Original Article

Effects of Intravenous Injection of Glycyrrhizin on Serum Biochemical Parameters and Appetite in Inflamed Arian Broiler Chickens

Mitra Nowrouzpour , Amin Rahdari , Farshid Hamidi*

Department of Basic Sciences, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, Mashhad, Iran.

Use your device to scan and read the article online

How to Cite This Article Nowrouzpour, M., Rahdari, A., & Hamidi, F. (2025). Effects of Intravenous Injection of Glycyrrhizin on Serum Biochemical Parameters and Appetite in Inflamed Arian Broiler Chickens. *Iranian Journal of Veterinary Medicine*, *19*(4), 757-766. http://dx.doi.org/10.32598/ijvm.19.4.1005600

doi http://dx.doi.org/10.32598/ijvm.19.4.1005600

ABSTRACT

Background: Broiler chicken populations are currently facing a pressing issue in the form of bacterial infections, which significantly impact their growth and developmental processes. Glycyrrhizin (GL), a compound discovered in licorice, is a unique and versatile compound with various psycho-chemical properties that contribute to its diverse biological activities. It also has immunomodulatory, anti-inflammatory, antiviral, hepatoprotective, anticancer and anti-inflammatory properties, contributing to overall poultry health.

Objectives: This study aims to modulate the effect of GL on appetite and serum markers by mitigating inflammation in chickens.

Methods: The effects of GL and lipopolysaccharide (LPS) on broiler chickens were investigated. Twenty-four one-day-old male Arian broiler chickens (Simorgh Co., Mashhad, Iran) were divided into four control groups and three treatment groups receiving LPS alone or with GL at two different dosages. Treatments were administered intravenously on day 20, and feed intake and blood samples were monitored.

Results: LPS injection significantly reduced feed intake compared to the control group at 4.5, 5 and 6 h. after injection (P<0.05). Furthermore, the co-administration of LPS+GL resulted in a dose-dependent increase in cumulative feed consumption compared to that in the LPS group at 4.5, 5 and 6 h. following the injection. Additionally, the groups treated with LPS and GL showed reduced activity of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) enzymes relative to the group that received only LPS, suggesting that GL may exert a hepatoprotective effect. GL mitigated the negative effects of LPS and improved the albumin-to-globulin (A/G) ratio, highlighting its potential as an anti-inflammatory agent.

Conclusion: GL positively influences appetite and liver function in inflamed Arian broilers.

Keywords: Arian broiler, Glycyrrhizin (GL), Lipopolysaccharide (LPS), Appetite, Biochemical parameters

Article info:
Received: 05 Jun 2024
Accepted: 27 Jul 2024
Publish: 01 Oct 2025

*** Corresponding Author:**
Farshid Hamidi, Associate Professor.
Address: *Department of Basic Sciences, Faculty of Veterinary Medicine, Ferdowsi University of Mashhad, Mashhad, Iran.*
Phone: *+98 (51) 38805599*
E-mail: *Farshidhamidi@um.ac.ir*

Introduction

The poultry industry has experienced significant growth and expansion over the past two decades, playing a crucial role in bridging the gap between the demand for high-quality protein and its supply for human consumption. The increasing demand for high-quality, disease-free protein sources has increased the emphasis on the importance of sustainable and safe poultry production systems (Qui et al., 2024). Despite the poultry industry's efforts to address these concerns, it continues to face significant challenges in the form of various diseases, such as bacterial and viral infections, that can impact the health and well-being of both birds and consumers (Rafiq et al., 2022; Partovi et al., 2021).

Numerous studies have been conducted on the significance of combating infections in broilers, highlighting the critical nature of this issue (Boroomand et al., 2023; Eshaghniya et al., 2024). Broiler chickens face increasing challenges in the form of bacterial diseases, which significantly impede their growth and development (Gholipour-Shoshod et al., 2023; Morovati et al., 2022). Lipopolysaccharide (LPS), a crucial component of the cell wall of gram-negative bacteria, plays a pivotal role in the pathogenesis of these diseases. LPS can induce oxidative stress and inflammation in poultry, which can compromise their antioxidant capacity and trigger the production of pro-inflammatory cytokines (Leshchinsky & Klasing, 1988). The multifaceted impact of LPS on poultry health underscores the importance of understanding its role in bacterial diseases and developing effective strategies to mitigate its effects, ultimately ensuring the sustainability of the poultry industry (Pang et al., 2023). LPS is crucial in triggering cell and tissue damage, ultimately leading to multiple organ dysfunctions and various histopathological changes (Ding et al., 2018; Zhang et al., 2020). Studies have shown that exposure to LPS leads to decreased antioxidant levels and activity of antioxidant enzymes while simultaneously elevating the levels of pro-inflammatory factors (Zheng et al., 2016).

