Crimson Publishers
Wings to the Research

Review Article

Influence of Dietary Turmeric Powder Supplementation on Different Nutritional Parameters in the Poultry Sector

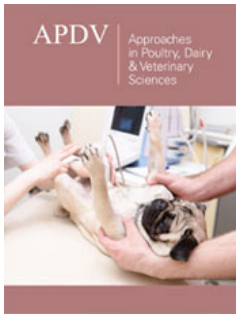
Parveen Kumar Ahlawat[1], Rajesh Dalal[1], Kennady Vijayalakshmy[2]*, Praveen Kumar[3] and Devvrat Kosti[1]

[1]Research Scholar, Department of Animal Nutrition, India

[2]Research Scholar, Department of Animal Physiology, India

[3]Research Scholar, Department of Veterinary Medicine, India

ISSN: 2576-9162



***Corresponding author:** Kennady Vijayalakshmy, Research Scholar, Department of Animal Physiology, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, 125004, Haryana, India

Submission: April 25, 2023
Published: May 12, 2023

Volume 9 - Issue 3

How to cite this article: Parveen Kumar Ahlawat, Rajesh Dalal, Kennady Vijayalakshmy*, Praveen Kumar and Devvrat Kosti. Influence of Dietary Turmeric Powder Supplementation on Different Nutritional Parameters in the Poultry Sector. Appro Poult Dairy & Vet Sci 9(3). APDV. 000714. 2023.
DOI: 10.31031/APDV.2023.09.000714

Abstract

Some feed techniques are being used by poultry farmers to improve production in order to satisfy the rising demand for eggs, but they could also indirectly stress the birds' metabolisms and other systems. Natural plant compounds and extracts, like Turmeric, can be included in the diet to help people overcome these problems. Broilers' feed intake can be improved, and cholesterol levels can be greatly reduced by adding Turmeric, which has several advantageous characteristics, to the diets at levels of 0.75% and 1%. Birds given a high carbohydrate diet and Turmeric powder supplements for 30 days before sexual maturity can produce 20% more eggs. In light of this, this review examines how feeding Turmeric affects feed intake, feed conversion ratio, nutrient digestibility, biochemical parameters, egg production, egg quality, intestinal morphology, gut bacteria, and the genetic expression of toll-like receptors.

Keywords: Biochemical; Egg quality; Gut bacteria; Intestinal morphology; Production

Introduction

In India, the majority of the population of the country is still dependent on agriculture and allied activities. Hence, there is huge scope for the poultry industry to expand in the coming years. Poultry farming has become an organized industry with the introduction of improved breeds, nutritional interventions and scientific management. Antibiotic feed additives are used as growth promoters in antibiotic-resistant poultry feeds to prevent intestinal pathogens. These antibiotics have been banned due to the development of antibiotic-resistant bacteria and the alteration of the natural gut microflora of birds. Turmeric (Curcuma longa Linn), a plant belonging to the Zingiberaceae family, has long been used to colour and flavour food as well as to treat many inflammatory diseases and other illnesses. Turmeric supplementation may be advantageous for the growth, development, and output of poultry. According to Zava [1], Turmeric can alter lipid profiles and cholesterol levels. According to Kohli [2], curcumin, the active ingredient, affects lipid metabolism, inhibits peroxidation, and increases the formation of bile, which is necessary for the emulsification of lipids Seo [3]. Turmeric powder supplementation can enhance liver metabolism and increase the production of vitellogenin. The developing follicles get vitellogenin through the blood, which is then delivered there and deposited on the yolk. Turmeric has a wide spectrum of biological actions including antioxidative, anticarcinogenic, antihepatotoxic, anti-inflammatory and hypocholesterolemic. Various research findings with the use of Turmeric powder as a feed additive have been summarized under the following heads:

Feed intake

Yarru [4] recorded increased feed intake of chicks fed Turmeric powder (0.5%). Al-Kassie [5] fed five levels of a mixture cumin and Turmeric at the rate of 0.00, 0.25, 0.50, 0.75 and

