International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM October 2022, 13(10):1040-1046 Print ISSN 0976-3988 Online ISSN 0976-4038 **Article** AR3198

Research Article *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2022.3198

Effect of Dietary Inclusion of Turmeric (*Curcuma longa*) and Garlic (*Allium Sativum*) Powders as Feed Additives on Growth Performance and Cell Mediate Immune Response of Broiler Chicken

Sonali Choudhary[1], Nazam Khan[2], R. K. Sharma[1], Jasvinder Singh Sasan[3] and Vikas Mahajan[2]

[1]Division of Animal Nutrition, [2]Division of ILFC, [3]Division of Veterinary Anatomy, F.V.Sc. & A.H., SKUAST-J, R.S. Pura, Jammu and Kashmir (181 102), India

Open Access

Corresponding jssasan216@gmail.com

0000-0002-7175-477X

ABSTRACT

The study was conducted during 2019 at the Faculty of Veterinary Sciences & Animal Husbandry, Sher-e-Kashmir University of Agricultural Sciences & Technology-Jammu, India to investigate the effect of dietary inclusion of garlic, turmeric and their combinations on performance of broilers (Cobb strain). 240-day old unsexed broiler chicks were procured, weighed and randomly divided into 5 dietary treatments (n=48): antibiotic (C), 1% turmeric (T_1), 1% garlic (T_2), 0.6% turmeric±0.4% garlic (T_3), 0.6% garlic±0.4% turmeric (T_4) replicated 4times (12 birds / replicate). The diets formulated were isocaloric and isonitrogenous. Experimental trial lasted for 42 days. Feed consumption of broilers on weekly basis showed non-significant variation during first two weeks, but at 3rd week, feed intake was higher (p<0.05) in antibiotic growth promoter supplemented group than garlic supplemented groups. Weekly body weight and body weight gain during the entire trial did not differ except at week 1. Average weekly FCR was similar (P>0.05) throughout the experimental trial of different dietary treatments, but was numerically better in garlic fed group. Weekly PER showed no difference. Average CMI response of broiler birds was statistically higher (p<0.05) in T_1 than T_4 with intermediate values in C, T_2 and T_3 at 24 hours, indicating that turmeric has immunomodulatory properties. But, at 48 and 72 hours, there was no difference found in CMI response. The mean values of cell mediated immune response showed no significant difference. It was concluded that turmeric and garlic powder supplementation (@ 1%) either alone or in combination may substitute antibiotics without any adverse effect.

KEYWORDS: Broilers, garlic, turmeric, antibiotics, chicken, feed additives, chicken

***Citation* (VANCOUVER):** Choudhary et al., Effect of Dietary Inclusion of Turmeric (*Curcuma longa*) and Garlic (*Allium Sativum*) Powders as Feed Additives on Growth Performance and Cell Mediate Immune Response of Broiler Chicken. *International Journal of Bio-resource and Stress Management*, 2022; 13(10), 1040-1046. HTTPS://DOI.ORG/10.23910/1.2022.3198.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 26th July 2022 RECEIVED in revised form on 16th September ACCEPTED in final form on 07th October 2022 PUBLISHED on 18th October 2022

1. INTRODUCTION

Among agricultural sector, poultry leads the race as fastest growing and most organized segment and contributes around Rs. 1.30 lakh crore directly to the GDP of India, despite providing direct and indirect employment. There is 16.81% increase in poultry population in 20th livestock census (2017) (851.81 million numbers) in comparison with 19th livestock census (2012) (729.2 million numbers) and is further expected to grow. Poultry meat is an important source of animal protein for both rural and urban population and owing to their relatively low fat and cholesterol content than other meat, it is considered as a healthy animal food (Jung et al., 2011).