The central nervous system is particularly affected by LPS, which can lead to changes in feeding behavior and overall nutritional status (Ghiasi et al., 2023; Yousefvand et al., 2018). The hypothalamus is recognized as the pivotal brain region governing feed intake (Yousefvand & Hamidi, 2020; Emadi et al., 2021). It assimilates signals from the gastrointestinal tract, pancreas, hepatic system, adipose structures and diverse cerebral regions (Yousefvand & Hamidi, 2022). Existing research has elucidated a significant interrelation between the immunological, neuronal, neurohumoral, endocrine, and neuroendocrine networks within the central nervous system that coordinate nutritional ingestion in the context of bacterial infections (Zendehdel et al., 2013).

LPS significantly affects nutrition and weight by decreasing feed intake and animal weakness. This can lead to disorders, such as anorexia and fever, due to its inflammatory effects. Medicinal plants are extensively studied for their various benefits, such as anti-inflammatory, analgesic and antioxidant properties (Zendehdel et al., 2012). *Glycyrrhiza glabra*, commonly known as licorice, has been utilized as a therapeutic agent for inflammation. Research has demonstrated that supplementing chicken diets with licorice can enhance their growth performance by influencing the expression of genes related to growth, lipid metabolism and antioxidant pathways, thereby modulating antioxidant activity in avian species (Toson et al., 2023). The licorice root extract contains up to 25% glycyrrhizin (GL). GL, the main active compound in licorice root, has been shown to benefit inflammation (Li et al., 2014). GL and glycyrrhetinic acid have demonstrated efficacy in inhibiting the growth of gram-positive organisms, including Bacillus subtilis and *Staphylococcus aureus*, and gram-negative pathogens, such as *Escherichia coli* and *Pseudomonas aeruginosa*. This suggests the broad-spectrum antibacterial potential of these compounds (Langer et al., 2016; Nitalikar et al., 2010). The administration of GL to broilers increased body mass and improved the feed conversion ratio (FCR) compared to the control group (Ocampo et al., 2016). However, the precise correlation between GL intake and food consumption Arian broilers remains unclear. The current study hypothesized that GL administration would positively affect inflammation in Arian broiler chickens challenged with LPS. To address this knowledge gap, our study aimed to examine the influence of GL administration on appetite and serum biochemical markers in Arian broiler chickens challenged with LPS.

Materials and Methods

Reagents, animals and experimental design

LPS (*E. coli* 055:B5) was obtained from Sigma-Aldrich Chemical Co. (#L2880; St. Louis, MO, USA). LPS was dissolved in sterile 0.9% sodium chloride (NaCl) solution (1 mg/mL saline). Also, GL with a purity of ≥ 98% was purchased from Sigma-Aldrich.

A total of 24 one-day-old male Arian broiler chickens (Simorgh Co., Iran) were randomly assigned to four treatment groups, each consisting of six birds, in a completely randomized design. Birds were reared under standard environmental conditions at 22±1 ˚C, 50% relative humidity, and continuous lighting (Olanrewaju et al., 2006). The birds were provided access to mash feed and water ad libitum during the 21 days of the study. Table 1 presents the chemical composition of the diets and additives. Broiler chicks were randomly allocated into four groups: Control (normal saline), 1 mg/kg LPS, 1 mg/kg LPS+40 mg/kg GL and 1 mg/kg LPS+80 mg/kg GL. When the chicks reached a weight of 700 g at 20 days of age, groups 2, 3 and 4 received an intravenous (IV) injection of LPS and GL, while the control group was administered a saline solution of equal volume (0.9%) as a placebo. The health of the animals was monitored daily throughout the study using standard diagnostic methods. This study determined the GL and LPS doses based on previous studies (Mano et al., 2023; Tan et al., 2014; Tsai et al., 1992).

Measurement of feed intake

After the injections, chicks were deprived of food for 3 hours. Then, the mice were transferred to separate cages. Fresh food and water were provided, and cumulative feed intake was recorded 3.5, 4, 4.5, 5 and 6 hours after the injection. The chicken's body weight was measured before they were placed in individual cages.

Serum biochemistry

Blood samples were taken from the vein under the wing eight hours after injection and placed in 5 mL vacutainer tubes without anticoagulant. The tubes were then centrifuged at 3000×g for 10 minutes at 4 ˚C and the resulting serum was collected and stored at -80 ˚C for further analysis. Serum levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), total protein (TP), albumin, globulin, and the albumin to globulin ratio (A/G) were measured using a BS-800 chemistry analyzer (Shenzhen Mindray, Biomedical Electronics Co., China).

Body temperature

In group 2, the rectal temperature of each chick was measured before and at 1, 3, 5 and 8 hours after LPS injection using a digital thermometer. The tip of the thermometer was inserted at least 2 cm into the cloacum.

