.03
	20 mL LE/L DW		PC: +56 NC: +83	PC: +40 NC: +43	PC: -0.01 NC:+0.02
	25 mL LE/L DW		PC: +71 NC: +98	PC: +52 NC: +55	PC: -0.01 NC: +0.02
	10 mL LE/L DW	F	PC: +25 NC:+60	PC: +16 NC: +87	PC: -0.01 NC:-0.13
	15 mL LE/L DW		PC: +73 NC: +108	PC: +76 NC:+147	PC: -0.08 NC: -0.20
	20 mL LE/L DW		PC: +104 NC: +139	PC: +118 NC: +189	PC: -0.12 NC: -0.24
	25 mL LE/L DW		PC: +112 NC: +147	PC: +154 NC: +225	PC: -0.18 NC: -0.30
	10 mL LE/L DW	T	PC: +43 NC: +104	PC: +33 NC:+108	PC: -0.01 NC: -0.05
	15 mL LE/L DW		PC: +116 NC: +178	PC: +105 NC:+180	PC: -0.04 NC: -0.08
	20 mL LE/L DW		PC: +160 NC: +222	PC: +157 NC: +232	PC: -0.06 NC: -0.10
	25 mL LE/L DW		PC: +3 NC: +65	PC: +206 NC: +280	PC: -0.09 NC: -0.13
[7] Rashidi et al. [24]	3 g LE/kg diet	S	0	+16	-0.09
	6 g LE/kg diet		+2	+6	-0.01
	3 g LE/kg diet	G	+2	-15	+0.03
	6 g LE/kg diet		-14	-66	+0.12
	3 g LE/kg diet	F	-68	-116	+0.10
	6 g LE/kg diet		-130	-126	-0.03
	3 g LE/kg diet	T	-66	-115	+0.06
	6 g LE/kg diet		-142	-186	+0.07
[8] Geravand et al. [16]	0.2 g LEO/kg diet	T	+168	+59	-0.06
	0.4 g LEO/kg diet	T	-168	-300	+0.16
[9] Abo-Samaha et al. [6]	0.4 g/L DW	G	+126	+53	+0.04
	0.8 g/L DW		+70	-13	+0.08
	0.4 g/L DW	F	+155	+216	-0.27
	0.8 g/L DW		+205	+66	+0.05
	0.4 g/L DW	T	+277	+306	-0.11
	0.8 g/L DW		+283	+78	+0.05
[10] Dheyaul-deen Salahdin et al. [7]	1.0 g LEO/kg diet	S	+2	+1	0
	2.0 g LEO/kg diet		+1	+3	-0.01
	3.0 g LEO/kg diet		0	+1	0
	1.0 g LEO/kg diet	G	+1	+3	0
	2.0 g LEO/kg diet		+1	+1	0
	3.0 g LEO/kg diet		-2	+2	-0.01
	1.0 g LEO/kg diet	F	+2	-3	+0.01
	2.0 g LEO/kg diet		+1	-4	+0.01
	3.0 g LEO/kg diet		+3	-2	+0.01
	1.0 g LEO/kg diet	T	+5	+1	0
	2.0 g LEO/kg diet		+2	0	0
	3.0 g LEO/kg diet		+1	+1	0
Toson et al. [8]	1.0 g LE/kg diet	S	+18	+47	-0.06
	2.0 g LE/kg diet		+6	+63	-0.10
	3.0 g LE/kg diet		+24	+77	-0.10
	1.0 g LE/kg diet	F	+112	+26	+0.05
	2.0 g LE/kg diet		-36	+141	-0.19
	3.0 g LE/kg diet		+102	+185	-0.23
	1.0 g LE/kg diet	T	+131	+73	0
	2.0 g LE/kg diet		+108	+204	-0.13
	3.0 g LE/kg diet		+168	+261	-0.15

[1]The growth performance data from Al-Daraji et al. [18]'s study were excluded from the table since they were presented graphically. [2] Due to the lack of data on growth performance, the study conducted by Ibrahim et al. [23] was excluded from the table. [3] Calculations for data over the entire trial period couldn't be performed due to the unspecified hatching weight of the birds. [4] Each of the performance parameters was assessed against its own control group at RDAA concentration. [5] Positive (PC) and negative (NC) control groups were created based on stocking density. PC consisted of 12 birds/m^2, equating to 0.08 m^2 of floor space per bird, while NC comprised 18 birds/m^2, corresponding to 0.05 m^2 of floor space per bird. [6] As a positive control, antibiotics were used, but neither their specific name nor dosage were specified. [7] The diet contained 0.5 mg/kg of aflatoxin B1. [8] A commercially available LEO was used (Zard Band Pharmaceutical Co., Tehran, Iran). [9] A commercially available licorice was used to prepare licorice solutions (Sekem Group, Cairo, Egypt).[10] An essential oil extracted from licorice root was used.

S: starter period, G: grower period, F: finisher period, T: total period, PC: positive control, NC: negative control, FI: feed intake, BWG: body weight gain, FCR: feed conversion ratio, LE: licorice extract, LEO: licorice essential oil, DW: drinking water.

Table 4. Effect of licorice (*Glycyrrhiza glabra* L.) extract on slaughter and carcass trait in broilers[1]

Reference	Dosage	DP	AF	Liver	Heart	Spleen	Gizzard	Pancreas	Femur	Breast	GIT	Thighs	Drum-sticks	Bursa	Pro-ventric-ulous	Thymus	Legs	Gallblad-der
[2] Al-Daraji et al. [18]	0.15 g LE/kg diet	V: -0.38 noV: -0.57	+1.15	+4.98	+17.65	+60.00	+7.31											
	0.30 g LE/kg diet	V: -0.10 noV: -0.26	+3.85	+4.65	+13.73	+50.00	+8.08											
	0.45 g LE/kg diet	V: +2.73 noV: -0.60	+1.15	+1.33	+5.88	+20.00	+2.31											
Sedghi et al. [19]	0.5 g LE/kg diet		R95: -34.10 R100: -33.04	R95: +0.58 R100: +7.02	R95: -3.68 R100: +10.44	R95: +11.90 R100:-17.16			R95: +1.01 R100: +5.61	R95: +9.47 R100: +5.38	R95: -4.56 R100: -6.49							
	1.0 g LE/kg diet		R95: -31.34 R100: -37.39	R95: +6.36 R100: +5.26	R95: -9.01 R100: +13.05	R95: +3.42 R100: -21.64			R95: +1.11 R100: +4.59	R95: +3.68 R100: +2.69	R95: -0.48 R100: +5.21							
	2.0 g LE/kg diet		R95: -29.03 R100: -34.78	R95: +4.05 R100: +4.09	R95: -12.68 R100: +1.20	R95: +9.40 R100: -17.16			R95: +3.03 R100: +2.55	R95: +0.53 R100: +3.23	R95: -0.36 R100: -1.39							
[3] Beski et al. [20]	0.5 g LE/L DW	+0.82		-1.10	-2,.15	-28.26		+8.62		+6.03		-3.23	0	+19.73				
	0.7 g LE/L DW	+1.37		+6.89	-4.30	-41.30		-1.29		+6.03		-5.81	+5.47	+21.77				
	0.9 g LE/L DW	+2.60		+4.96	-6.45	-40.76		-9.48		+5.48		-0.65	+3.13	+4.08				
[4] Rashidi et al. [24]	0.5 g/LE kg diet	PC: +5.00 NC: +1.61	PC: +33.33 NC: +25.00	PC: +3.85 NC: -3.57			PC: +7.41 NC: +11.54			PC: -4.54 NC: +5.00		PC: 0 NC: -5.26						

