

# Effect of Adding Thyme Powder on the Physiological Characteristics of Quail

Gulala. W. Ameen

Department of Animal Production, College of Agriculture, Kirkuk University, Kirkuk, Iraq

**Received:** 2026 19, Jan

**Accepted:** 2026 28, Feb

**Published:** 2026 05, Mar

Copyright © 2026 by author(s) and BioScience Academic Publishing. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).



Open Access

<http://creativecommons.org/licenses/by/4.0/>

**Annotation:** The aim of the current research was to determine the impact of dietary supplementation by thyme (*Thymus vulgaris*) powder on the Japanese quail (*Coturnix coturnix japonica*) with respect to a few hematological and biochemical measurements. Sixty-four, 45 days old, birds collapsed randomly into four dietary treatments in a completely randomized design (CRD). The four replicas were used in each treatment and each replica was made up of four birds. The trial period was eight weeks (56 days). The diets were as follows: T1, a basic diet free of thyme (control); T2, a basic diet with 0.5 percent thyme powder in it; T3, a basic diet containing 0.75 percent thyme powder in it; and T4, a basic diet containing 1 percent thyme powder in it.

Statistical analyses showed that thyme supplementation produced significant ( $P < 0.05$ ) changes in hemoglobin, packed cell volume, white blood cell, and lymphocyte proportion with the largest response changes being recorded in 0.75 percent inclusion rate. Parameters of lipid-profile also showed a change; the total cholesterol showed a very significant decrease, and the level of the high-density lipoprotein (HDL) in the T3 group was higher than in the other treatment groups. There were no statistically significant differences between the groups in terms of total protein, albumin and globulin and uric acid concentrations. Hepatic enzyme levels, such as alanine aminotransferase (ALT) and aspartate

aminotransferase (AST), were within the normal physiological range, which showed that liver functioning was not harmed.

In general, the addition of thyme powder at a 0.75 percent inclusion level to the diet improved the hematological as well as the specific biochemical parameters without damaging the hepatic integrity. Therefore, thyme powder can be considered to have an effective natural feed additive with physiological and immunological effects to Japanese quail.

**Keywords:** Powdered thyme, Japanese quail, Hematological, biochemistry, Lipid.

---

## Introduction

The gradual ban on antibiotic growth promoting agents in rearing of poultry has also spurred the interest of developing natural alternatives which can increase the productivity of poultry besides ensuring that their health is not endangered by the presence of the drug in their bodies. The use of phytogetic feed additives (mainly medicinal and aromatic plants) has been identified as having antimicrobial, antioxidant and immunomodulatory effects, and as a result of this, the effect has attracted a lot of scholarly interest due to the documented effects (Greathead, 2003; Franz et al., 2010). The most promising of them has become thyme ( *Thymus vulgaris* ), as a natural supplement in the diet of poultry.

Thymol and carvacrol, the phytochemical compounds of thyme, have strong antimicrobial and antioxidants properties (Bozin et al., 2006). These compounds selectively favour the gut health by suppressing the growth of pathogenic bacteria and enhancing the growth of the beneficial microflora thus increasing the absorption of nutrients and causing physiological responses (Jamroz et al., 2006). There is a direct connection between a better immunological condition, greater metabolic efficiency, and a better gut integrity of poultry (Mountzouris et al., 2011).

Thyme has also been reported to have an effect on lipid metabolism and blood biochemistry as well as possessing antimicrobial properties. Essential oils and phenolic compounds of thyme have the power to inhibit lipid peroxidation and improve serum lipid profile in poultry (Placha et al., 2014). Furthermore, it has been established that herbal feed supplements could increase the secretion of enzymes in the digestive system, protein consumption, and, as a result, positively affect haematological indices (Ozek et al., 2011). The reason is that the academic interest in natural bioactive compounds is growing due to the presence of such strong antioxidant properties and the existence of a wide range of therapeutic possibilities, which will lead to their use in nutrition and biomedical studies in the future (Mhamad et al., 2025; Mhamad and Palani, 2025).