Statistical analysis

All data were preliminarily processed using Excel software, version 2016. Statistical analyses were performed using SPSS software, version 25 and the results are presented as Mean±SEM. Statistical analyses were performed using one-way analysis of variance followed by Tukey's test. Differences were considered statistically significant at $P<0.05$.

Results

Figure 1 shows the feeding response of Arian broilers to IV injection.

Cumulative feed intake

Figure 2 shows the feeding response of Arian broilers to IV injection of LPS and GL. IV injection of 1 mg/kg doses of LPS significantly reduced feed intake compared to the control group at 4.5, 5 and 6 h. after injection ($P<0.05$). In addition, IV injections of LPS+GL (at doses of 40 and 80 mg/kg) resulted in a dose-dependent increase in cumulative feed consumption compared to the LPS group at 5 and 6 h. after the injection ($P<0.05$). No differences were observed in any of the groups compared to the control group at 3.5 and 4 hours post-injection ($P>0.05$).

Data are expressed as Mean±SE of the mean (SEM). Different letters (a, b, c and d) indicate significant differences between the treatments at each time point ($P<0.05$).

Effect of IV injection of LPS on rectal temperature

As shown in Figure 2, rectal temperature significantly changed in the LPS group at 1, 3, 5 and 8 hours after injection compared to that in the control group. After LPS administration, the body temperature dropped and rose above the normal range.

Serum biochemical parameters

As shown in Table 2, serum biochemical indicators exhibited significant differences 8 hours after the injection. The serum biochemical indicators of AST and ALT were significantly higher in the LPS group than in the other groups ($P<0.05$). In contrast, the GL groups displayed significantly decreased AST and ALT activities compared to those in the LPS group ($P<0.05$). The results showed that ALP indicators did not differ significantly among the four groups ($P>0.05$). The TP content was higher in the LPS+GL groups than in the LPS and control groups ($P<0.05$). Furthermore, the LPS group showed signifi-

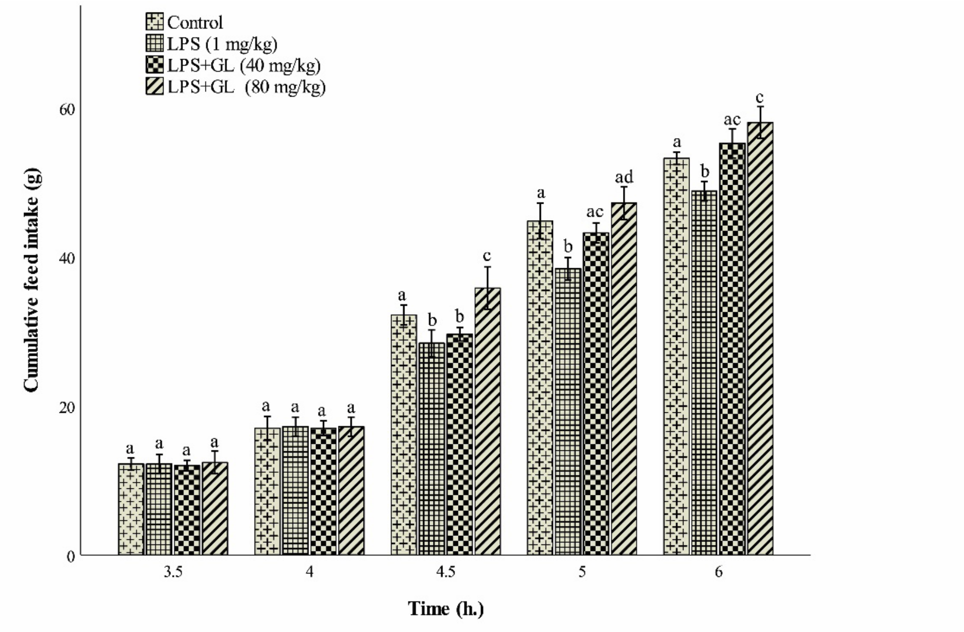

Figure 1. Effects of IV injection of control solution, LPS and LPS+GL on cumulative feed intake in Arian broilers

cantly reduced albumin concentrations compared to the other groups (P<0.05). In contrast, globulin levels were significantly higher in the LPS group than in other groups.