1% and observed significantly higher feed intake for all treatments as compared to the control group. Akbarian [6] recorded that feed intake of male broiler chicks during different weeks was not influenced by Turmeric rhizome powder, black pepper or their interactions. Sadeghi [7] observed that in comparison to the control group, Turmeric fed group resulted in increased average daily feed intake between 7-14 days of age. Rajput [8] observed no significant effect of dietary supplementation of curcumin on feed intake throughout the trial. Abou-Elkhair [9] observed that feed intake of broiler chicks during different weeks was not influenced by black pepper, Turmeric powder, coriander seeds or their combinations. Mondal [10] observed significantly lower feed intake of broilers in treatment receiving 0.5% Turmeric of feed from 1 to 14 days of age as compared to the control. There was no significant difference in feed intake value among different Turmeric fed treatments as compared to the control Al-Mashhadani [11], Qasem [12] recorded no significant increase in daily feed intake with addition of Turmeric powder as compared to the control groups. The broilers receiving 20g/kg of Turmeric powder had significantly lower daily feed intake as compared to the control group. Fallah & Mirzaei [13]. recorded significantly higher feed intake at 42 days of age in broilers receiving different levels of Turmeric + thyme powders as compared to the control group.

Body weight gain

Al-Sultan [14] recorded higher body gain in birds fed diet containing Turmeric at 0.5% level as compared to the control group. Samarasinghe [15] recorded that supplementation of Turmeric (1g/kg), MOS (Mannonoligosaccharide) and virginiamycin increased the weight gain of broilers by 5.3, 3.4 and 6.2% respectively. Durrani [16] observed significantly higher body weight in birds fed diet containing Turmeric at 0.5% of the diet as compared to control and other treatment groups. Yarru [4] recorded that addition of 0.5% Turmeric powder to the diet significantly ($P<0.05$) improved body weight gain of chicks. Al-Kassie [5] fed five levels of a mixture cumin and Turmeric at the rate of 0.00, 0.25, 0.50, 0.75 and 1% and observed significant effects ($P<0.05$) on chicks for all treatments as compared to the control. Akbarian [6] recorded that body weight gain of broilers during different weeks were not influenced by Turmeric rhizome powder, black pepper or their combinations. Sadeghi [7] observed that infusion of cinnamon, thyme and Turmeric alone or its combination did not influence live body weight, average daily gain in comparison to the control group. Rajput [8] recorded non-significant effect on live body weight at starter period (21d), however, during finisher period (42d), live body weight was significantly improved in birds fed diet containing Turmeric at 200mg/kg dietary level as compared to control and other groups [16]. Naderi [17] recorded that addition of 2.5g Turmeric powder per kg feed significantly increased body weight gain during starter (0 to 21d) period as compared to control group. Mondal [10] observed highest body weight gain in broilers receiving Turmeric powder at 0.5% dietary level as compared to the control. Al-Mashhadani [11] observed significantly ($P<0.05$) higher body weight gain in birds supplemented with 0.2 and 0.4% Turmeric powder as compared to the control group. Qasem [12] observed no significant increase in body weight and daily weight gain with addition of Turmeric powder as compared to the control group. The broilers receiving 20g/kg of Turmeric powder resulted in significantly ($P<0.05$) lower body weight and daily weight gain as compared to the control.

Feed Conversion Efficiency

Al-Sultan [14] reported that feed conversion efficiency of birds receiving 0.5% Turmeric in their diets were the best as compared to the control group. Al-Kassie [5] fed five levels of a mixture cumin and Turmeric at the rate of 0.00, 0.25, 0.50, 0.75 and 1% and observed significantly better feed FCR in 0.50, 0.75 and 1% treatment groups as compared to the control group. Akbarian [6] showed no significant effect on FCR by dietary supplementation of Turmeric rhizome powder and its combination with black pepper as compared to the control group. Sadeghi [7] recorded a significantly higher FCR in Turmeric-supplemented birds in comparison to control group during the period of 1-7 days of age. Rajput [8] observed no significant effect on FCR at starter period (21d); however, during finisher period (42d), feed conversion ratio was significantly improved in broilers receiving 200mg/kg Turmeric as compared to control. A significant improvement in FCR was seen on addition of 2.5g/kg Turmeric powder as compared to the control group Naderi [17]. Abou-Elkhair [9] found that dietary inclusion of black pepper, coriander seeds, Turmeric powder and their combinations improved the cumulative feed conversion ratio during the whole period of 5 weeks as compared to the control group. Qasem [12] recorded no significant difference in the FCR between the Turmeric supplemented and control groups. Mondal [10] observed significantly lowest FCR in treatment group (0.5% Turmeric powder) as compared to control and other treatment groups. Fallah and Mirzaei [13]. did not observe significant differences in FCR among control and other Turmeric supplemented groups.