Chemical feed additives like antibiotic growth promoters (ABGP) have been intensively used in broiler ration to improve productivity because it stimulates growth of favorable micro-organisms in the gastro-intestinal tract (Paul et al., 2022) and suppress the growth of micro-organisms which compete for critical nutrients apart from improving nutrient absorption as well as elimination of any sub-clinical disease. The poultry industry successfully uses antibiotics at sub therapeutic doses to improve meat production through increased feed conversion, growth rate promotion and disease prevention (Chattopadhyay, 2014). But, they are notorious for bacterial resistance, drug residues in meat and their negative impacts on consumer's health. Resistant bacteria in poultry have been characterized and both horizontal transmission and vertical transmission of some of them, especially *Escherichia coli*, from breeder flocks to poultry houses are well documented (Dierikx et al., 2013; Kemmett et al., 2013). Antibiotics can be used successfully at sub therapeutic doses in poultry production to promote growth (Engberg et al., 2000; Emami et al., 2013).

As the economy progresses and the purchasing power of the consumer increases there is more and more demand for safe poultry products. In order to meet the high demands, production must be increased but owing to the drawbacks of using antibiotics, there is need to look for alternative feed additives. A range of phytogenic feed additives have been tested for their effect on performance of broilers but none of them can cover all functions of antibiotics. In the absence of an ideal replacement candidate, outright ban on ABGP may lead to huge loss to poultry industry. So, the focus is to search for suitable phytogenic feed additive, which can replace ABGP on functional basis and more so. The phytogenic feed additives stimulate appetite, enhance feed intake, improves endogenous enzyme secretion, activates immune response and has antibacterial, antiviral and antioxidant actions (Toghyani et al., 2011). Some herbs that are commonly known for their beneficial effects as condiment of human food has also been evaluated as additives in poultry feed.

Curcuma longa (Turmeric) and *Allium sativum* (garlic) are two such commonly available herbs that have been shown to have beneficial effects on growth rate and feed conversion efficiency in broilers (Rajput et al., 2012). The active ingredients of turmeric are curcumin, demethoxycurcumin, bisdemethoxycurcumin and tetrahydrocurcumin (Huang et al., 1995) and has antioxidant, antibacterial, antiviral, antiprotozoal, antifungal, anti-inflamatory, anti-carcinogenic, anti-hypertensive and hypo-cholesteremic activities (Chen and Huang, 2009). It has been reported that supplementation of turmeric up to 1% positively affected the performance of broiler chickens (Durrani et al., 2006; Kumari et al., 2007; Rajput et al., 2012; Swathi et al., 2012; Al-Mashhadani, 2014; Naderi et al., 2014; Sethy et al., 2016; Singh et al., 2018). Garlic has been reported to possess pharmacologically active principles viz. allicin, alliin, ajoene, diallyl sulphide, dithiin, s-allylcysteine that extend antibacterial, anti-inflammatory, antiseptic, anti-parasitic and immunomodulatory role, thereby making it important in poultry nutrition. Its use in poultry diet up to 1% level improves body weight gain and augments the meat quality parameters (Puvaca et al., 2013). Garlic supplementation at 1% resulted in improved growth and performance of the broilers (Chowdhary et al., 2021). As garlic and turmeric possess different active principles, their combination may potentiate the effect of each other. Therefore, present study was undertaken to ascertain the effect of turmeric and garlic powders supplementation either alone or in combinations as feed additives on growth performance of broiler chicken.

2. MATERIALS AND METHODS

The present study was carried out during 2019 house at experimental site, Faculty of Veterinary Sciences & Animal Husbandry, Sher-e-Kashmir University of Agricultural Sciences & Technology-Jammu, India. 240 one-day old, unsexed broiler chicks were purchased and randomly distributed into five dietary treatments of 48 birds each and brooded on partitioned deep litter. Each group was sub-divided into 4 replicates of 12 birds per replicate in a complete randomized block design. Five isocaloric and isonitrogenous maize-soya based diets were formulated as per ICAR (2013) and supplemented with antibiotics, turmeric powder and garlic powder: Control (C) containing basal diet (Levofloxacin @ 2.5 g l^{-1} drinking water), T_1 comprising basal diet and turmeric powder (1% of basal diet), T_2 containing basal diet and garlic powder (1% of basal diet), T_3 containing basal diet along with turmeric powder (0.6%) and garlic powder (0.4%) and T_4 containing basal diet and turmeric powder (0.4%) and garlic powder (0.6%). The basal diet (pre-starter, starter and finisher) was same for all the chicks but additionally antibiotics, turmeric and garlic