Discussion

The growth performance of animals raised in unsanitary environments is believed to be negatively impacted by an overactive immune response, characterized by inflammation. This response is associated with decreased feed intake, reduced muscle protein synthesis, and diverting energy and protein resources towards defense mechanisms, ultimately leading to impaired growth (Cook, 2011; KC, 1988). The results of our experiment indicated that IV administration of LPS led to a decrease in feed intake compared to that in the control group at 4.5, 5 and 6 minutes post-injection. In a related study, researchers discovered that intracerebroventricular and intraperitoneal (IP) injections of LPS significantly decreased feed consumption in chickens (Ghiasi et al., 2023). Our results showed a significant dose-dependent increase in cumulative feed intake in the LPS+GL group compared to that in the LPS group at 4.5, 5 and 6 h. after administration. The results also indicated that the feeding response to IV

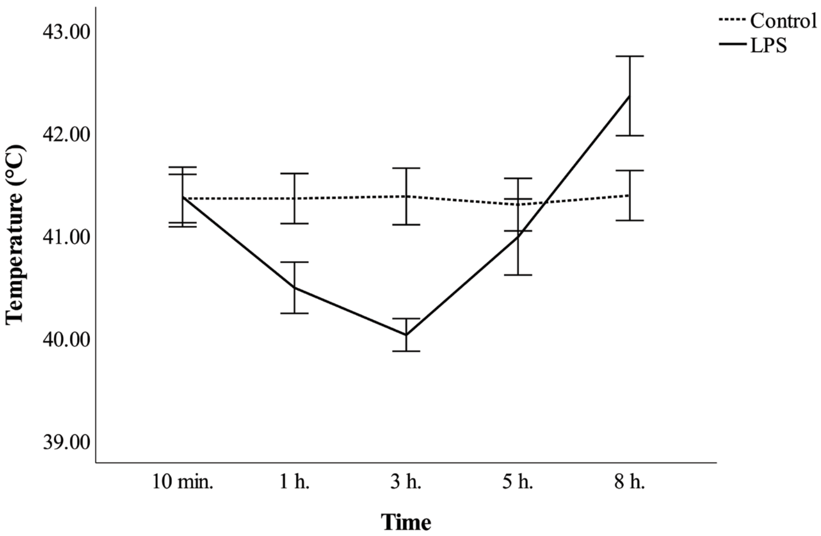

Figure 2. The effect of IV injection of LPS on rectal temperature measured 10 minutes before injection, 1, 3, 5 and 8 hours after injection

Table 1. Chemical composition of the used broiler diets and additives in the diets

	Items	Pre-starter (1 to 12 Days)	Starter (13 to 24 Days)
Ingredients	Corn	58.35	59.01
	Soybean meal	33.02	33
	Soy oil	1.16	2.16
	Corn gluten meal	3.18	2
	$CaHPO_4$	2	1.65
	Limestone	1.25	1.25
	NaCl	0.36	0.36
	DL-Methionine	0.28	0.17
	L-Lys	0.2	0.2
	Vitamin premix	0.1	0.1
	Mineral premix	0.1	0.1
	Total	100	100
Calculated nutrient content	ME, calculated (kcal/kg)	3000	3000
	CP	21.21	21
	Calcium	0.96	0.91
	Available phosphorus	0.46	0.4
	Lys	1.15	1.15
	Met	0.57	0.5
	TSAA	0.86	0.86
	Thr	0.78	0.73
	Trp	0.22	0.22

Abbreviations: NaCl: Sodium chloride; CP: Crude protein; TSAA: Total sulfur amino acids; $CaHPO_4$: Dicalcium phosphate; ME: Metabolizable energy.

injection of LPS and GL is time-dependent, with notable differences observed at specific hours post-injection. In another study, the use of GL as an additive in the drinking water of broiler chickens has been investigated as a potential strategy to enhance both the production and health outcomes in the flock. Furthermore, they found that broiler chickens treated with 0.03% GL showed statistically significant improvements in weight gain (7.6% higher) and FCR compared to non-treated controls. Additionally, the mortality rate among the treated birds was reduced from 8.17% to 5.95% (Ocampo et al., 2016).

A study on the effect of IV injection of LPS on rectal temperature revealed significant changes in body temperature, initially dropping below the normal range and then increasing above it. This suggests that LPS may induce a stress response in chickens, leading to changes in body temperature. Endotoxin-induced fever has been observed in various species, including chicken (Wang et al., 2022). Consistent with our research, chickens exhibit elevated body temperatures and loss of appetite after LPS injection (Johnson, 1998). De Boever et al. (2008) focused on the impact of LPS on body temperature in broiler chickens. After administering a potent LPS dose, the chicken's body temperature initially decreased to be-

Table 2. Effects of GL on some serum biochemical parameters of LPS-stimulated broilers

Groups	Mean±SE						
	ALT (U/L)	AST (U/L)	ALP (U/L)	TP (g/dL)	Albumin (g/dL)	Globulin (g/dL)	A/G
Control	3.26±0.018[a]	261±4.35[a]	18.73±0.61	3.3±0.038[a]	1.99±0.037[a]	1.76±0.036[a]	1.12±0.02[a]
LPS	3.4±0.043[b]	291±3.72[b]	18.6±0.52	3.31±0.033[a]	1.88±0.037[b]	2.17±0.029[b]	0.87±0.023[b]
LPS+GL (40 mg)	3.34±0.013[bc]	275±5[ab]	18.36±0.6	3.44± 0.062[a]	2.1±0.042[a]	1.71±0.028[a]	1.23±0.039[ac]
LPS+GL (80 mg)	3.24±0.024[ac]	267±3.72[ac]	18.43±0.51	3.49±0.038[b]	210±0.034[a]	1.67±0.015[a]	1.25±0.023[c]

Abbreviations: ALT: Alanine transaminase; AST: Aspartate transaminase; ALP: Alkaline phosphatase; TP: Total protein; GL: Glycyrrhizin; A/G: Albumin to globulin ratio; LPS: Lipopolysaccharide.