Japanese quail (*Coturnix coturnix japonica*) is a commercially important poultry species that is marked with fast growth rate, low maturity and high productivity. Quail have often been used as model organisms in the assessment of the physiological and biochemical implications of dietary intervention due to their short life-history and relative lack of sensitivity to changes in diet (Minvielle, 2004). As a result, this study on the impact of thyme powder supplementation on haematology and biochemistry of Japanese quail has a scientific and practical implication.

Even though various studies have been done to determine the impact of thyme on broiler chickens, there is limited information on the effects of thyme to haematological parameters of Japanese quail, especially when they are kept in production environments in this country. Based on this, this paper set out to determine the impact of different levels of dietary inclusion of thyme

powder (0.5, 0.75, and 1% w/w) on haematological, biochemical, lipid profile and hepatic enzyme parameters in Japanese quail.

## Materials and Methods

Research was done in the Animal Production Fields of the College of Agriculture, University of Kirkuk. The experimental group was a total of sixty-four juvenile Japanese quail (*Coturnix coturnix japonica*) with an average of forty five days of age. There was a completely randomized design (CRD) of these birds, who were randomly assigned to four dietary treatment groups. Every treatment had four replicas with four birds in each replicate making a total of sixteen birds. The experiment took a duration of eight weeks (56 days). Birds were kept in similar environmental and management conditions and fed and watered ad libitum.

The fundamental feeding of the Japanese quail was developed as per the National Research Council (1994) requirements. Wheat, soybean meal (47.0 percent crude protein) and corn were the main sources of energy and protein. It was supplemented with a vegetable oil to adjust values of metabolizable energy. Limestone and monocalcium phosphate were also incorporated respectively, to serve the calcium and phosphorus requirements. Furthermore, an enzyme mixture and toxin binder was added to increase the nutrient utilization and feed safety. To provide the necessary level of vitamins and other necessary micro constituents, a vitamin-mineral mixture was also added.

Proximate analysis of the basal diet constituted about 23 per cent crude protein and 3,000 kcal kg<sup>-1</sup> metabolizable energy. This composition had also 1.05% available calcium, 0.50% available phosphorus, 0.21% available sodium, 1.46% available Lysine, 0.60% available methionine, 4.03% crude fat and 2.82% crude fiber. These are the same values as those which provide the optimum standards of physiological performance of Japanese quail.

The treatments were as follows; T1 Basal diet, T2 Basal diet + 0.5% thyme powder, T3 Basal diet + 0.75% thyme powder and T4 Basal diet + 1.0% thyme powder. The powdered thyme was mixed well in the basal diet before administration.

Blood samples of the brachial vein of each bird in each replicate were collected at the end of the experimental period (56 days) using sterile disposable syringes. About 3mL of blood was collected each bird. Some of the samples were moved to EDTA-treated tubes as an anticoagulant to complete the hematological analyses and the rest to plain tubes to permit separation of serum. The storage of the biochemical parameters was at -20 deg C in serum after centrifugation at 3000 rpm over 15 minutes.

Hematological parameters that were measured were red blood cells (RBCs), white blood cells (WBCs), hemoglobin (Hb), packed cell volume (PCV), leukocyte differentials on bone marrow, and the ratio of heterophil to lymphocyte (H/L). Biochemical parameters in serum like total protein, albumin, globulin, albumin/globulin (A/G) ratio, uric acid, total cholesterol, triglycerides, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and hepatic enzymes (ALT and AST) were measured with the help of commercial diagnostic kits according to the instructions of the manufacturer and analyzed by the automated biochemical analyzer (Accent-200, Cormay, Poland).

The data were analyzed statistically with the help of the Statistical Analysis System (SAS, 2004). Duncan Multiple Range Test (Duncan, 1955) was used to compare treatment means at a significance level of  $P = 0.05$ .