powder was supplemented. The ingredient composition of broiler pre-starter, starter and finisher chicks is presented in Table 1 and chemical composition of feed ingredients and feed additive is depicted in Table 2. The trial lasted for 42 days. Each bird had an average floor space of 1.3 square feet. A 24 hours photoperiod was maintained by using electric bulbs. The day-old chicks were already pre-vaccinated against Marek's disease whereas on 6th day, all chicks were vaccinated against Ranikhet disease using F1 strain vaccine through intra-occular route. On 12th day, IBD vaccination was done whereas on 24th day, a repeat vaccination against Ranikhet disease was done by using Lasota strain (through drinking water). The birds were weighed at the start of the experiment and weekly thereafter and average daily feed intake was also calculated. The feed conversion ratio was calculated by dividing the feed consumed by the live weight gain for a particular period. The protein efficiency ratio was calculated by the formula as body weight gain (g)/protein intake (g) for a particular period. The feed samples were analyzed for proximate analysis as per Anonymous (2010).

At 4 weeks of age, cell mediated immune status was also assessed on eight birds per treatment by measuring foot pad thickness generated through in vivo cutaneous delayed type hypersensitivity (DTH) reaction against phytohaemagglutinin-P (PHA-P) (Smits et al., 1999). Statistical analysis was done as per Snedecor and Cochran (1994). The means in different treatments were subjected to Duncan's multiple range test (Duncan 1955) for ranking mean values of different parameters (p<0.05).

Table 1: Ingredient composition (%) of basal diet

Attributes	Experimental Diets		
	Pre-starter	Starter	Finisher
Maize	60.5	60.88	67.5
Meat bone meal	5	5	5
Soya bean meal	31.08	30.36	24.5
Salt	0.25	0.25	0.25
Sodium bicarbonate	0.01	0.01	0.01
Soya bean oil	2	2.6	2.2
DL-Methionine	0.17	0.13	0.09
Lysine	0.12	0	0
DCP	0.13	0	0
LSP	0.59	0.54	0.29
Vitamin supplement	0.05	0.05	0.05
Trace minerals	0.1	0.1	0.1

3. RESULTS AND DISCUSSION

The data on feed consumption of broilers on weekly basis showed non significantvariation during first two weeks, but at 3rd week, feed intake was higher (p<0.05) in group C than group T_2 and T_4 whereas T_1 and T_3 showed intermediate values (Table 3).

But at 5th week,T_1 and T_3 had significantly higher feed intake than T_2, whereas feed intake of C and T_4 were intermediate. Similarly at 6th week, T_3 had higher (p<0.05) feed intake than C but the values of T_1, T_2 and T_4 lies in between. It may be inferred that turmeric supplementation (either alone or in combination) enhanced the feed intake than garlic supplemented groups. This may be explained in the light of fact that turmeric possesses appetite stimulant, stomachic and carminative properties, which might be responsible for improved feed intake (Chakraborty et al., 2011). Similar results were reported by earlier researchers on supplementing turmeric in graded levels or in combination with garlic (Karangiya et al., 2016). However, some researchers showed improved feed intake on garlic supplementation (Patel et al., 2014). These differences might be due to the fact that in the present study control group represents ABGP fed group, whereas majority of researchers have compared garlic supplementation with basal diet only.

The average body weight (g; BW) and body weight gain (g; BWG) of entire growth trial in C, T_1, T_2, T_3 and T_4 groups is presented in Table 4 and 5, respectively. The weekly BW and BWG during the entire trial did not differ except at week 1, where they were found higher (p<0.05) in T_2 than T_1, T_3 and T_4, but ABGP fed group has intermediate BW and BWG. The above results signified that garlic either alone or in combination with turmeric improves BWG, which may be attributed to active principle allicin (present in

Table 2: Proximate composition of feed ingredients and additives (on DMB)

Particulars	CP	EE	CF	TA	NFE	Ca	P	Calculated ME (kcal/kg)
Maize	9.15	4.01	2.11	1.51	83.22	0.26	0.33	3340
Soybean Meal	45.5	5.4	7.58	8.09	33.43	0.4	0.91	2300
Meat Bone Meal	47.79	7.71	9.05	21.41	14.04	10.77	5.18	2100
Turmeric Powder	9.14	5.59	4.32	3.82	77.13	-	-	-
Garlic Powder	18.48	0.57	3.22	4.74	72.99	-	-	-