Note: Control, IV administration of normal saline (0.9%); LPS, IV administration of 1 mg/kg LPS; LPS+GL (40 mg) (80 mv), IV administration of 1 mg/kg LPS+40 mg/kg or 80 mg/kg GLA. Within rows without the same superscript are significantly different (P<0.05).

low-normal levels before increasing. This phenomenon has been corroborated by other studies that examined the effects of IV and IP injections of LPS in chickens (Uyanga et al., 2022; Xie et al., 2000).

The study's analysis of serum biochemical indicators revealed significant differences in AST and ALT levels among the groups. The LPS group exhibited higher AST and ALT activity than the GL group, indicating potential liver damage (Hong et al., 2023). In this regard, the results of other studies showed that IP injection of LPS increases ALT and AST levels (Yu et al., 2017). In contrast, the GL group displayed decreased AST and ALT activities, suggesting a protective effect of GL on liver function. Also, GL exhibits advantageous pharmacological properties, such as anti-ulcer, anti-inflammatory, and antioxidant properties. It is recognized for its effectiveness as a liver-protecting agent (Orazizadeh et al., 2014). Furthermore, a study conducted by Yu et al. (2017) demonstrated that GL can reduce the activities of ALT and AST, thereby mitigating potential damage to hepatic cells.

The A/G ratio is a significant parameter for the assessment of the health and physiological status of broiler chickens. The A/G ratio is an essential indicator of immune status, as globulins are involved in the immune response and a lower ratio may suggest an active immune response or inflammation (Sugiharto et al., 2024). In confirming the present study's results, the LPS-challenged groups exhibited a significant alteration in the A/G ratio, with a marked increase in globulin levels, indicative of an inflammatory response (Pang et al., 2023). Our results indicate that GL can ameliorate the adverse impacts induced by LPS while concurrently augmenting the A/G ratio. This suggests a potential therapeutic role of GL in the modulation of inflammatory responses. Consistent with our study, GL counteracts the inflammatory cascade triggered by LPS and its effect on the A/G ratio through the modulation of specific signaling pathways (Chen et al., 2022).

The present study identified variations in the serum protein patterns among the different groups. The results also showed significant reductions in albumin concentration in the LPS group, which could indicate liver damage or inflammation. Moreover, the increase in globulin levels in the LPS group might be related to the immune response to LPS. It should be emphasized that numerous pathological conditions are often associated with minor or more significant changes in serum protein profiles, including variations in the concentrations of albumin and globulins (Kaneko, 1997). Exposure of broilers to LPS triggers an immune response that compromises their growth, primarily due to the disruption of protein metabolism within the body (Nawaz et al., 2021). As a result, the nutrients that would normally support growth are redirected to combat the inflammatory response, ultimately hindering the growth performance of broilers. In the context of the acute-phase response, serum albumin is a prominent negative acute-phase protein (APP), whose synthesis is diminished during inflammation. This phenomenon is attributed to the heightened demand for amino acids to produce positive APPs, necessitating hepatic protein synthesis reorganization. In line with the current study's results, albumin production is downregulated, and amino acids are redirected towards synthesizing positive APPs, thereby reflecting the body's adaptive response to inflammation (Abdullah, 2021).

Conclusion

In conclusion, the effects of GL on feed intake and serum biochemical parameters in inflamed Arian broilers suggest that LPS has negative effects and that GL may positively impact feed intake and liver function in broiler chickens under certain conditions. Further research is needed to fully understand the mechanisms underlying these effects and explore the potential applications of GL in poultry nutrition and health management.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Ferdowsi University of Mashhad, Mashhad, Iran (Code: IR.UM.REC.1402.221).

Funding

This research was financially supported by Ferdowsi University of Mashhad, Mashhad, Iran (Grant No.: 61395).

Authors' contributions

Data curation, investigation, analysis and writing the original draft: Mitra Nowrouzpour and Amin Rahdar; Conceptualization, methodology, supervision, project administration, investigation, validation, review and editing: Farshid Hamidi.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank the Ferdowsi University of Mashhad, Mashhad, Iran for their support.