[5,6] Iqbal et al. [17]	10 mL LE/L DW	PC: +0.27 NC: +1.35	PC: +2.12 NC: +7.64	PC: +2.10 NC: +7.60	PC: +2.16 NC: +7.56		PC: +2.10 NC: +7.57			PC: +2.36 NC: +7.59		PC: +2.10 NC: +7.59						
	15 mL LE/L DW	PC: +1.39 NC: +2.49	PC: +7.18 NC: +12.98	PC: +7,21 NC: +12.98	PC: +7.18 NC: +12.86		PC: +7.22 NC: +12.96			PC: +7.20 NC: +12.97		PC: +7.20 NC: +12.97						
	20 mL LE/L DW	PC: +1.48 NC: +2.58	PC: +10.19 NC: +16.15	PC: +10.19 NC: +16.12	PC: +10.20 NC: +16.04		PC: +10.20 NC: +16.10			PC: +10.18 NC: +16.10		PC: +10.18 NC: +16.10						
	25 mL LE/L DW	PC: +3.78 NC: +4.91	PC: +15.39 NC: +21.63	PC: +15.45 NC: +21.66	PC: +15.37 NC: +21.48		PC: +15.45 NC: +21.63			PC: +15.42 NC: +21.63		PC: +15.43 NC: +21.63						
[7] Rashidi et al. [24]	3 g LE/ kg diet	-1.48	0	-0.43		-7.69				-1.70		+7.12		+9.52		-26.32		
	6 g LE/ kg diet	-1.28	-39.13	-10.78		+7.69				-2.09		+0.22		+23.81		-5.26		
[3] Abo-Samaha et al. [6]	0.4 g/L DW		-23.08	+0.43	+9.76	-23.08	+7.37				-1.73			+127.8	-9.38	-29.41		
	0.8 g/L DW		-40.00	+4.74	0	+7.69	+4.21				-9.38			-27.78	0	-14.71		
[8] Dheyauldeen Dheyauldeen Salahdin et al. [7]	1.0 g LEO/kg diet	+2.35	-16.16	0		+23.08				+7.45				+15.38			+8.33	-35.29
	2.0 g LEO/kg diet	+0.78	-18.78	-1.14		+15.38				+2.13				+7.69			+2.13	-17.65
	3.0 g LEO/kg diet	+3.14	-23.58	-0.57		+7.69				+8.51				+7.69			+8.51	-29.41
Toson et al. [8]	1.0 g LE/kg diet	+0.10	-3.30	+1.89	+2.50		+1.60											
	2.0 g LE/kg diet	+1.67	-10.99	+1.51	+3.75		+4.79											
	3.0 g LE/kg diet	+2.07	-12.09	+1.13	+3.75		+3.72											

[1] Due to the lack of data on slaughter and carcass trait of broilers, the study conducted by Ibrahim et al. [28], Ibrahim et al. [23] and Geravand et al. [16] were excluded from the table. [2] Diets contaminated with 2 mg aflatoxin/kg. [3] An aqueous licorice extract, produced by mixing licorice root powder with water, was used. [4] Positive and negative controls were created using a stocking density-based trial scheme. [5] In the trial groups, the extract was prepared by boiling one liter of water with fifty grams of licorice root powder for three hours at 80°C. [6] A positive and negative control diet was created depending on whether antibiotics were used in the diet. [7] The control group is free from aflatoxin B1, though both trial groups contain 0.5 mg/kg aflatoxin B1. [8] An essential oil extracted from licorice root was used.

V: with viscera, noV: without viscera, DP: dressing percentage, AF: abdominal fat, GIT: gastro-intestinal tract, R95: diet containing 95% of the recommended digestible amino acid concentrations, R100: diet containing 100% of the recommended digestible amino acid concentrations, DW: drinking water, PC: positive control, NC: negative control, LE: licorice extract, LEO: Licorice essential oil.

licorice root powder is mixed with drinking water, filtered, and administered to broiler chicks during the starter period. This phenomenon is primarily attributable to the absence of a secondary dilution effect resulting from the extraction process.
Similarly, six studies provide growth performance data specifically related to the grower periods. In this dataset, four studies examine the effects of LE, one assesses the consequences of incorporating LEO into the diet, and the remaining study explores the effects of introducing LE into drinking water. Notable results emerge from studies involving amino acid restriction [19], stocking density [21], and those administering LE supplementation in drinking water [20]. In the absence of amino acid restriction, the inclusion of 0.5 g LE/kg in the diet significantly enhances FI by 115 g and BWG by 79 g for broiler chickens throughout the grower period, simultaneously leading to a notable reduction in FCR by 0.03 units [19]. Similarly, adding 0.5 g LE/kg to the diet demonstrates stress-reducing properties, increasing FI by 65 g and BWG by 97 g even with a 50% increase in stocking density (12 chicks/m^2 vs 18 chicks/m^2). Additionally, the FCR exhibits an additional reduction of 0.08 units in the negative control (18 chicks/m^2) compared to the positive control (12 chicks/m^2) [21]. n contrast, when an equal quantity of LE is administered in the form of drinking water, the improvements in FI by 40 g, BWG by 16 g, along with the reduction in FCR by 0.02 units, are not as prominent as observed when LE is integrated into the diet [20].

During the finisher period, the inclusion of 1-3 g LEO/kg in the diet shows minimal discernible impacts, whether positive or negative, on FI, BWG, and FCR [7]. Adding LE to drinking water enhances FI and BWG during this period, similar to the results found in the starter and grower periods. Specifically, adding 0.4 g of powdered form (with a reduction of 0.27) or 25 ml of water-extracted form (with a reduction of 0.3) to the water significantly decreases the FCR. Nevertheless, it is important to emphasize that when LE was administered in drinking water along with antibiotic-supplemented feed, it reduced FI and BWG compared to those receiving antibiotic-free feed. Consequently, it is evident that the simultaneous use of LE and antibiotics results in an adverse synergistic effect.