Table 3: Effect of supplementation of turmeric and garlic powder on weekly feed intake (g) of broiler chicken

Particulars	Groups				
	C	T_1	T_2	T_3	T_4
Week 1	108.05± 4.72	100.65±6.37	98.21±7.37	96.49±7.80	91.33±6.25
Week 2	262.33± 10.80	268.65±15.66	262.92±10.96	281.01±18.75	247.81±19.76
Week 3	684.25^{b}±14.48	656.09^{ab} ±16.57	611.42^{a}±17.54	641.30^{ab}±13.61	622.31^{a}±17.54
Week 4	823.63±15.06	824.92±18.25	828.96±22.11	821.26±28.18	845.78±23.96
Week 5	1367.12^{ab}±27.86	1446.57^{b}±23.23	1288.44^{a}±29.52	1394.97^{b}±35.40	1351.74^{ab}±37.35
Week 6	1201.87^{a}±38.96	1310.95^{ab}±38.55	1320.21^{ab}±38.54	1439.61^{b}±65.00	1327.78^{ab}±33.34

^{ab}Mean with different superscript within a row differ significantly ($p<0.05$)

Table 4: Effect of supplementation of turmeric and garlic powder on body weight (g) of broiler chicken

Particulars	Groups				
	C	T_1	T_2	T_3	T_4
Week 0	40.35±0.29	39.41±0.56	39.37±0.55	39.42±0.45	39.20±0.15
Week 1	126.65^{ab}±1.96	122.12^{a}±3.04	135.17^{b}±5.63	120.15^{a}±4.11	119.97^{a}±3.37
Week 2	326.70±7.74	325.82±7.54	330.12±11.43	317.67±11.64	318.21±6.49
Week 3	750.91±16.45	754.51±16.89	773.80±21.33	740.47±15.12	736.75±21.68
Week 4	1175.17±30.28	1189.91±27.07	1193.42±22.40	1163.65±26.28	1210.32±31.13
Week 5	1798.72±44.11	1873.57±34.93	1834.47±35.30	1821.39±28.05	1855.45±24.78
Week 6	2257.4±32.99	2236.65±44.48	2391.22±72.31	2401.65±46.04	2346.22±46.34

^{ab}Mean with different superscript within a row differ significantly ($p<0.05$)

Table 5: Effect of supplementation of turmeric and garlic powder on body weight gain (g) of broiler chicken

Particulars	Groups				
	C	T_1	T_2	T_3	T_4
Week 1	86.3^{ab}±2.16	82.72^{a}±2.56	95.81^{b}±5.69	80.72^{a}±3.83	79.56^{a}±2.17
Week 2	200.05±5.83	203.72±4.75	194.95±8.17	197.52±14.25	192.79±13.14
Week 3	424.21±9.98	428.67±11.62	443.67±10.23	422.84±3.61	428.92±7.51
Week 4	424.27±31.73	435.41±14.95	419.62±9.19	423.17±28.46	474.12±23.53
Week 5	623.55±38.1	683.67±12.39	641.05±17.68	657.75±20.33	630.65±23.40
Week 6	458.67±34.02	474.75±37.12	556.75±41.24	580.25±57.48	545.12±49.83

^{ab}Mean with different superscript within a row differ significantly ($p<0.05$)

garlic). Allicin is responsible for promoting useful intestinal flora. These results are in line with the findings of earlier researchers who reported that garlic resulted in higher body weight and BWG in broilers (Karangiya et al., 2016).

The higher body weight gain and better utilization of feed may be the probable reason for better FCR in garlic supplemented groups. It can be inferred that turmeric, garlic either alone or in combinations may substitute ABGP as evident from the FCR. The present results corroborate with the findings of Patel et al. (2014) and Ratika et al. (2016) who too found improved FCR on garlic supplementation. Similarly, Singh et al. (2018) reported comparable FCR in 1% turmeric and ABGP fed groups in broilers. Weekly PER also showed no difference among different treatments (Table 7). The information on this aspect is scanty, so the results cannot be discussed due to lack of literature.