Nutrient Metabolizability

Samarasinghe [15] observed increased energy metabolizability and Net Protein Utilization (NPU) by supplementing virginiamycin, mannonoligosaccharides and Turmeric (1g/kg level). Higher levels (2 and 3g/kg) of Turmeric reduced the NPU and energy metabolizability. Rajput [8] observed improved utilization of fat with dietary supplementation of 200mg curcumin/kg of feed, higher utilization of ME with supplementation of 150mg curcumin/kg of feed.

Carcass Characteristics and Meat Quality

Al-Sultan [14] observed non-significant difference in protein percent of breast and thigh, lower fat percentage (1.0%) in carcasses of birds receiving 1.0% Turmeric and higher bursa and thymus weight in birds receiving diet containing 0.5% Turmeric. Durrani [16] observed non-significant difference in mean weight of liver, heart and gizzard weight in Turmeric fed group as compared to the control. There was reduction in liver weights of chicks fed

Turmeric powder diet as compared to the control group Yarru [4]. Al-Kassie [5] fed five levels of a mixture cumin and Turmeric at the rate of 0.00, 0.25, 0.50, 0.75 and 1% and observed no significant difference between treatments and control group in dressing and edible giblets percentage. Daneshyar [18] observed non-significant differences between the treatments for pH, concentrations of fat, DM and ash of the thigh meat. Furthermore, as compared to the control diet, Turmeric rhizome powder supplementation consumption did not change the pH, fat or ash content but decreased the DM and triglyceride and increased the protein content of thigh meat. Al-Jaleel [19] revealed no significant differences in giblets of Turmeric fed group as compared to the control group. Decrease in dressing percentage, increase in liver weight in control group as compared to the treated group was also recorded. Sadeghi [7] observed significantly ($P<0.05$) decreased weight of ready-to-cook poultry in diet supplemented with thyme, Turmeric and cinnamon.

None of the treatments significantly affected the relative weights of the liver, pancreas, heart, abdominal fat, spleen, cecum and bursa. Abou-Elkhair. Recorded no differences in carcass yield across the groups. Higher values of liver (% body weight) were obtained in birds fed T6 (mixture of 0.5% black pepper, 0.5% coriander seeds and 0.5%Turmeric powder) as compared to the control group. The broilers also had a relatively higher weight of proventriculus as compared to the control group. There was significant decrease in fat content of broiler with supplementation of Turmeric powder in diet Mondal [10]. Among different dietary treatments, amount of abdominal fat was lowest in 0.5% Turmeric powder diet compared to control diet. There was non-significant effect of Turmeric powder on the weight of internal organs (Heart, Liver and Gizzard) of broilers fed experimental rations. The highest dressing yield was found in 0.5% Turmeric powder supplemented diets as compared to the control diet. Al-Mashhadani [11] observed that carcass yield was not influenced by the dietary supplementation of Turmeric. Organ's weight was not statistically influenced by Turmeric supplementation. However, inclusion of Turmeric powder at level of 0.4 % causes a significant increase in gizzard weight as compared to the other treatment groups.

Gut Morphology

Sadeghi [7] observed that thyme and Turmeric significantly ($P<0.05$) increased entire small intestine weight in comparison to the control birds. Turmeric fed group resulted in significantly ($P<0.05$) increased ileum weight. None of the other treatments significantly influenced the relative weights and lengths of the duodenum, jejunum or entire small intestine. Rajput [8] observed significantly higher duodenal villus heights at 21 and 42 days, jejunum villus heights at 21 day and greater ileum villus heights in birds receiving Turmeric supplemented diet in comparison to the control. The duodenal villus width was significantly greater in group supplemented with 200mg Turmeric per kg of feed at 21 d while at 42 d, control and group supplemented with 150mg Turmeric per kg of feed exhibited more width. Furthermore, at 42nd day jejunum villus width was significantly more in Turmeric fed group as compared to the control. The intestinal crypt depth in curcumin supplemented groups was significantly less for all segents of small intestine, as compared to those of control group. Likewise, the duodenum (21 and 42 d), jejunum (21 d) and ileum (21 and 42 d), villus height to crypt depth ratios were higher in curcumin fed groups as compared to the control. They observed a significantly higher villus height of ileum in Turmeric fed group as compared to the control. Turmeric along with bioflavonoid also resulted in significantly higher villus width, crypt depth and surface area of the ileum portion of intestine in Turmeric supplemented group as compared to the control.