For a comprehensive assessment spanning all periods, it has been established that incorporating 0.5-1.0 g of LE/kg into diets without amino acid restrictions may result in a reduction of 43-241 g in FI, an increase of 214-517 g in BWG, and a reduction in FCR by 0.08 to 0.38 units [19,28]. On the other hand, adding LE at 3 g or higher to the diet caused adverse effects on FI and BWG while simultaneously increasing FCR [21]. Elevated FI and BWG were observed when powdered LE was added to drinking water at concentrations of 0.5 g/L and higher. However, the FCR was not successfully reduced. It was discovered that lowering the LE dosage to 0.4 g/L caused a decline of around 0.11 units in FCR [6]. LEO has, however, shown conflicting effects on diets, highlighting the need for further research in this field. According to Geravand et al. [16], dding LEO to the diet at doses of 0.4 g/kg and higher decreased FI and BWG and increased FCR. However, Dheyauldeen Salahdin et al. [7] found that adding up to 1-3 g/kg of LEO to the diet had minimal effects on FI, BWG, and FCR.

Prior research has documented the advantageous impact of flavonoids on intestinal functions, potentially explaining the observed enhancement in growth performance in broiler chickens when including flavonoid-rich plant extracts in their diet [29,30]. The results of current systematic review show that, supplementing broiler chicks' diets with LE may improve their growth characteristics, as this ingredient has been shown to improve digestibility, stimulate the secretion of digestive enzymes, prevent tissue oxidation, and modulate the gut microbial balance, all of which contribute to the chicks' increased BWG [31]. Furthermore, numerous studies suggest that the increase in FI is due to LE's favorable impact on feed palatability, stimulating appetite due to its antioxidant-rich nature, while simultaneously reducing oxidative stress and reactive oxygen species (ROS) production [32,33]. Similarly, the increase in FCR observed with LE supplementation in either diet or drinking water can be attributed to its ability to improve digestibility, fortify intestinal microflora, and increase endogenous digestive enzyme secretion [8,34]. It additionally enhances blood circulation in the mucous membranes of the gut, thereby improving the efficiency of nutrient utilization [20]. Furthermore, studies have shown that LE's active constituents—including glycyrrhizin, glycyrrhizic acid, glabridin, apigenin, and licochalcone—have a positive effect on broiler growth performance due to their antimicrobial, antioxidant, and anti-inflammatory properties [16,35]. These active constituents, mainly flavonoids, may increase levels of insulin-like growth factor-1 and stimulate animal growth by influencing the regulation of growth hormone and hepatic growth hormone receptors [36].

3.3. Effect of *Glycyrrhiza glabra* L. supplementation on slaughter and carcass traits

Nine of the twelve studies that were reviewed focused on characteristics related to slaughter and carcasses (Table 4). In five of these studies, dietary supplementation included LE, and in one study, LEO was incorporated into the diet. Meanwhile, the remaining three studies involved adding LE to the drinking water. Except for the one study, the incorporation of 0.45 g or higher of LE in the dietary intake led to a rise in dressing percentage ranging from 0.10% to 5.0% in comparison to the control groups in all the conducted investigations. Nevertheless, the investigation carried out by Rashidi et al. [21] revealed a decrease in dressing percentage ranging from 1.28% to 1.48% after incorporating 3-6 g of LE into the diet. The observed dressing percentage enhancement showed a range of between 0.82% and 2.60% in the trial where powdered LE was supplied by drinking water at a concentration of 0.5-0.9 g/L [20]. On the other hand, in the study carried out employing the water-extracted LE form at a concentration of 10-25 ml/L combined with an antibiotic-supplemented diet, the observed range of increase in dressing percentage ranged from 0.27% to 3.78% [17]. Notably, when an antibiotic-free diet was integrated, the observed improvement in dressing percentage ranged from

1.35% to 4.91% [17]. Likewise, the inclusion of 1-3 g/kg of LEO in the diet resulted in a dressing percentage increment ranging from 0.78% to 3.14% [7].

Prior research has shown that the flavonoids present in LE can reduce abdominal fat in broiler chickens [8] and other species [35,37], possibly through mechanisms such as energy intake suppression, reduced lipid absorption, increased fatty acid oxidation, or decreased fatty acid biosynthesis [8]. However, conflicting findings exist regarding LE's effect on abdominal fat. For instance, studies by Sedghi et al. [19], Rashidi et al. [21], and Toson et al. [8] indicate that dietary LE supplementation leads to reduced abdominal fat, whereas Al-Daraji et al. [18] and Rashidi et al. [21] report an increase in abdominal fat with LE supplementation. Similarly, Beski et al. [20] and Iqbal et al. [17] find that adding LE to drinking water increases abdominal fat, while Abo-Samaha et al. [6] suggest a decrease in abdominal fat when LE is added to drinking water. Notably, the addition of LEO to the diet results in a decrease in abdominal fat [7]. Variations in study designs, methods of obtaining LE, dosages, and environmental factors could contribute to conflicting results.

The study findings revealed that the addition of LE in powdered form to the diet resulted in an increase in liver weight among four studies. However, one study noticed a decrease in liver weight [21]. The increase in stocking density is accompanied by a decrease in liver weight [38]. Furthermore, it has been established that the addition of powdered LE to the diet increases the weight of the heart and gizzard, but decreases the weight of the heart when additional amino acid restriction is present in the diet. However, different findings were observed in two studies that specifically examined the spleen weight. The study conducted by Al-Daraji et al. [18] showed that the incorporation of LE into the diet led to an increase in the weight of the spleen. Conversely, Sedghi et al. [19] observed a decrease in spleen weight without amino acid restriction.

When LE powder is mixed into drinking water, it results in a reduction in heart and spleen weight. However, Beski et al. [20] establish that liver weight increases and pancreas weight decreases when the concentration of LE in drinking water exceeds 0.7 g/L. In the study employing an aqueous extract form [17], it was observed that liver, heart, and gizzard weights increased. The increase became more apparent as the stocking density increased. While adding LEO to the diet reduced liver weight slightly, it was discovered that it increased spleen weight in inverse proportion to the increasing dose [7].

Furthermore, it has been ascertained that introducing LE into the diet typically results in an augmentation of femur, breast, and bursa weights, while concomitantly reducing the weights of the gastrointestinal tract and thymus [19,21,38]. Similarly, the addition of LE to drinking water yields comparable effects by increasing femur, breast, and bursa weights, while concurrently decreasing thymus weight [6,17,20]. Conversely, the inclusion of LEO into the diet tends to elevate breast, bursa, and leg weights, while typically causing a decrease in gallbladder weight [7].

Prior research has suggested that incorporating LE into broiler diets enhances growth performance by facilitating organ development [39]. The potent anti-inflammatory characteristics of licorice root may explain the observed increase in organ weight by helping detoxify and nurture the liver, lymphoid organs, and other visceral tissues [40]. Furthermore, dietary supplementation of LE has been linked to its role in enhancing metabolism and immune responses, especially under stressful conditions [6]. According to Sohail et al. [33] (2018) findings, adding antioxidants to the diet of stressed avians increased feed consumption and decreased oxidative damage caused by ROS.