References

Abdullah, M. A. (2021). Acute phase proteins in veterinary medicine: A review. *Journal of Animal Science and Veterinary Medicine, 6*(6), 188-194. [DOI:10.31248/JASVM2020.216]

Boroomand, Z., Hadi Haghbin Nazar Pak, H., Faryabi, S., & Hosseini, H. (2023). The role of newcastle disease virus in broiler chickens with high mortality of Kerman province. *Archives of Razi Institute, 78*(6), 1861–1867. [DOI:10.32592/ari.2023.78.6.1860] [PMID]

Chen, Y., Qu, L., Li, Y., Chen, C., He, W., & Shen, L., et al. (2022). Glycyrrhizic acid alleviates lipopolysaccharide (LPS)-Induced acute lung injury by regulating angiotensin-converting enzyme-2 (ACE2) and Caveolin-1 signaling pathway. *Inflammation, 45*(1), 253–266. [DOI:10.1007/s10753-021-01542-8] [PMID]

Cook M. E. (2011). Triennial Growth Symposium: a review of science leading to host-targeted antibody strategies for preventing growth depression due to microbial colonization. *Journal of Animal Science, 89*(7), 1981–1990. [DOI:10.2527/jas.2010-3375] [PMID]

De Boever, S., Beyaert, R., Vandemaele, F., Baert, K., Duchateau, L., & Goddeeris, B., et al. (2008). The influence of age and repeated lipopolysaccharide administration on body temperature and the concentration of interleukin-6 and IgM antibodies against lipopolysaccharide in broiler chickens. *Avian Pathology, 37*(1), 39–44. [DOI:10.1080/03079450701784875] [PMID]

Ding, Q., Wang, Y., Zhang, A. L., Xu, T., Zhou, D. D., & Li, X. F., et al. (2018). ZEB2 attenuates LPS-Induced inflammation by the NF-κB pathway in HK-2 cells. *Inflammation, 41*(2), 722–731. [DOI:10.1007/s10753-017-0727-x] [PMID]

Emadi, L., Jonaidi, H., Nazifi, S., Khasti, H., Rohani, E., & Kaiya, H. (2022). [The effects of central ghrelin on serum parameters related to energy metabolism in neonatal chicks (Persian)]. *Iranian Journal of Veterinary Medicine, 16*(2), 110-118. [DOI:10.22059/ijvm.2021.325585.1005182]

Eshaghniya, A., Haghbin Nazarpak, H., Ghalyanchilangeroudi, A., & Hosseini, H. (2024). Evaluation of protective immunity in chickens vaccinated with combined IB H120/D274 and IB H120 against IS/1494/06 in Iran. *Archives of Razi Institute, 79*(3), 575–586. [DOI:10.32592/ARI.2024.79.3.575] [PMID]

Ghiasi, S., Zendehdel, M., Haghbinnazarpak, H., Asghari, A., & Sheikhi, N. (2023). Central and peripheral effects of lipopolysaccharide on food choice and macronutrient selection in meat-type chick. *Archives of Razi Institute, 78*(3), 843–851. [DOI:10.22092/ari.2022.359882.2495] [PMID]

Gholipour-Shoshod, A., Rahimi, S., Zahraei Salehi, T., Karimi Torshizi, M. A., Behnamifar, A., & Ebrahimi, T., et al. (2023). [Evaluating the competitiveness of medicinal plants with antibiotics to control salmonella enterica serovar typhimurium in broiler chickens (Persian)]. *Iranian Journal of Veterinary Medicine, 17*(2), 155-166. [DOI:10.32598/IJVM.17.2.1005233]

Hong, W., Fu, W., Zhao, Q., Xue, C., Cai, W., & Dong, N., et al. (2023). Effects of oleanolic acid on acute liver injury triggered by lipopolysaccharide in broiler chickens. *British Poultry Science, 64*(6), 697–709. [DOI:10.1080/00071668.2023.2251119] [PMID]

Johnson, R. W. (1998). Immune and endocrine regulation of food intake in sick animals. *Domestic Animal Endocrinology, 15*(5), 309-319. [DOI:10.1016/s0739-7240(98)00031-9] [PMID]

Kaneko, J. J. (1997). Serum proteins and the dysproteinemias. In J. J. Kaneko., J. W. Harvey., M. L. Bruss (Eds.), *Clinical biochemistry of domestic animals* (pp. 117-138). Cambridge: Academic Press. [DOI:10.1016/B978-012396305-5/50006-3]

Klasing, K. C., & Barnes, D. M. (1988). Decreased amino acid requirements of growing chicks due to immunologic stress. *The Journal of Nutrition, 118*(9), 1158–1164. [DOI:10.1093/jn/118.9.1158] [PMID]