Haematology

Al-Sultan [14] observed that the higher levels of Turmeric inclusion (0.5 and 1.0%) increased both erythrocytic and total leukocytic count. Sadeghi [7] showed that none of the herbal infusions (Cinnamon, Thyme, Turmeric and their combination, 5g/L) significantly affected the hematocrit value relative to the control group. Al-Jaleel [19] observed non-significant differences among blood characteristics of broiler (PCV, RBC, Hb, WBC, H/L Ratio) and albumin globulin traits. H/L ratio, level of albumin was significantly lower in Turmeric treated group as compared to the control group. He also observed significantly higher level of globulin in Turmeric supplemented groups as compared to the control group. The Hb concentration in neem fed group (10.5g/dL) was significantly ($P<0.05$) higher when compared to Turmeric fed group (9.85g/dL) Nayaka [20]. Feeding of Neem alone and its combination with Turmeric and Vitamin E increased PCV values significantly as compared to control. The supplementation of Turmeric or Vitamin E alone to basal diet did not change PCV values significantly. Naderi [17] observed significantly increased lymphocytes percentage with Turmeric powder supplementation at the levels of 2.5g/kg and 7.5g/kg of the diet as compared to the control group. The percentage of heterophils was significantly reduced by Turmeric powder at the level of 2.5g/kg of the diet. In addition, supplementation also reduced the ratio of heterophils/lymphocytes as compared with the control group.

Serum Parameters

Daneshyar [18] observed lower plasma triglyceride concentrations and lower total cholesterol concentration in serum of Turmeric fed group as compared to the control. There were no significant differences in plasma LDL concentration between the treatments Furthermore, lower concentrations of plasma triglyceride and higher concentrations of HDL were evident with Turmeric rhizome powder supplementation as compared to the control. Al-Kassie [5] fed five levels of a mixture Cumin and Turmeric @ 0.00, 0.25, 0.50%, 0.75 and 1% and observed a depression in cholesterol level in groups 4 (0.75%) and 5 (1%) as compared to other groups. Akbarian [6] revealed that the Turmeric rhizome powder, black pepper and their combination did not have a significant effect on LDL, HDL and Cholesterol in serum of chicks. Chloride concentration and total electrolytes balance of serum were significantly decreased by Turmeric rhizome powder. Sodium and potassium concentrations of serum were not

influenced by Turmeric rhizome powder, black pepper or their combination. Rajput [8] recorded that the concentrations of plasma cholesterol were significantly reduced in dose dependent manner throughout the trial. Plasma T4 level was significantly higher (44.39nmol/L) in birds receiving Turmeric supplemented diet (200mg/kg) as compared to control; However, concentrations of T3 and TSH were not significantly affected by the supplementation of curcumin throughout the trial. Abou-Elkhair [9] revealed that the concentration of serum albumin, cholesterol and GOT (Glutamate Oxaloacetate Transaminase) were non-significantly different as compared to those of the control group. Serum globulin concentration was significantly higher ($P<0.01$) in T6 (mixture of 0.5 % black pepper, 0.5% coriander seeds and 0.5% Turmeric powder) than the control and other treatment groups. There was no significant difference in the serum cholesterol concentrations among treatments and the control group. Serum concentrations of GPT (Glutamate Pyruvate Transaminase) and ALKP (Alkaline Phosphatase) enzyme activities decreased ($P<0.01$) in T6 (mixture of 0.5 % black pepper, 0.5% coriander seeds and 0.5% Turmeric powder) as compared to control. Hosseini-Vashan [21] observed decreased blood cholesterol in birds fed 8g Turmeric rhizome powder per kg of diet. Concentrations of LDL and triglyceride were not affected by Turmeric rhizome powder. The birds fed Turmeric rhizome powder had significantly higher blood high density lipoproteins as compared to the control. Fallah & Mirzaei [13] recorded highest triglycerides in control group and the lowest triglycerides in Turmeric + thyme fed groups. There were no significant differences in blood glucose, total protein, uric acid and triglycerides concentrations among different treatment groups. There was significant effect on total cholesterol, high density lipoproteins and low-density lipoproteins concentrations in Turmeric fed group as compared to the control group.