3.4. Effect of *Glycyrrhiza glabra* L. supplementation on blood biochemistry and hematological parameters

Blood indices are dependable markers of overall well-being, reflecting responses to internal and external stimuli, including stress [41]. The health and immune systems of chickens are closely linked to their oxidative status, which arises from an imbalance in ROS production and elimination [42]. The elimination of excess ROS relies on the functioning of several enzymes, including superoxide dismutase and catalase [4]. Among the twelve studies examined, nine particularly emphasized characteristics linked to blood biochemical parameters in broiler chickens as shown in Table 5. Five of the trials under consideration included LE supplementation, whereas two incorporated LEO supplementation into the dietary regimen and two gave LE through drinking water. Glucose, total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), globulin, and total protein levels were all lowered by dietary LEO at 0.4 g/kg or higher, while albumin and alanine aminotransferase (ALP) were slightly affected [7,16]. Likewise, in investigations where LE was introduced into the drinking water, divergent outcomes were observed in relation to triglyceride levels, even though there was a consistent decrease in glucose, total cholesterol, HDL, and LDL [6,17]. Furthermore, according to Abo-Samaha et al. [6] study, the inclusion of LE in the drinking water led to a decrease in alanine transaminase (ALT), aspartate transaminase (AST), albumin, and malondialdehyde (MDA) levels. It can be inferred that doses of 0.8 g/L and higher resulted in an elevation of catalase and glutathione (GSH) levels.

In contrast, the results of other trials in which LE was included in the diet showed considerable discrepancies. For example, Sedghi et al. [19] noted a reduction in glucose levels when incorporating 0.5-2.0 g/kg LE into the diet, whereas Rashidi et al. [24] observed an initial elevation in blood glucose levels with the addition of 0.5 g/kg LE to the diet, which later decreased as stocking density increased. Employing comparable doses to those used by Sedghi et al. [19], Ibrahim et al. [23] obtained contrasting findings. Unlike Sedghi et al. [19], Ibrahim et al. [23] determined that the inclusion of 1.5 g/kg or more of LE in the diet resulted in an elevation of total cholesterol. Furthermore, when 2.0 g/kg of LE was added to the diet, the glucose-increasing effect disappeared, but LDL levels increased. It is noteworthy that the data pertaining to HDL in

Table 5. Effect of licorice (*Glycyrrhiza glabra* L.) extract on blood biochemical parameters in broilers[1]

Reference	Dosage	GLU	TC	TG	HDL	LDL	VLDL	ALT	AST	ALP	Globulin	Albumin	TP	GSH	MDA	CAT
[2] Sedghi et al. [19]	0.5 g LE/kg diet	R100:-10.00	R100: -22.71	R100: -20.59	R100: +17.48	R100: -28.80	R100: -22.06									
	1.0 g LE/kg diet	R100: -10.34	R100: -22.22	R100: -11.76	R100: +17.91	R100: -30.74	R100: -14.71									
	2.0 g LE/kg diet	R100: -5.17	R100: -32.85	R100: -20.15	R100: +17.48	R100: -38.52	R100: -22.06									
[3] Rashidi et al. [24]	0.5 g/LE kg diet	PC: +2.58 NC: -14.22	PC: +15.84 NC: 0	PC: +20.51 NC: +1.08												
Ibrahim et al. [22]	0.50 g LE/kg diet	+2.73	-9.19		-14.50	-9.13		-28.56	+2.05		-6.13	+5.81	-3.27	+10.51	-9.58	
	1.00 g LE/kg diet	+13.28	-1.12		-6.51	-2.90		-17.15	-4.10		-1.83	+7.55	0	+10.87	-15.75	
	1.50 g LE/kg diet	+20.70	+3.06		-23.01	-8.98		-14.24	-3.69		+9.14	+1.47	+4.58	+11.23	-19,38	
	2.00 g LE/kg diet	-0.78	+9.19		-9.00	+24.43		-11.41	-1.64		-22.26	+5.81	-13.07	+12.68	-20.48	
[4,5] Iqbal et al. [17]	10 mL/L LE		PC: -52.86 NC: -3.92	PC: -55.16 NC: -68.59	PC: +4.93 NC: -3.65	PC: +11.58 NC: -3.68										
	15 mL/L LE		PC: -20.77 NC:+61.48	PC: +182.6 NC: +97.95	PC: +4.93 NC: -9.11	PC: -2.45 NC: -15.79										
	20 mL/L LE		PC: +9.39 NC: +123.0	PC: +107.8 NC: +45.55	PC: -5.94 NC: -13.64	PC: +2.43 NC: -11.57										
	25 mL/L LE		PC: -18.90 NC: +65.28	PC: +5.79 NC: -25.90	PC: +8.91 NC:0	PC: +2.43 NC: -11.57										
[6] Rashidi et al. [24]	3 g LE/kg diet						+11.38	+9.29	-24.92						+12.55	
	6 g LE/kg diet						-3.39	0	-24.92						+2.66	
[7] Geravand et al. [16]	0.2 g LEO/ kg diet		-12.17	-24.49	-8.82	-15.21				0	-9.52	-11.11	-10.26			
	0.4 g LEO/ kg diet		-7.83	+8.16	-7.35	-6.52				+1.28	-33.33	0	-15,38			

[8] Abo-Samaha et al. [6]	0.4 g/L DW	-23.65	-26.73	-40.16	+50.26	-34.12		-26.55	-28.68		-6.76	-11.86	-10.65	+20.68	-30.19	+18.87
	0.8 g/L DW	-21.96	-27.06	-34.84	+55.54	-35.69		-41.60	-27.27		+35.14	-9.75	+0.97	+25.64	-33.33	+20.78
[9] Dheyauldeen Salahdin et al. [7]	1.0 g LEO/ kg diet	-17.01	+0.58	+6.27	+5.90	-26.06										
	2.0 g LEO/ kg diet	-25.40	-8.75	+4.58	+11.17	-40.85										
	3.0 g LEO/ kg diet	-29.51	-13.80	+3.79	[10] IV	-62.64										
Toson et al. [8]	1.0 g LE/kg diet		-0.41	+4.74				-1.19	-6.83	-4.28	+8.70	+4.00	+7.78			+3.71
	2.0 g LE/kg diet		-3.72	+7.87				-0.28	-8.40	+18.55	+23.19	+11.64	+17.18			-0.71
	3.0 g LE/kg diet		-5.86	-9.38				-1.67	-10.54	+4.62	+35.14	+13.82	+24.23			-1.83

[1] Due to the lack of data on blood biochemical parameters of broilers, the study conducted by Al-Daraji et al. [18], Beski et al.[20] and Ibrahim et al. [28] were excluded from the table. [2] The blood biochemistry analysis was performed only on trial groups that contained 100% of the recommended digestible amino acids. [3] Positive and negative controls were created using a stocking density-based trial scheme. [4] In the trial groups, the extract was prepared by boiling one liter of water with fifty grams of licorice root powder for three hours at 80°C. [5] A positive and negative control diet was created depending on whether antibiotics were used in the diet. [6] The control group is free from aflatoxin B1, though both trial groups contain 0.5 mg/kg aflatoxin B1. [7] A commercially available licorice essential oil was used (Zard Band Pharmaceutical Co., Tehran, Iran). [8] A commercially available licorice was used to prepare licorice solutions (Sekem Group, Cairo, Egypt). [9] An essential oil extracted from licorice root was used. [10] The value given was incorrect, so it could not be calculated.