## Results

### Hematological Parameters

Table 1 gives the dietary supplementation results of thyme powder on the hematological parameters of Japanese quail. The counts of red blood cells (RBC) did not find any statistically significant difference in the experimental groups. There was a significant influence on packed

cell volume (PCV) ( $P \leq 0.05$ ) with the highest PCV in treatment T3 (0.75mg thyme), then in T2, and the lowest PCV in the control treatment T1. All thyme-supplemented groups (T2, T3 and T4) compared to the control had significant increases in hemoglobin levels, (Hb). The white blood cell (WBC) was significantly different with the highest count being T3, T4 and T2 respectively with the lowest being T1. The percentage of heterophils and heterophil/lymphocyte (H/L) ratio did not show any statistically significant differences in treatment. On the other hand, T3 had a significant percentage of lymphocytes compared to the other treatments but monocyte percentage was significantly lower in T3 than in the other groups. Supplementation of thyme did not have a substantial impact on the percentage of eosinophils.

### Serum Biochemical parameters.

Table 2 is a summary of the serum biochemical parameters. There were no significant changes in total protein and albumin, globulin/albumin (A/G) ratio, and uric acid, which can be attributed to the dietary thyme supplementation. The treatments had a considerable ( $P \leq 0.05$ ) impact on the total cholesterol (TC); T2 showed the highest level of TC, whereas T3 had a low level of TC, which is close to that in the control group.

### Serum Lipid Profile

Table 3 represents the effects of addition of thyme powder on serum lipid fractions. The interventions had a significant impact ( $P \leq 0.05$ ) on the level of low-density lipoprotein (LDL) with the highest level recorded in T4 and T2 and lowest in the control group. The level of high-density lipoprotein (HDL) was significantly elevated in T3 when compared to the other treatments. The TG peaks were noted in T3, and then in T2, with the highest values of the TG covered by the control group.

### Liver Enzymes

Table 4 displays the liver enzymes (ALT and AST). It did not find any significant difference in the alanine aminotransferase (ALT) activity in reaction to the supplementation with thyme. The treatment had a significant impact on the activity of aspartate aminotransferase (AST) ( $P 0.05$ ); the minimal levels of AST were observed in T4, and the highest concentration was observed in T2, where T3 and T1 yielded intermediate values.

**Table 1: Impacts of Dietary Supplementation with Thyme ( *Thymus vulgaris* ) Powder on Hematological parameters in Japanese Quail (Means  $\pm$  SE).**

Parameter	T1	T2	T3	T4
RBCs ( $\times 10^6 / \mu\text{l}$ )	2.44 $\pm$ 0.16	2.45 $\pm$ 0.11	2.46 $\pm$ 0.30	2.47 $\pm$ 0.11
PCV (%)	25.70 $\pm$ 0.55 c	28.40 $\pm$ 0.89 b	30.66 $\pm$ 2.07 a	26.50 $\pm$ 1.52 bc
Hb (g/dl)	6.68 $\pm$ 0.15b	9.90 $\pm$ 0.47 a	11.04 $\pm$ 2.04 a	10.08 $\pm$ 1.16 a
WBCs ( $\times 10^3 / \mu\text{l}$ )	18.20 $\pm$ 1.09 c	25.01 $\pm$ 2.00 b	31.40 $\pm$ 1.7 a	28.20 $\pm$ 2.28 b
Heterophil (%)	8.05 $\pm$ 0.71	8.70 $\pm$ 1.64	8.80 $\pm$ 1.41	9.50 $\pm$ 2.07
Lymphocyte (%)	70.60 $\pm$ 0.89 bc	72.00 $\pm$ 1.22 bc	75.40 $\pm$ 2.07 a	73.20 $\pm$ 1.48 c
H/L ratio	0.11 $\pm$ 0.01	0.12 $\pm$ 0.03	0.10 $\pm$ 0.02	0.13 $\pm$ 0.03
Monocyte (%)	16.05 $\pm$ 1.00 a	14.60 $\pm$ 0.58 a	11.40 $\pm$ 1.81 b	15.30 $\pm$ 0.84 a
Eosinophil (%)	2.40 $\pm$ 0.55	2.60 $\pm$ 1.14	2.20 $\pm$ 0.45	2.00 $\pm$ 0.71