Gene Expression

Yarru [4] conducted an experiment on hepatic gene expression and recorded non-significant difference in gene expression among the 4 treatment groups for CAT. Turmeric alone in the diet increased ($P<0.05$) the expression of hepatic SOD and GPx. Turmeric alone in the diet also increased the expression of EH genes ($P<0.05$) and decreased the expression of CYP1A1 genes. There was non-significant difference in gene expression among the 4 treatment groups for IL-2 genes. Turmeric alone in the diet decreased the expression of IL-6.

Immunological Response

Sadeghi [7] observed that the cinnamon and herbal mix infusions significantly improved the immune response to the NDV vaccine in comparison to the control group and those that received only the Turmeric infusion. Naderi [17] recorded that effects of dietary supplementation of Turmeric powder and cinnamon powder on antibody titers to IBD and NDV vaccines were non-significant. However, supplementation of the diet with Turmeric powder at the level of 2.5g/kg of the diet caused a significant increase in anti-IBV titer compared to the control group. Akhavan-Salamat & Ghasemi [22] recorded higher serum secondary total and IgG anti-SRBC titers in Turmeric fed groups as compared to the control. Qasem [12] found highly significant differences in antibody titre between the unvaccinated chickens (negative control) and the vaccinated chickens at 2-, 5- and 6-weeks post vaccination. However, the different level of Turmeric did not have any significant effects on the titers of antibodies specific for NDV compared with positive controls. The antibody titer showed significant differences between the positive control and other dietary groups at 3rd and 4th weeks except in group that received 20g/kg Turmeric for which the positive control was lower than for other treatments groups. Highly significant differences in antibody titer to IBV were observed between all groups treated with Turmeric powder and negative control groups at 3, 4, 5 and 6 weeks. The antibody titer to IBDV was not significantly different between treated and positive control group on 4th and 5th weeks. At 6th week, groups fed 14 and 16g/kg Turmeric had high antibody titer than positive control and other treated groups. However highly significant differences were observed between all groups and negative control at 4, 5, and 6 weeks. Hosseini-Vashan [21] observed that the titer of antibody production against ND was not affected by the type of oil or Turmeric rhizome powder concentration in the either before or after heat stress. Fallah & Mirzaei [13] recorded that the highest anti body Newcastle titres at 18 and 28 days were observed in chicks receiving Turmeric + thyme powders in diet and the lowest values were observed in control group. However, there was non-significant difference in anti-body Newcastle titres between control and other groups at 18 and 28 days. Birds receiving Turmeric + thyme powders had the highest anti body influenza titres at 18 and 28 days compared to the other groups, and the lowest anti body Influenza titres was observed in control group.

Conclusion

According to the current review, Turmeric may improve the immunological profile and gut morphology of chicken, among other production characteristics. The Haematological and Biochemical profile of the fowl may exhibit increased diversity as a result of supplementation, enhancing the nutritious value of goods like eggs for customers. In order to standardise the use of Turmeric in the diets and enable more accurate results, more specific information regarding the source, form, and dose level of Turmeric in feed is required. However, the data are very diverse in terms of responses in poultry.

References

1. Zava DT, Dollbaum CM, Blen M (1998) Estrogen and progestin bioactivity of foods, herbs, and spices. Experimental Biology and Medicine 217(3): 369-378.
2. Kohli K, Ali J, Ansari MJ, Raheman Z (2005) Curcumin: A natural anti-inflammatory agent. Indian Journal of Pharmacology 37(3): 141-147.
3. SeoKI, Choi MS, Jung, Kim HJ, Yeo J, et al. (2008) Effect of curcumin supplementation on blood glucose, plasma insulin, and Glucose Homeostasis related enzyme activities in diabetic dbdb mice. Mol Nutr Food Res 52(9): 995-1004.
4. Yarru LP, Settivari RS, Gowda NKS, Antoniou E, Ledoux DR, et al. (2009) Effects of turmeric (*Curcuma longa*) on the expression of hepatic genes

associated with biotransformation, Antioxidant, and immune systems in broiler chicks fed aflatoxin. Poult Sci 88(12): 2620-2627.