R100: diet containing 100% of the recommended digestible amino acid concentrations, PC: positive control, NC: negative control, DW: drinking water, IV: incorrect value, GLU: glucose, TC: total cholesterol, TG: triglyceride, HDL: high density lipoprotein, LDL: low density lipoprotein, VLDL: very low density lipoprotein, ALT: alanine transaminase, AST: aspartate transaminase, ALP: alkaline phosphatase, TP: Total protein, GSH: glutathione, MDA: malondialdehyde, CAT: catalase.

Table 6. Effect of licorice (*Glycyrrhiza glabra* L.) extract on blood hematological parameters in broilers[1]

Reference	Dosage	WBC	RBC	Hemoglobin	Hematocrit	Monocyte	Heterophil	Lymphocyte	H/L
[2] Sedghi et al. [19]	0.5 g LE/ kg diet	R100: +0.32	R100: +0.69			R100: 0	R100: +7.35	R100: -1.52	R100: +12.5
	1.0 g LE/ kg diet	R100: +3.49	R100: +1.34			R100: 0	R100: +86.03	R100: -9.73	R100: +125.0
	2.0 g LE/ kg diet	R100: -0.32	R100: -90.12			R100: -100.0	R100: +14.71	R100: -1.17	R100: +16.88
[3,4] Iqbal et al. [17]	10 mL/L LE DW			PC: +5.83 NC: -8.63	PC: +8.91 NC: -3.83				
	15 mL/L LE DW			PC: +24.42 NC:+7.41	PC: +19.59 NC: +5.61				
	20 mL/L LE DW			PC: +8.58 NC: -6.26	PC: +9.39 NC: -3.41				
	25 mL/L LE DW			PC: -0.83 NC: -14.39	PC: +0.14 NC: -11.58				
[5] Rashidi et al. [24]	3 g LE/kg diet						+2.91	-1.25	+3.70
	6 g LE/kg diet						-0.58	0	0
[6] Geravand et al. [16]	0.2 g LEO/ kg diet	-2.90	-0.42		+11.15	-17.86	0	+0.29	0
	0.4 g LEO/ kg diet	-2.27	+2.54		+10.41	-35.71	0	+0.73	0
Toson et al. [8]	1.0 g LE/ kg diet	+5.38	+4.74	+2.24		+4.88	+6.91	-2.01	+8.70
	2.0 g LE/ kg diet	+1.97	+11.46	+8.14		-13.07	-1.71	+1.48	-4.35
	3.0 g LE/ kg diet	+10.24	+7.11	+6.71		-14.62	+13.77	+4.46	-17.39

[1] Due to the lack of data on blood hematological parameters of broilers, the study conducted by Al-Daraji et al. [18], Rashidi et al. [24], Beski et al. [20], Ibrahim et al. [28], Ibrahim et al. [23], Abo-Samaha et al. [6], and Dheyauldeen Salahdin et al. [7] were excluded from the table. [2] The blood hematological analysis was performed only on trial groups that contained 100% of the recommended digestible amino acids. [3] In the trial groups, the extract was prepared by boiling one liter of water with fifty grams of licorice root powder for three hours at 80 °C. [4] A positive and negative control diet was created depending on whether antibiotics were used in the diet. [5] The control group is free from aflatoxin B1, though both trial groups contain 0.5 mg/kg aflatoxin B1. [6] A commercially available licorice essential oil was used (Zard Band Pharmaceutical Co., Tehran, Iran).

R100: diet containing 100% of the recommended digestible amino acid concentrations, PC: positive control, NC: negative control, WBC: white blood cell, RBC: red blood cell, H/L: heterophil/lymphocyte ratio, LE: licorice extract, LEO: licorice essential oil, DW: drinking water

these two studies exhibited complete opposition: Sedghi et al. [19] reported an increase in HDL when adding 0.5-2.0 g/kg LE to the diet, whereas Ibrahim et al. [23] reported a decrease in HDL. Similarly, lowering ALT and AST levels were seen when LE was added to the diet at dosages of 1.0 g/kg or higher. However, the effects of LE supplementation on albumin, globulin, and total protein levels were inconsistent across studies [23,43]. Consistent with our findings, prior studies have demonstrated that LE exhibits antioxidant properties by increasing serum superoxide dismutase and catalase levels while significantly decreasing MDA levels, attributed to its flavonoid content [44]. Furthermore, muscle damage due to lipid peroxidation induced by cell membrane disruption is usually associated with elevated serum AST and ALP levels, which is indicative of cellular damage that may lead to necrosis or changes in cell membrane permeability [45,46]. Further, glycyrrhizic acid, one of active main constituents of LE, prevents alterations in the permeability of cell membranes and increases hepatocyte survival rates [6]. Nevertheless, the outcomes of this systematic review indicate that LE supplementation led to a decrease in serum AST and ALP concentrations, aligning with the findings of Rashidi et al. [21] and Toson et al. [43].

Natural active compounds in licorice extract include five flavonoids (glabridin, liquiritigenin, isoliquiritigenin, liquiritin, and licochalcone E) and three triterpenoids [47]. A variety of mechanisms have been implicated in the beneficial effects of these compounds in combating diabetes and its associated complications [48]. As a consequence, the hypoglycemic attributes of LE, whether integrated into the diet or administered via drinking water, assume a pivotal role in modulating glucose levels through their influence on glucose and lipid metabolism. It has also been shown that LE acts as a hypolipidemic agent, reducing levels of cholesterol, LDL, and triglycerides [49].

The observable increase in white blood cells (WBC) and the phagocytic capacity of granulocytes, mononuclear cells, and granulocytes in broiler chicks may be attributed to the utilization of natural feed supplements known for their immunomodulatory effects [50]. Specifically, Kauffman et al. [51] demonstrated that licorice extract enhances immunity by stimulating the production of WBC within the body and increasing interferon levels, an important immune system chemical that fights viruses. In this systematic review, five out of the twelve studies examined were specifically dedicated to evaluating biochemical and hematological parameters in broiler chickens, as outlined in Table 6. Within this subset, three studies employed LE supplementation, one incorporated LEO supplementation into the dietary regimen, and the remaining one administered LE through the drinking water. In these studies, Sedghi et al. [19] reported that the inclusion of 0.5-1.0 g/kg LE in the diet led to an increase in both WBC and red blood cell (RBC) counts. In contrast, when 2.0 g/kg LE was added to the diet, it resulted in a decrease in the counts of WBC and RBC.