**Notes:** The values are presented in terms of means $\pm$  standard error (SE).

The means in the same row that will have different superscript letters (a, b, c) are said to be very different at  $P = 0.05$  according to the Duncan multiple range test (Duncan, 1955).

T1 and T4 are the basal diet and the basal diet plus 0.5 and 1 percent thyme powder respectively.

RBCs = Red blood cells; WBCs = White blood cells; PCV = Packed cell volume; Hg = Hemoglobin; H/L ratio = Heterophil-to-lymphocyte ratio.

**Table 2: Effect of Dietary Thyme (*Thymus vulgaris*) Powder Supplementation on Serum Biochemical Parameters of Japanese Quail (Means  $\pm$  SE)**

Parameter	T1	T2	T3	T4
TP (gm/dL)	4.12 $\pm$ 0.52	4.39 $\pm$ 0.39	4.84 $\pm$ 0.88	4.17 $\pm$ 0.53
Alb (gm/dL)	2.32 $\pm$ 0.54	2.15 $\pm$ 0.89	2.13 $\pm$ 0.63	1.44 $\pm$ 0.58
Glob (gm/dL)	1.95 $\pm$ 0.45	2.24 $\pm$ 0.32	2.51 $\pm$ 0.60	2.32 $\pm$ 0.51
A/G	1.52 $\pm$ 0.78	0.98 $\pm$ 0.46	1.02 $\pm$ 0.55	1.10 $\pm$ 0.71
UA (mg/dl)	9.66 $\pm$ 0.05	8.92 $\pm$ 1.62	9.81 $\pm$ 0.88	8.78 $\pm$ 0.40
TC (mg/dl)	100.36 $\pm$ 6.73 c	125.78 $\pm$ 6.69 a	95.11 $\pm$ 6.74 b	106.35 $\pm$ 7.32 cb

**Notes:** The values are in terms of means plus standard error (SE). The letters included in the form of superscripts (a, b, c) show statistically significant differences between the rows with P = 0.05, depending on the Multiple Range Test (Duncan, 1955). T1 is a control condition of a regular basal diet that was not supplemented with thyme powder; T2 is the basal diet supplemented with thyme powder 0.5; T3 is the basal diet supplemented with thyme powder 0.75; T4 is the basal diet supplemented with thyme powder 1. TP= total protein; Alb= albumin; Glob= globulin; A/G= albumin/globulin ratio; UA= uric acid; TC= total cholesterol.

**Table 3: Effect of Dietary Thyme (*Thymus vulgaris*) Powder Supplementation on Serum Lipid Profile of Japanese Quail (Means  $\pm$  SE)**

Parameter	T1	T2	T3	T4
LDL (mg/dl)	68.69 $\pm$ 3.87 c	95.51 $\pm$ 4.19 b	75.61 $\pm$ 4.87 cb	94.115 $\pm$ 4.59 a
HDL (mg/dl)	36.68 $\pm$ 2.21 c	39.80 $\pm$ 7.85 b	43.30 $\pm$ 4.57 a	40.51 $\pm$ 2.66 bc
TG (mg/dl)	45.59 $\pm$ 2.60 c	55.89 $\pm$ 4.22 b	61.77 $\pm$ 4.56 a	49.48 $\pm$ 3.70 bc

Mean values are discussed as mean standard error (SE).

Means in each row, identified by separate superscript letters (a, b, c), are considered significantly different at P = 0.05 as shown by Duncan Multiple Range Test (Duncan, 1955).