Langer, D., Czarczynska-Goslinska, B., & Goslinski, T. (2016). Glycyrrhetinic acid and its derivatives in infectious diseases. *Current Issues in Pharmacy and Medical Sciences, 29*(3), 118-123. [DOI:10.1515/cipms-2016-0024]

Leshchinsky, T. V., & Klasing, K. C. (2001). Divergence of the inflammatory response in two types of chickens. *Developmental and Comparative Immunology, 25*(7), 629–638. [DOI:10.1016/s0145-305x(01)00023-4] [PMID]

Li, J. Y., Cao, H. Y., Liu, P., Cheng, G. H., & Sun, M. Y. (2014). Glycyrrhizic acid in the treatment of liver diseases: Literature review. *BioMed Research International, 2014*(1), 872139. [DOI:10.1155%2F2014%2F872139]

Mano, Y., Abe, K., Takahashi, M., Higurashi, T., Kawano, Y., & Miyazaki, S., et al. (2023). Optimal administration of glycyrrhizin avoids pharmacokinetic interactions with high-dose methotrexate and exerts a hepatoprotective effect. *Anticancer Research, 43*(4), 1493–1501. [DOI:10.21873/anticanres.16298] [PMID]

Morovati, S., Bassami, M., Kalidari, G., Tavassoli, A., Razmyar, J., & Ghahramani Seno, M. (2022). Characterization of the full length p and m genes in a newcastle disease virus isolated from chicken farms in northeast of Iran. *Iranian Journal of Veterinary Medicine, 16*(2), 126-143. [Link]

Nawaz, S., Asif, M., Bhutta, Z. A., Kulyar, M. F., Hussain, R., & Ramzan, A., et al. (2021). A comprehensive review on acute phase proteins in chicken. *European Poultry Science, 85*, 1-18. [DOI:10.1399/eps.2021.344]

Nitalikar, M. M., Munde, K. C., Dhore, B. V, & Shikalgar, S. N. (2010). Studies of antibacterial activities of glycyrrhiza glabra root extract. *International Journal of PharmTech Research, 2*(1), 899-901. [Link]

Ocampo, C. L., Gómez-Verduzco, G., Tapia-Perez, G., Gutierrez, O. L., & Sumano, L. H. (2016). Effects of glycyrrhizic acid on productive and immune parameters of broilers. *Brazilian Journal of Poultry Science, 18*(3), 435-442. [DOI:10.1590/1806-9061-2015-0135]

Olanrewaju, H. A., Thaxton, J. P., Dozier, W. A., Purswell, J., Roush, W. B., & Branton, S. L. (2006). A review of lighting programs for broiler production. *International Journal of Poultry Science, 5*(4), 301-308. [DOI:10.3923/ijps.2006.301.308]

Orazizadeh, M., Fakhredini, F., Mansouri, E., & Khorsandi, L. (2014). Effect of glycyrrhizic acid on titanium dioxide nanoparticles-induced hepatotoxicity in rats. *Chemico-Biological Interactions, 220*, 214-221. [DOI:10.1016/j.cbi.2014.07.001] [PMID]

Pang, X., Miao, Z., Dong, Y., Cheng, H., Xin, X., & Wu, Y., et al. (2023). Dietary methionine restriction alleviates oxidative stress and inflammatory responses in lipopolysaccharide-challenged broilers at early age. *Frontiers in Pharmacology, 14*, 1120718. [DOI:10.3389/fphar.2023.1120718] [PMID]

Partovi, R., Seifi, S., Alian, S., & Nikpay, A. (2021). Appraisal of dietary prebiotic supplementation on meat properties and carcass characteristics of broiler chickens after experimental infection with eimeria species. *Iranian Journal of Veterinary Medicine, 15*(3), 346-357. [DOI:10.22059/IJVM.2020.303786.1005095]

Qui, N. H., Linh, N. T., Thu, N. Thi N. T. A., Nang, K., & Hoai, P., et al. (2024). Immunological response and nutritional effects of Lactobacillus spp.-fermented Garlic on Turkey broilers. *Archives of Razi Institute, 79*(2), 345-354. [DOI:10.32592/ARI.2024.79.2.345]

Rafiq, K., Tofazzal Hossain, M., Ahmed, R., Hasan, M. M., Islam, R., & Hossen, M. I., et al. (2022). Role of different growth enhancers as alternative to in-feed antibiotics in poultry industry. *Frontiers in Veterinary Science, 8*, 794588. [DOI:10.3389/fvets.2021.794588] [PMID]

Sugiharto, S., Zulpa, Y., Agusetyaningsih, I., Widiastuti, E., Wahyuni, H. I., & Yudiarti, T., et al. (2024). Physiological responses and intestinal conditions of broiler chickens treated with encapsulated Acalypha australis L. leaf extract and chitosan. *Veterinary World, 17*(5), 994–1000. [DOI:10.14202/vetworld.2024.994-1000] [PMID]