However, Toson et al. [43] noted an increase in WBC and RBC counts, even when a dose as high as 3.0 g/kg LE was added to the diet. In both studies, 2.0 g/kg LE reduced monocyte counts. In both studies, 2.0 g/kg LE reduced monocyte counts, but heterophils and lymphocytes yielded conflicting results [19,43]. In contrast, the inclusion of LEO in the diet has been observed to decrease the counts of WBC and monocytes while increasing the numbers of hematocrit and lymphocytes [16]. Moreover, in antibiotic-free diets, hemoglobin and hematocrit levels dropped when LE was added to drinking water, but increased in antibiotic-rich diets [17].

Conclusions and Future Prospects

In conclusion, this systematic review of the impact of *Glycyrrhiza glabra* L. supplementation on broiler chicken diets revealed diverse outcomes across growth performance, slaughter traits, carcass parameters, and blood biochemistry and hematological parameters. The variation in dosages, forms, and methods of administration highlights the need for standardized protocols. Therefore, researchers in this field should consider several factors in the future. For instance, to expand the geographical reach of research outcomes, there is a necessity for conducting more studies beyond the Asian region. There is a need for further investigation into the mechanisms underlying the observed effects on growth performance, slaughter weight, carcass traits, and blood parameters. By understanding how *Glycyrrhiza glabra* L. works physiologically and biochemically, poultry diets can be optimized. It would also be helpful for poultry producers to look for sustainable and effective alternatives to traditional growth-promoting additives to explore the synergistic or antagonistic effects of licorice when used in conjunction with other feed additives, especially in antibiotics-free diets.

Author Contributions

Conceptualization, S.E.; methodology, S. E., V.P., C.T., M.L. and A.P; software, S.E.; investigation, S.E. and V.P.; data curation, S.E., V.P. and A.P.; writing—original draft preparation, S. E.; writing—review and editing, S.E., V.P., C.T., M.L. and G.C.; visualization, S.E.; supervision: C.T. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. Akbari Moghaddam Kakhki, R.; Bakhshalinejad, R.; Zoidis, E. Interactive Effects of α-Tocopheryl Acetate and Zinc Supplementation on the Antioxidant and Immune Systems of Broilers. *Br. Poult. Sci.* **2018**, *59*, 679–688, doi:10.1080/00071668.2018.1521510.
2. Zengin, M.; Sur, A.; İlhan, Z.; Azman, M.A.; Tavşanlı, H.; Esen, S.; Bacaksız, O.K.; Demir, E. Effects of Fermented Distillers Grains with Solubles, Partially Replaced with Soybean Meal, on Performance, Blood Parameters, Meat Quality, Intestinal Flora, and Immune Response in Broiler. *Res. Vet. Sci.* **2022**, *150*, 58–64, doi:10.1016/j.rvsc.2022.06.027.
3. Alagawany, M.; Elnesr, S.S.; Farag, M.R. Use of Liquorice (*Glycyrrhiza Glabra*) in Poultry Nutrition: Glob-