T 1 refers to the basal diet without thyme powder (control); T 2 refers to the basal diet plus 0.5 per cent thyme powder; T 3 refers to the basal diet plus 0.75 per cent thyme powder; T 4 refers to the basal diet plus 1 per cent thyme powder.

LDL is an abbreviation of low density lipoprotein.

The high-density lipoprotein is known as HDL.

TG denotes triglycerides.

**Table 4: Effect of Dietary Thyme (*Thymus vulgaris*) Powder Supplementation on Liver Enzyme Activity (ALT and AST) in Japanese Quail (Means  $\pm$  SE)**

Parameter	T1	T2	T3	T4
ALT (U/L)	63.66 $\pm$ 2.56	64.31 $\pm$ 2.53	65.05 $\pm$ 2.82	64.82 $\pm$ 2.71
AST (U/L)	360.93 $\pm$ 2.07 ab	369.69 $\pm$ 3.67 a	362.27 $\pm$ 3.88 ab	334.65 $\pm$ 2.76 c

**Note:** The values are represented in terms of means along with the standard errors (SE).

Means that have discrete superscript letters (a, b, c) are significantly different at the 0.05 level of significance as calculated using Multiple Range Test by Duncan (Duncan, 1955).

T1 represents a control diet which comprises of the basal formulation but excludes the presence of thyme powder.

T2 refers to a basal feed that has 0.5% powdered thyme.

T3 refers to the simple diet that contains 0.75 percent of thyme powder.

T4 represents a low-energy diet and added with 1% thyme powder.

The name of alanine aminotransferase is abbreviated as ALT.

AST is an abbreviation of aspartate aminotransferase.

### Discussion

In the current research, the effects of dietary supplementation with the powder of the thyme (*Thymus vulgaris*) on hematological and biochemical variables in Japanese quail were investigated. The findings showed that moderate supplementation especially at 0.75% (T3) had positive effects on various blood measurements without causing negative liver outcomes.

There were notable increases in hemoglobin concentration (Hb), packed cell volume (PCV), and white blood cell (WBC) counts in the thyme-supplemented groups with the most notable increase being in T3. These modifications indicate an improved response of hematopoiesis and immune competence. These positive changes can literally be explained by biologically active substances of thyme, which are predominantly thymol and carvacrol and have strong antioxidant and antimicrobial effects (Burt, 2004). It is stated that antioxidants can alleviate oxidative stress in erythrocyte and provide a positive effect on poultry hematology (Surai, 2014). Similar impacts of thyme supplement on hematological indices have been reported in broilers (Al-Kassie, 2009; Toghyani et al., 2010), which suggests that thyme could increase marrow activity and immunological effectiveness.

The significant percentage of lymphocyte in T3 also highlights the immunomodulatory effect of thyme. The adaptive immunity is characterized by lymphocytes and the increase in the number of lymphocytes signifies a better immune condition. On the other hand, heterophil/lymphocyte (H/L) ratio did not significantly change which showed that heterophil supplementation did not cause physiological stress. H/L ratio is an established measure of poultry stress (Gross & Siessel, 1983), and its consistency is, therefore, a measure of good welfare.

In terms of serum biochemical parameters, no significant changes in the level of total protein, albumin, globulin or uric acid were indeed observed to change due to dietary treatment with thyme indicating that thyme supplementation is not associated with protein metabolism or kidney functioning. The same results were obtained by Toghyani et al. (2010) who have reported no harmful effects on serum protein fractions in thyme-fed broilers.

Moderate supplementation (0.75% cholesterol) statistically decreased total cholesterol levels; this included level gave a more desirable lipid profile than the higher levels of inclusion. The phenolic compounds of thyme are also reported to have hypocholesterolemic effects which might be due to inhibition of the hepatic cholesterol production and increase in the bile acid secretion (Lee et al., 2003). Lipid metabolism and lipid peroxidation as indicated by phytochemical additives in poultry have been researched as well (Botsoglou et al., 2002; Windisch et al., 2008). The significant rise in the high-density lipoprotein (HDL) cholesterol in T3 is believed to be beneficial, because HDL counteracts the reverse cholesterol transportation. Thyme supplementation did not cause significant lipid imbalances although there were changes in the level of low-density lipoprotein (LDL) in relation to various treatments. These results are in concordance to the perception that lower levels of phytochemical additives can be more effective as compared to higher levels (Hashemi and Davoodi, 2011).