Cellular integrity is very important for receiving and responding to messages, needed to coordinate an immune response (Latshaw, 1991). The average CMI response of broiler birds was statistically higher ($p<0.05$) in T_1 than T_4 with intermediate values in C, T_2 and T_3 at 24 h, indicating that turmeric has immunomodulatory properties (Table

Table 6: Effect of supplementation of turmeric and garlic powder on feed conversion ratio of broiler chicken

Particulars	Groups				
	C	T_1	T_2	T_3	T_4
Week 1	1.26±0.08	1.22±0.09	1.03±0.08	1.20±0.09	1.14±0.10
Week 2	1.32±0.07	1.32±0.08	1.35±0.10	1.44±0.14	1.27±0.15
Week 3	1.61±0.05	1.53±0.08	1.38±0.07	1.51±0.04	1.53±0.13
Week 4	1.98±0.17	1.90±0.08	1.98±0.07	1.98±0.21	1.79±0.06
Week 5	2.22±0.14	2.11±0.04	2.01±0.09	2.13±0.10	2.09±0.04
Week 6	2.65±0.15	2.77±0.11	2.40±0.17	2.56±0.08	2.73±0.11

Table 7: Effect of supplementation of turmeric and garlic powder on protein efficiency ratio of broiler chicken

Particulars	Groups				
	C	T_1	T_2	T_3	T_4
Week 1	3.66±0.22	3.78±0.28	4.48±0.34	3.85±0.30	4.09±0.38
Week 2	3.49±0.19	3.48±0.20	3.39±0.24	3.23±0.29	3.73±0.43
Week 3	2.88±0.11	3.05±0.14	3.39±0.17	3.07±0.07	3.16±0.24
Week 4	2.39±0.18	2.45±0.10	2.36±0.09	2.42±0.24	2.60±0.08
Week 5	2.34±0.14	2.42±0.04	2.56±0.12	2.42±0.12	2.45±0.05
Week 6	1.95±0.13	1.86±0.07	2.16±0.14	2.06±0.17	1.89±0.09

Table 8: Effect of supplementation of turmeric and garlic powders on cell mediated immune response (CMI) of broiler chicken

Groups	Periods (hours)				Mean±SE
	0	24	48	72	
C	100	119.68^{ab}±3.76	140.57±8.03	132.50±6.86	123.19±4.68
T_1	100	138.15^{b}±4.96	155.60±4.36	141.24±3.79	133.75±5.58
T_2	100	133.94^{ab}±9.36	154.90±5.20	142.30±4.83	132.79±5.87
T_3	100	132.74^{ab}±3.61	154.61±2.60	134.35±5.20	130.42±5.28
T_4	100	117.12^{a}±4.84	145.55±3.92	133.32±4.88	124.00±4.74

^{ab}Mean with different superscript within a column differ significantly ($p<0.05$)

8). But, at 48 and 72 h, there was no difference found in CMI response. Likewise, the mean values of CMI response showed no significant difference. Similarly, Kumari et al., (2007) recorded significant high antibody titres in broiler chicks fed with TP at the level of 1 g kg^{-1}. However, some researchers found better immune response on GP supplementation (Rahimi et al., 2011). But these authors have checked antibiotic titre and /or lymphocytes and immunoglobulin G. The literature pertaining to effect of GP and/or TP supplementation on cell mediated immunity is not available to the best of our knowledge, so results cannot be discussed.

4. CONCLUSION

Turmeric and garlic powder supplementation (@ 1% as dietary additive) either alone or in combinations was found a viable alternative to ABGP in the feeding of broiler chicken as evident by performance parameters.

5. REFERENCES

Al-Mashhadani, H.E., 2014. Effect of different levels of turmeric supplementation (*Curcuma longa*) on broiler performance, carcass characteristics and bacterial count. Egyptian Poultry Science Journal 35(1), 25–39.