al Impacts on Performance, Carcass and Meat Quality. *WORLDS Poult. Sci. J.* **2019**, *75*, 293–303, doi:10.1017/S0043933919000059
4. Reda, F.M.; El-Saadony, M.T.; El-Rayes, T.K.; Farahat, M.; Attia, G.; Alagawany, M. Dietary Effect of Licorice (*Glycyrrhiza Glabra*) on Quail Performance, Carcass, Blood Metabolites and Intestinal Microbiota. *Poult. Sci.* **2021**, *100*, doi:10.1016/j.psj.2021.101266.
5. Dhama, K.; Tiwari, R.; Khan, R.U.; Chakraborty, S.; Gopi, M.; Karthik, K.; Saminathan, M.; Desingu, P.A.; Sunkara, L.T.; Upadhayay, U.; et al. Growth Promoters and Novel Feed Additives Improving Poultry Production and Health, Bioactive Principles and Beneficial Applications: The Trends and Advances-a Review. *Int. J. Pharmacol* **2014**, *10*, 129–159, doi:10.3923/ijp.2014.129.159.
6. Abo-Samaha, M.I.; Alghamdi, Y.S.; El-Shobokshy, S.A.; Albogami, S.; Abd El-Maksoud, E.M.; Farrag, F.; Soliman, M.M.; Shukry, M.; Abd El-Hack, M.E. Licorice Extract Supplementation Affects Antioxidant Activity, Growth-Related Genes, Lipid Metabolism, and Immune Markers in Broiler Chickens. *LIFE-BASEL* **2022**, *12*, doi:10.3390/life12060914.
7. Dheyauldeen Salahdin, O.; Othman, H.; Hafsan, H.; Mohammed, F.; Ahmed Hamza, T.; Kadhim, M.M.; Aravindhan, S.; Prakaash, A.S.; Fakri Mustafa, Y.; Salahdin, D.; et al. Effect of Licorice Essential Oil (*Glycyrrhiza glabraglabra*) on Performance and Some Biochemical Parameters of Broiler Chickens. *Arch. Razi Inst.* **2023**, *78*, 89–99, doi:10.22092/ARI.2022.359522.2442.
8. Toson, E.; Abd El Latif, M.; Mohamed, A.; Gazwi, H.S.S.; Saleh, M.; Kokoszynski, D.; Elnesr, S.S.; Hozzein, W.N.; Wadaan, M.A.M.; Elwan, H. Efficacy of Licorice Extract on the Growth Performance, Carcass Characteristics, Blood Indices and Antioxidants Capacity in Broilers. *Animal* **2023**, *17*, 100696, doi:10.1016/j.animal.2022.100696.
9. Shibata, S. A Drug over the Millennia: Pharmacognosy, Chemistry, and Pharmacology of Licorice. *Yakugaku zasshi* **2000**, *120*, 849–862.
10. Mahmoud, H.K.; Reda, F.M.; Alagawany, M.; Farag, M.R. Ameliorating Deleterious Effects of High Stocking Density on Oreochromis Niloticus Using Natural and Biological Feed Additives. *Aquaculture* **2021**, *531*, doi:10.1016/j.aquaculture.2020.735900.
11. Karahan, F.; Avsar, C.; Ozyigit, I.I.; Berber, I. Antimicrobial and Antioxidant Activities of Medicinal Plant *Glycyrrhiza Glabra* Var. Glandulifera from Different Habitats. *Biotechnol. Biotechnol. Equip.* **2016**, *30*, 797–804, doi:10.1080/13102818.2016.1179590.
12. Pastorino, G.; Cornara, L.; Soares, S.; Rodrigues, F.; Oliveira, M.B.P.P. Liquorice (*Glycyrrhiza Glabra*): A Phytochemical and Pharmacological Review. *Phyther. Res.* **2018**, *32*, 2323–2339, doi:10.1002/ptr.6178.
13. Karkanis, A.; Martins, N.; Petropoulos, S.A.; Ferreira, I.C.F.R. Phytochemical Composition, Health Effects, and Crop Management of Liquorice (*Glycyrrhiza Glabra* L.): A Medicinal Plant. *Food Rev. Int.* **2018**, *34*, 182–203, doi:10.1080/87559129.2016.1261300.
14. Alagawany, M.; Elnesr, S.S.; Farag, M.R.; Abd El-Hack, M.E.; Khafaga, A.F.; Taha, A.E.; Tiwari, R.; Yatoo, M.I.; Bhatt, P.; Marappan, G.; et al. Use of Licorice (*Glycyrrhiza Glabra*) Herb as a Feed Additive in Poultry: Current Knowledge and Prospects. *ANIMALS* **2019**, *9*, doi:10.3390/ani9080536.
15. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *Int. J. Surg.* **2010**, *8*, 336–341, doi:10.1016/j.ijsu.2010.02.007.
16. Geravand, M.; Sharifi, S.D.; Yaghobfar, A.; Mohammadi, A.; Hosseini, S.A.; Ghazanfari, S. Growth Performance, Ascites Sensitivity, and Ileal Microbiota as Affected by Licorice Essential Oil in Broiler Chicken Diets. *Livest. Sci.* **2021**, *251*, 104670, doi:10.1016/j.livsci.2021.104670.
17. Iqbal, H.F.; Bashir, M.K.; Iqbal, M.Z.; Shahid-ur-Rehman; Ashraf, M.; Bilal, M.Q.; Usman, M.; Bahar-e-Mustafa Effect of Licorice (*Glycyrrhiza Glabra*) Extract on Growth Performance, Carcass Parameters and Hematology of Broilers. *PAKISTAN J. Agric. Sci.* **2020**, *57*, 505–508, doi:10.21162/PAKJAS/19.9312.
18. Al-Daraji, H.J.; Al-Ani, I.A.; Minati, J.K.; Al-Hitti, H.E. Use of Licorice Ectract in Counteracting Aflatoxicosis in Broilers. *Iraqi J. Agric. Sci.* **2005**, *36*, 197–206.
19. Sedghi, M.; Golian, A.; Kermanshahi, H.; Ahmadi, H. Effect of Dietary Supplementation of Licorice Extract and a Prebiotic on Performance and Blood Metabolites of Broilers. *S. Afr. J. Anim. Sci.* **2010**, *40*, 371-380 WE-Science Citation Index Expanded (SCI.
20. Beski, S.S.M.; Shekhu, N.A.; Sadeq, S.A.B.M.; Al-Khdri, A.M.; Ramadhan, N.H.; Al-Bayati, S.H. Effects of the Addition of Aqueous Liquorice (*Glycyrrhiza Glabra*) Extract to Drinking Water in the Production Performance, Carcass Cuts and Intestinal Histomorphology of Broiler Chickens. *Iraqi J. Agric. Sci.* **2019**, *50*, 842–849, doi:10.36103/ijas.v50i3.701.
21. Rashidi, N.; Khatibjoo, A.; Taherpour, K.; Akbari-Gharaei, M.; Shirzadi, H. Effects of Licorice Extract, Probiotic, Toxin Binder and Poultry Litter Biochar on Performance, Immune Function, Blood Indices and Liver Histopathology of Broilers Exposed to Aflatoxin-B1. *Poult. Sci.* **2020**, *99*, 5896–5906, doi:10.1016/j.psj.2020.08.034.
22. Williams, S.R.O.; Jacobs, J.L.; Chandra, S.; Soust, M.; Russo, V.M.; Douglas, M.L.; Hess, P.S.A. The Effect of Direct-Fed Lactobacillus Species on Milk Production and Methane Emissions of Dairy Cows. *Animals* **2023**, *13*, doi:10.3390/ani13061018.
23. Ibrahim, C.A.; shanoon, A.Q.; Hameed AL-Dalawi, R.H.; Hasan, K.N. The Effect of Use of Plant *Glycyrrhiza Glabra* on Productive Performance and Some Biochemical Qualities of Blood for the Broiler Chickens Ross308. *Syst. Rev. Pharm.* **2020**, *11*, 706–708, doi:10.31838/srp.2020.12.111.
24. Rashidi, N.; Ghorbani, M.R.; Tatar, A.; Salari, S. Response