The activities of hepatic enzymes (ALT and AST) did not deviate significantly, and there were no significant changes in the treatment. The fact that AST had reduced in T4 indicates that liver integrity was maintained after thyme supplementation. The safety of thyme in the experimented levels is supported by the stability of liver enzyme activity, which is also supported by other past studies to investigate the effects of herbal feed additives on poultry diets (Hashemi and Davoodi,

2011).

Altogether, the data demonstrates that dietary supplementation in the form of thyme powder 0.75 per cent improves hematological indicators, strengthens immune system, and positively changes certain lipid indicators in Japanese quail without affecting the functioning of the liver. Such positive impacts are probably due to the antioxidant, antimicrobial and metabolic regulatory properties of the bioactive compounds in thyme.

### Conclusion

This paper demonstrates high positive results of oral administration of a *Thymus vulgaris* powder dietary supplement on a range of hematological and biochemical parameters in Japanese quail without any adverse effect on hepatic functioning. The inclusion level of 0.75% thyme powder has shown the best results with a significant increase in hemoglobin concentration, packed cell volume, white blood cell count, lymphocyte percentage, and HDL. In addition, thyme supplementation had no effect on total protein or liver enzyme activity, which indicated that the supplement was safe at the administered concentrations. Therefore, it can be recommended to use 0.75 percent thyme powder as a natural feed additive to improve physiological and immune conditions in Japanese quail.

### References

1. Al-Kassie, G. A. M. (2009). Influence of two plant extracts derived from thyme and cinnamon on broiler performance. *Pakistan Veterinary Journal*, 29(4), 169–173.
2. Botsoglou, N. A., Florou-Paneri, P., Christaki, E., Fletouris, D. J., & Spais, A. B. (2002). Effect of dietary oregano essential oil on performance of chickens and on iron-induced lipid oxidation of breast, thigh and abdominal fat tissues. *British Poultry Science*, 43(2), 223–230. <https://doi.org/10.1080/00071660120121436>
3. Bozin, B., Mimica-Dukic, N., Simin, N., & Anackov, G. (2006). Characterization of the volatile composition of essential oils of some Lamiaceae species and the antimicrobial and antioxidant activities of the entire oils. *Journal of Agricultural and Food Chemistry*, 54(5), 1822–1828. <https://doi.org/10.1021/jf051922u>
4. Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods—A review. *International Journal of Food Microbiology*, 94(3), 223–253. <https://doi.org/10.1016/j.ijfoodmicro.2004.03.022>
5. Duncan, D. B. (1955). Multiple range and multiple F tests. *Biometrics*, 11(1), 1–42. <https://doi.org/10.2307/3001478>
6. Franz, C., Baser, K. H. C., & Windisch, W. (2010). Essential oils and aromatic plants in animal feeding—A European perspective. *A review. Flavour and Fragrance Journal*, 25(5), 327–340. <https://doi.org/10.1002/ffj.1967>
7. Greathead, H. (2003). Plants and plant extracts for improving animal productivity. *Proceedings of the Nutrition Society*, 62(2), 279–290. <https://doi.org/10.1079/PNS2002197>
8. Gross, W. B., & Siegel, H. S. (1983). Evaluation of the heterophil/lymphocyte ratio as a measure of stress in chickens. *Avian Diseases*, 27(4), 972–979. <https://doi.org/10.2307/1590198>
9. Hashemi, S. R., & Davoodi, H. (2011). Herbal plants and their derivatives as growth and health promoters in animal nutrition. *Veterinary Research Communications*, 35(3), 169–180. <https://doi.org/10.1007/s11259-010-9458-2>
10. Jamroz, D., Wiliczekiewicz, A., Wartecki, T., Orda, J., & Skorupinska, J. (2006). Use of active substances of plant origin in chicken diets based on maize and locally grown cereals. *British Poultry Science*, 47(4), 485–493. <https://doi.org/10.1080/00071660600873533>