Anonymous, 2012. 19th Livestock Census-All India Report. Ministry of Agriculture, Department ofAnimal Husbandry, Dairying and Fisheries. Krishi Bhawan, New Delhi. Available from https://dahd.nic.in/sites/default/filess/Livestock%20%205_0.pdf.Accessed on 10th August, 2022

Anonymous, 2010. Official Method of Analysis. (18th Edn.) Association of Official Analytical Chemist

International (AOAC), Washington, DC. Available from http://sutlib2.sut.ac.th/sut_contents/H125800.pdf. Accessed on 10th August, 2022

Anonymous, 2013. Nutrient Requirement of Animals-Poultry (ICAR-NIANP), Indian Council of Agricultural Research, New Delhi. Available from http://nianp.res.in/static/docs/AR_2013-14.pdf. Accessed on 10th August, 2022.

Anonymous, 2017. 20th Livestock Census-All India Report. Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries. Krishi Bhawan, New Delhi. Available fromhttps://dahd.nic.in/documents/statistics/livestock-census. Accessed on 10th August, 2022.

Chattopadhyay, M.K., 2014. Use of antibiotics as feed additives: a burning question. Frontiers in Microbiology 5, 334.

Chen, H.W., Huang, H.C., 2009 Effect of curcumin on cell cycle progression and apoptosis in vascular smooth muscle cells. British Journal of Pharmacology 124(6), 1029–1040.

Chowdhary, S., Khan, N., Sharma, R.K., Sasan, J.S., Mahajan, V. 2021. Effect of Dietary Inclusion of Turmeric (*Curcuma longa*) and Garlic(*Allium sativum*) Powders as Feed additives on Performance of Broiler Chicken. Indian Journal of Animal Nutrition 38(1): 92–99.

Dierikx, C.M., Van-der-Goot, J.A., Smith, H.E., 2013. Presence of ESBL/AmpC-producing *Eschcerichia coli* in the broiler production pyramid: A descriptive study. PLoS ONE 8(11), e79005.

Duncan, D.B., 1955. New multiple range and multiple test. Biometrics 11, 1–42.

Durrani, F.R., Ismail, M., Sultan, A., Suhail, S.M., Chandand, N., Durrani, Z., 2006. Effect of different levels of feed added turmeric (*Curcuma longa*) on the performance of broiler chicks. Journal of Agriculture and Biological Sciences 1, 9–11.

Emami, N.K., Naeini, S.Z., Ruiz-Feria, C.A. 2013. Growth performance, digestibility, immune response and intestinal morphology of male broilers fed phosphorus deficient diets supplemented with microbial phytase and organic acids. Livestock Science 157(2–3), 506–513.

Engberg, R.M., Hedemann, M.S., Leser, T.D., Jensen, B.B., 2000. Effect of zinc bacitracin and salinomycin on intestinal microflora and performance of broilers. Poultry Science 79(9), 1311–1319.

Huang, M.T., Ma, W., Lu, Y.P., Chang, R.L., Fisher, C., Manchand, P.S., Newmark, H.L., Conney, A.H., You, M., 1995. Effects of curcumin, demethoxycurcumin, bisdemethoxy curcumin and tetrahydrocurcumin on 12O- tetradecanoylphorbol-13-acetateinduced tumor promotion. Carcinogenesis16(10), 2493–2497.

Jung, Y.K., Jeon, H.J., Jung, S., Choe, J.H., Lee, J.H., Heo, K.N., Kang, B.S., Jo, C.R., 2011. Comparison of quality traits of thigh meat from Korean native chickens and broilers. Korean Journal for Food Science of Animal Resources 31(5), 684–692.

Karangiya, V.K., Savsani, H.H., Patil, S.S., Garg, D.D., Murthy, K.S., Ribadiya, N.K., Vekariya, S.J., 2016. Effect of dietary supplementation of garlic, ginger and their combination on feed intake, growth performance and economics in commercial broilers. Veterinary World 9(3), 245–250.

Kemmett, K., Humphrey, T., Rushton, S., Close, A., Wigley, P., Williams, N.J., 2013. A longitudinal study simultaneously exploring the carriage of APEC virulence associated genes and the molecular epidemiology of faecal and systemic *E. coli* in commercial broiler chickens. PLOS One, 8(6), e67749. https://doi.org/10.1371/ journal.pone.0067749.