of Broiler Chickens Reared at High Density to Dietary Supplementation with Licorice Extract and Probiotic. *J. Anim. Physiol. Anim. Nutr. (Berl).* **2019**, *103*, 100–107, doi:10.1111/jpn.13007.
25. Council, N.R. *Nutrient Requirements of Poultry: 1994*; National Academies Press, 1994; ISBN 0309048923.
26. Aviagen, W.R. 308: Broiler's Management and Nutrition Specification. *ROSS An Aviagen Brand* **2018**.
27. Aviagen, W. Ross 308 Broiler Nutrition Specifications. *Aviagen Huntsville, AL, USA* **2014**.
28. Ibrahim, D.; Sewid, A.H.; Arisha, A.H.; abd El-fattah, A.H.; Abdelaziz, A.M.; Al-Jabr, O.A.; Kishawy, A.T.Y. Influence of *Glycyrrhiza Glabra* Extract on Growth, Gene Expression of Gut Integrity, and Campylobacter Jejuni Colonization in Broiler Chickens. *Front. Vet. Sci.* **2020**, *7*, 1–12, doi:10.3389/fvets.2020.612063.
29. Starčević, K.; Krstulović, L.; Brozić, D.; Maurić, M.; Stojević, Z.; Mikulec, Ž.; Bajić, M.; Mašek, T. Production Performance, Meat Composition and Oxidative Susceptibility in Broiler Chicken Fed with Different Phenolic Compounds. *J. Sci. Food Agric.* **2015**, *95*, 1172–1178, doi:https://doi.org/10.1002/jsfa.6805.
30. Zhou, Y.; Mao, S.; Zhou, M. Effect of the Flavonoid Baicalein as a Feed Additive on the Growth Performance, Immunity, and Antioxidant Capacity of Broiler Chickens. *Poult. Sci.* **2019**, *98*, 2790–2799, doi:https://doi.org/10.3382/ps/pez071.
31. Salary, J.; Kalantar, M.; Ala, M.S.; Ranjbar, K.; Matin, H.R.H. Drinking Water Supplementation of Licorice and Aloe Vera Extracts in Broiler Chickens. *Sci. J. Anim. Sci.* **2014**, *3*, 41–48.
32. Lashin, I.A.; Iborahem, I.; Ola, F.A.; Talkhan, F.; Mohamed, F. Influence of Licorice Extract on Heat Stress in Broiler Chickens. *Anim. Heal. Res. J* **2017**, *5*, 40–46.
33. Sohail, M.; Rakha, A.; Butt, M.S.; Asghar, M. Investigating the Antioxidant Potential of Licorice Extracts Obtained through Different Extraction Modes. *J. Food Biochem.* **2018**, *42*, e12466.
34. Kalantar, M.; Hosseini, S.M.; Yang, L.; Raza, S.H.A.; Gui, L.; Rezaie, M.; Khojastekey, M.; Wei, D.; Khan, R.; Yasar, S. Performance, Immune, and Carcass Characteristics of Broiler Chickens as Affected by Thyme and Licorice or Enzyme Supplemented Diets. *Open J. Anim. Sci.* **2017**, *7*, 105.
35. Tominaga, Y.; Mae, T.; Kitano, M.; Sakamoto, Y.; Ikematsu, H.; Nakagawa, K. Licorice Flavonoid Oil Effects Body Weight Loss by Reduction of Body Fat Mass in Overweight Subjects. *J. Heal. Sci.* **2006**, *52*, 672–683, doi:10.1248/jhs.52.672.
36. Ouyang, K.; Xu, M.; Jiang, Y.; Wang, W. Effects of Alfalfa Flavonoids on Broiler Performance , Meat Quality , and Gene Expression. **2016**, *341*, 332–341.
37. Aoki, F.; Honda, S.; Kishida, H.; Kitano, M.; Arai, N.; Tanaka, H.; Yokota, S.; Nakagawa, K.; Asakura, T.; Nakai, Y.; et al. Suppression by Licorice Flavonoids of Abdominal Fat Accumulation and Body Weight Gain in High-Fat Diet-Induced Obese C57BL/6J Mice. *Biosci. Biotechnol. Biochem.* **2007**, *71*, 206–214, doi:10.1271/bbb.60463.
38. Rashidi, N.; Ghorbani, M.R.; Tatar, A.; Salari, S. Response of Broiler Chickens Reared at High Density to Dietary Supplementation with Licorice Extract and Probiotic. *J. Anim. Physiol. Anim. Nutr. (Berl).* **2019**, *103*, 100–107, doi:10.1111/jpn.13007.
39. Alagawany, M.; Elnesr, S.S.; Farag, M.R.; El-Hack, M.E.A.; Khafaga, A.F.; Taha, A.E.; Tiwari, R.; Yatoo, M.I.; Bhatt, P.; Marappan, G.; et al. Use of Licorice (*Glycyrrhiza Glabra*) Herb as a Feed Additive in Poultry: Current Knowledge and Prospects. *Animals* **2019**, *9*, doi:10.3390/ani9080536.
40. Bown, D. *The Royal Horticultural Society Encyclopedia of Herbs & Their Uses.*; Dorling Kindersley Limited, 1995; ISBN 0751302031.
41. Privada, I.; Amaral, P.C.; Zimermann, C.; Santos, L.R.; Noro, M.; Prá, M.D.; Pilotto, F.; Rodrigues, L.B.; Dickel, E.L. Evaluation of Physiological Parameters of Broilers with Dorsal Cranial Myopathy. *Brazilian J. Poult. Sci.* **2017**, *19*, 69–74.
42. Lee, M.T.; Lin, W.C.; Lee, T.T. Potential Crosstalk of Oxidative Stress and Immune Response in Poultry through Phytochemicals — A Review. *Asian-Australas J Anim Sci* **2019**, *32*, 309–319, doi:10.5713/ajas.18.0538.
43. Toson, E.; Latif, M.A.; Mohamed, A.; Gazwi, H.S.S.; Saleh, M.; Kokoszynski, D.; Elnesr, S.S.; Hozzein, W.N.; Wadaan, M.A.M.; Elwan, H. Efficacy of Licorice Extract on the Growth Performance, Carcass Characteristics, Blood Indices and Antioxidants Capacity in Broilers. *ANIMAL* **2023**, *17*, doi:10.1016/j.animal.2022.100696.
44. Hashem, M.A.; Abdallah, A.A.; Eldeen, I.G.; Amer, M.M. Biochemical Studies on Rosemary and Licorice against Lead-Induced Oxidative Stress in Rats. *Zagazig Vet. J.* **2017**, *45*, 244–256.
45. Ali Rajput, S.; Sun, L.; Zhang, N.; Mohamed Khalil, M.; Gao, X.; Ling, Z.; Zhu, L.; Khan, F.A.; Zhang, J.; Qi, D. Ameliorative Effects of Grape Seed Proanthocyanidin Extract on Growth Performance, Immune Function, Antioxidant Capacity, Biochemical Constituents, Liver Histopathology and Aflatoxin Residues in Broilers Exposed to Aflatoxin B1. *Toxins (Basel).* 2017, *9*.
46. Sur, A.; Zengin, M.; Bacaksız, O.K.; Gökçe, Z.; Yılmaz, Ö.; Gürses, M.; Esen, V.K.; Azman, M.A.; Esen, S. Performance, Blood Biochemistry, Carcass Fatty Acids, Antioxidant Status, and HSP70 Gene Expressions in Japanese Quails Reared under High Stocking Density: The Effects of Grape Seed Powder and Meal. *Trop. Anim. Health Prod.* **2023**, *55*, doi:10.1007/s11250-023-03481-y.
47. Yang, L.; Jiang, Y.; Zhang, Z.; Hou, J.; Tian, S.; Liu, Y. The Anti-Diabetic Activity of Licorice, a Widely Used Chinese Herb. *J. Ethnopharmacol.* **2020**, *263*, 113216, doi:https://doi.org/10.1016/j.jep.2020.113216.
48. Wu, F.; Jin, Z.; Jin, J. Hypoglycemic Effects of Glabridin , a Polyphenolic Flavonoid from Licorice , in an Animal Model of Diabetes Mellitus. **2013**, 1278–1282, doi:10.3892/

mmr.2013.1330.
49. Alwash, Y.S.; Latif, A.R.A.; Al-Bayati, N.J. Effect of Licorice Extract on Lipid Profile in Hypercholestermic Male Rabbits. *Al-Qadisiyah Med. J.* **2011**, *7*, 167–178.
50. Geetha, V.; Nallani, S. Chemical Composition and Anti-Inflammatory Activity of Boswellia Ovalifoliolata Essential Oils from Leaf and Bark. *J. For. Res.* **2018**, *29*, 373–381, doi:10.1007/s11676-017-0457-9.
51. Kauffman, R.G.; Cassens, R.G.; Scherer, A.; Meeker, D.L. Variations in Pork Quality: History, Definition, Extent, Resolution. *Swine Heal. Prod. Off. J. Am. Assoc. Swine Pract.* **1993**.