11. Lee, K. W., Everts, H., Kappert, H. J., Yeom, K. H., & Beynen, A. C. (2003). Dietary carvacrol lowers body weight gain but improves feed conversion in female broiler chickens. *Journal of Applied Poultry Research*, 12(4), 394–399. <https://doi.org/10.1093/japr/12.4.394>
12. Mhamad, H. J., & Palani, Z. M. R. . (2025). Pharmacological Active Crocin (Antioxidant) in Saffron: A Review. *Spanish Journal of Innovation and Integrity*, 38, 8–17. Retrieved from <https://sjii.es/index.php/journal/article/view/169>
13. Mhamad, H. J., Palani, Z. M. R., & AL-Zubaidy, A. . (2025). Investigation of the Chemical Compounds, Antioxidant Effect and Therapeutic Properties of *Crocus sativus* L. (Iridaceae): A Review. *Indonesian Journal of Innovation and Applied Sciences (IJIAS)*, 5(1), 89-98. <https://doi.org/10.47540/ijias.v5i1.1829>
14. Minvielle, F. (2004). The future of Japanese quail for research and production. *World's Poultry Science Journal*, 60(4), 500–507. <https://doi.org/10.1079/WPS200433>
15. Mountzouris, K. C., Paraskevas, V., Tsirtsikos, P., Palamidi, I., Steiner, T., Schatzmayr, G., & Fegeros, K. (2011). Assessment of a phytogetic feed additive effect on broiler growth performance, nutrient digestibility and cecal microflora composition. *Animal Feed Science and Technology*, 168(3–4), 223–231. <https://doi.org/10.1016/j.anifeedsci.2011.03.009>
16. Ozek, K., Wellmann, K. T., Ertekin, B., & Tarim, B. (2011). Effects of dietary herbal essential oil mixture and organic acid preparation on laying traits, gastrointestinal tract characteristics, blood parameters and immune response of laying hens. *Journal of Animal and Feed Sciences*, 20(4), 575–586.
17. Palani, P. M. R. and Hussen, A J.(2022). Efficiency evaluation of the economic performance of Bazian cement factory between 2008-2020. *Journal of Garmian University*. 9(2):229–245.
18. Placha, I., Takacova, J., Ryzner, M., Cobanova, K., Laukova, A., Strompfova, V., & Faix, S. (2014). Effect of thyme essential oil and selenium on intestine integrity and antioxidant status of broilers. *British Poultry Science*, 55(1), 105–114. <https://doi.org/10.1080/00071668.2013.873777>
19. SAS Institute. (2004). SAS/STAT® 9.1 user's guide. SAS Institute Inc.
20. Surai, P. F. (2014). Polyphenol compounds in the chicken/animal diet: From the past to the future. *Journal of Animal Physiology and Animal Nutrition*, 98(1), 19–31. <https://doi.org/10.1111/jpn.12070>
21. Toghyani, M., Tohidi, M., Gheisari, A. A., & Tabeidian, S. A. (2010). Performance, immunity, serum biochemical and hematological parameters in broiler chicks fed dietary thyme as alternative for an antibiotic growth promoter. *African Journal of Biotechnology*, 9(40), 6819–6825.
22. Windisch, W., Schedle, K., Plitzner, C., & Kroismayr, A. (2008). Use of phytogetic products as feed additives for swine and poultry. *Journal of Animal Science*, 86(14 Suppl.), E140–E148. <https://doi.org/10.2527/jas.2007-0459>