Kumari, P., Gupta, M.K., Ranjan, R.K., Singh, K.K., Yadava, R., 2007. *Curcuma longa* as feed additive in broiler birds and its pathophysiological effects. Indian Journal of Experimental Biology 45(3), 272–277.

Latshaw, J.D., 1991. Nutrition-mechanism of immunosupression. Veterinary Immunology and Immunopathology 30(1), 111–120.

Naderi, M., Akbari, M.R., Asadi-Khoshoei, E., Khaksar, K., Khajali, F., 2014. Effects of dietary inclusion of turmeric (*Curcuma longa*) and cinnamon (*Cinnamomum verum*) powders on performance, organs relative weight and some immune system parameters in broiler chickens. Poultry Science Journal 2(2), 153–163.

Patel, R.M., Garg, D.D., Patel, V.R., Vahora, S.G., Katariya, M.A., Choubey, M., 2014. Effect of dietary supplementation of garlic (*Allium sativum*) and fenugreek (*Trigonella foenum-graecum* L.) seed powder on growth performance and blood biochemical parameters in broilers. Indian Journal of Poultry Science 49(1), 17–20.

Paul, S.S., Rao, S.V.R., Hegde, N., Williams, N.J., Chatterjee, R.N., Raju, M.V.L.N., Reddy, G.N., Kumar, V., Kumar, P.S.P., Mallick, S., Gargi, M., 2022. Effects of dietary antimicrobial growth promoters on performance parameters and abundance and diversity of broiler chicken gut microbiome and selection of antibiotic resistance genes. Frontiers in Microbiology 13, 1–19.

Puvaca, N., Stanacev, V., Glamocic, D., Levic, J., Peric, L., Stanacev, V., Milic, D., 2013. Beneficial effects of phytoadditives in broiler nutrition. World's Poultry

Science Journal 69(1), 27–34.

Rahimi, S., Teymouri, Z.Z., Karimi, T.M., Omidbaigi, R., Rokni, H., 2011. Effect of the three herbal extracts on growth performance, immune system, blood factors and intestinal selected bacterial population in broiler chickens. Journal of Agriculture, Science and Technology 13, 527–539.

Rajput, N., Muhammad, N., Yan, R., Zhong, X., Wang, T., 2012. Effect of dietary supplementation of curcumin on growth performance, intestinal morphology and nutrients utilization of broiler chicks. Journal of Poultry Science 50(1), 44–52.

Ratika, K., Tiwari, D.P., Mondal, B.C., 2016. Effect of dietary incorporation of garlic (*Allium sativum*) and turmeric (*Curcuma longa*) powder and their combination on feed intake, haemato-biochemical parameters and carcass traits in broiler chicken. Indian Journal of Animal Nutrition 33(2), 184–190.

Sethy, K., Swain, P., Behera, K., Nayak, S.M., Barik, S.R., Patro, P., Meher, P., 2016. Effect of turmeric (*Curcuma longa*) supplementation on growth and blood chemistry of broilers. Exploratory Animal and Medical Research 6(1), 75–79.

Singh, P.K., Kumar, A., Tiwari, D.P., Kumar, A., Palod, J., 2018. Effect of graded levels of dietary turmeric (*Curcuma longa)* powder on performance of broiler chicken. Indian Journal of Animal Nutrition 35(4), 428–435.

Smits, J.E., Bortolotti, G.R., Tella, J.L., 1999. Simplifying the phytohemagglutinin skin testing technique in studies of avian immunocompetance. Functional Ecology 13, 567–572.

Snedecor, G.W., Cochran, W.G., 1994. Statistical Methods. 8th Edition, The lowa state University, lowa U.S.A. ISBN: 978-0-813-81561-9.

Swathi, B., Gupta, P.S.P., Nagalaxhmi, P., 2012. Effect of tulsi and turmeric on broiler performance and blood constituents during heat stress in broilers. International Journal of Pharmacy and Biological Science 3(3), 446–453.

Toghyani, M., Toghyani, M., Gheisari, A., Ghalamkari, G., Eghbalsaied, S., 2011. Evaluation of cinnamon and garlic as antibiotic growth promoter substitutions on performance, immune responses, serum biochemical and haematological parameters in broiler chicks. Livestock Science 138(1), 167–173.