Tan, J., Liu, S., Guo, Y., Applegate, T. J., & Eicher, S. D. (2014). Dietary L-arginine supplementation attenuates lipopolysaccharide-induced inflammatory response in broiler chickens. *British Journal of Nutrition, 111*(8), 1394-1404. [DOI:10.1017/s0007114513003863] [PMID]

Toson, E., Abd El Latif, M., Mohamed, A., Gazwi, H. S. S., Saleh, M., & Kokoszynski, D., et al. (2023). Efficacy of licorice extract on the growth performance, carcass characteristics, blood indices and antioxidants capacity in broilers. *Animal, 17*(1), 100696. [DOI:10.1016/j.animal.2022.100696] [PMID]

Tsai, T., Liao, J., Shum, A. Y., & Chen, C. (1992). Pharmacokinetics of glycyrrhizin after intravenous administration to rats. *Journal of Pharmaceutical Sciences, 81*(9), 961-963. [DOI:10.1002/jps.2600810925] [PMID]

Uyanga, V. A., Zhao, J., Wang, X., Jiao, H., Onagbesan, O. M., & Lin, H. (2022). Dietary L-citrulline influences body temperature and inflammatory responses during nitric oxide synthase inhibition and endotoxin challenge in chickens. *Stress, 25*(1), 74-86. [DOI:10.1080/10253890.2021.2023495] [PMID]

Wang, H., Yang, F., Song, Z., Shao, H., Bai, D., & Ma, Y., et al. (2022). The influence of immune stress induced by Escherichia coli lipopolysaccharide on the pharmacokinetics of danofloxacin in broilers. *Poultry Science, 101*(3), 101629. [DOI:10.1016/j.psj.2021.101629] [PMID]

Xie, H., Rath, N. C., Huff, G. R., Huff, W. E., & Balog, J. M. (2000). Effects of Salmonella typhimurium lipopolysaccharide on broiler chickens. *Poultry Science, 79*(1), 33-40. [DOI:10.1093/ps/79.1.33] [PMID]

Yousefvand, S., Hamidi, F., Zendehdel, M., & Parham, A. (2018). Hypophagic effects of insulin are mediated via NPY1/NPY2 receptors in broiler cockerels. *Canadian Journal of Physiology and Pharmacology, 96*(12), 1301-1307. [DOI:10.1139/cjpp-2018-0470. PMID: 30326197] [PMID]

Yousefvand, S., & Hamidi, F. (2020). Role of paraventricular nucleus in regulation of feeding behaviour and the design of intranuclear neuronal pathway communications. *International Journal of Peptide Research and Therapeutics, 26*, 1231-1242. [DOI:10.1007/s10989-019-09928-x]

Yousefvand, S., & Hamidi, F. (2022). Role of lateral hypothalamus area in the central regulation of feeding. International *Journal of Peptide Research and Therapeutics, 28*(3), 83. [DOI:10.1007/s10989-022-10391-4]

Yu, Z., Guo, F., Zhang, Z., Luo, X., Tian, J., & Li, H. (2017). Protective effects of glycyrrhizin on lps and amoxicillin/potassium clavulanate-induced liver injury in chicken. *Pakistan Veterinary Journal, 37*(1), 13-18. [Link]

Zendehdel, M., Mokhtarpouriani, K., Babapour, V., Pourrahimi, M., & Hamidi, F. (2013). The role of 5-HT2A and 5-HT2C receptors on harmalineinduced eating behavior in 24-h food-deprived broiler cockerels. *Iranian Journal of Veterinary Research, 14*(2), 94-99. [DOI:10.22099/ijvr.2013.1581]

Zendehdel, M., Taati, M., Amoozad, M., & Hamidi, F. (2012). Antinociceptive effect of the aqueous extract obtained from Foeniculum vulgare in mice: The role of histamine H1 and H2 receptors. *Iranian Journal of Veterinary Research, 13*(2), 100-106. [DOI:10.22099/ijvr.2012.98]

Zhang, H., Chen, Y., Chen, Y., Li, Y., Jia, P., Ji, S., Zhou, Y., & Wang, T. (2020). Dietary pterostilbene supplementation attenuates intestinal damage and immunological stress of broiler chickens challenged with lipopolysaccharide. *Journal of Animal Science, 98*(1), skz373. [DOI:10.1093/jas/skz373] [PMID]

Zheng, X. C., Wu, Q. J., Song, Z. H., Zhang, H., Zhang, J. F., & Zhang, L. L., et al. (2016). Effects of Oridonin on growth performance and oxidative stress in broilers challenged with lipopolysaccharide. *Poultry Science, 95*(10), 2281-2289. [DOI:10.3382/ps/pew161] [PMID]

This Page Intentionally Left Blank