5. Al-Kassie GAM, Mohseen AM, Abdajaleel RA (2019) Modification of productive performance and physiological aspects of broilers on the addition of a mixture of cumin and turmeric to the diet. Research Opinions in Animal and Veterinary Sciences 1: 31-34.
6. Akbarian A, Golian A, Kermanshahi H, Gilani A, Moradi S (2012) Influence of turmeric rhizome and black pepper on blood constituents and performance of broiler chickens. Afr J Biotech 11(34): 8606-8611.
7. Sadeghi GH, Karimi A, Jahromi PSH, Azizi T, Daneshmand A (2012) Effects of cinnamon, thyme and turmeric infusions on the performance and immune response in of 1- to 21-day-old male broilers. Brazilian J Poult Sci 14(1): 15-20.
8. Rajput N, Muhammad N, Yan R, Zhong X, Wang T (2013) Effect of Dietary Supplementation of Curcumin on Growth Performance, Intestinal Morphology and Nutrients Utilization of Broiler Chicks. J Poult Sci 50(1): 44-52.
9. Abou ER, Ahmed HA, Selim S (2014) Effects of black pepper (*Piper Nigrum*), turmeric powder (*Curcuma Longa*) and coriander seeds (*Coriandrum Sativum*) and their combinations as feed additives on growth performance, carcass traits, some blood parameters and humoral immune response of broiler chickens. Asian Aust J Anim Sci 27(6): 847-854.
10. Mondal MA, Yeasmin T, Karim R, Siddiqui MN, Nabi SMR, et al. (2015) Effect of dietary supplementation of turmeric (C*urcuma longa*) powder on the growth performance and carcass traits of broiler chicks SAARC J Agri 13(1): 188-199.
11. Mashhadani HEA (2015) Effect of different levels of turmeric (*Curcuma longa*) supplementation on broiler performance, carcass characteristic and bacterial count. Journal of Veterinary Sciences 8(2): 12-19.
12. Qasem MAA, Alhajj MS, Ger Nabi AR, Al Mufaaraj SI (2015) Effect of turmeric powder as a dietary supplement on performance indicators and immune response in broiler chickens. J An Veter Advance 14(2): 30-35.
13. Fallah R, Mirzaei E (2016) Effect of dietary inclusion of turmeric and thyme powders on performance, blood parameters and immune system of broiler chickens. J Livestock Sci 7: 180-186.
14. Al-Sultan SI (2003) The effect of *Curcuma longa* (Turmeric) on overall performance of broiler chickens. Int J Poult Sci 2(5): 351-353.
15. Samarasinghe K, Wenk C, Silva K, Gunasekera JMDM (2003) Turmeric (*Curcuma longa*) root powder and mannanoligosaccharides as alternatives to antibiotics in broiler chicken diets. Asian-Aust J Anim Sci 16(10): 1495-1500.
16. Durrani FR, Ismail M, Sultan A, Suhail SM, Chand N, et al. (2006) Effect of different levels of feed added turmeric (*Curcuma longa*) on the performance of broiler chicks. J Agril Biol Sci 1(2): 9-11.
17. Naderi M, Akbari MR, Asadi KE, Khaksar K, Khajali F (2014) Effects of dietary inclusion of turmeric (*Curcuma longa*) and cinnamon (*Cinnamomumverum*) powders on performance, organs relative weight and some immune system parameters in broiler chickens. Poult Sci J 2(2): 153-163.
18. Daneshyar M, Ghandkanlo M, Bayeghra FS, Farhangpajhoh F, Aghaei M (2011) Effects of dietary turmeric supplementation on plasma lipoproteins, meat quality and fatty acid composition in broilers. South African J Ani Sci 41(4): 421-428.
19. Al-Jaleel RA (2012) Use of turmeric (*Curcuma longa*) on the performance and some physiological traits on the broiler diets. The Iraqi J Vet Medicine 36(1): 51-57.
20. Nayaka HBS, Umakantha B, Ruban SW, Murthy HNN, Narayanaswamy HD (2013) Performance and hematological parameters of Broilers Fed Neem, Turmeric, Vitamin E and their combinations. Emir J Food Agric 25(6): 483-488.
21. Vashan HSJ, Golian A, Yaghobfar A (2015) Effects of turmeric rhizome powder and source of oil metabolites, immune system and antioxidant status in heat stressed broiler chicken. J Livestock Sci Technol 3(2): 13-20.
22. Salamat HA, Ghasemi HA (2016) Alleviation of chronic heat stress in broilers by dietary supplementation of betaine and turmeric rhizome powder: dynamics of performance, leukocyte profile, humoral immunity, and antioxidant status. Trop Anim Health Prod 48(1): 181-188.