Original Research Article

Impact of Fenugreek Seed Powder Supplementation on Growth Performance in Commercial Broilers Exposed to Dexamethasone

ABSTRACT

Aims: This study aimed to evaluate the health benefits of dietary supplementation with fenugreek seed powder (FSP) in broiler chickens subjected to dexamethasone-induced stress.

Study design:A total of 216 day-oldVencobb broiler chicks were randomly allocated to four treatment groups, each with three replicates of 12 birds, for a 42-day trial.

Place and Duration of Study: The experiment was conducted for 42 days at the Instructional Poultry Farm of Govind Ballabh Pant University of Agriculture and Technology, located in Pantnagar, U.S. Nagar, Uttarakhand

Methodology:A total of 216 day-oldVencobb broiler chicks were randomly allocated to four treatment groups, each with three replicates of 12 birds, for a 42-day trial. The treatment groups included: T1 (control) - standard diet; T2 - standard diet with dexamethasone (1 mg/kg body weight); T3 - standard diet with dexamethasone (1 mg/kg body weight) and FSP (1% of the diet); and T4 - standard diet with FSP (1% of the diet).

Results: The results demonstrated dexamethasone administered T2 group birds displayed significantly reduced weight gain which was found to be ameliorated in T3 group birds as observed through improved feed intake, body weight gain and feed conversion ratio (FCR) in T3 as compared to T2. The broilers receiving a 1% FSP-supplemented diet (T3 and T4) exhibited significant improvements in feed intake, body weight gain and feed conversion ratio (FCR) compared to those without FSP supplementation ($P < 0.05$).

Conclusion: The findings suggest that incorporating FSP into broiler diets enhances growth performance and mitigates the adverse effects of dexamethasone-induced stress, making it a valuable dietary intervention under both normal and stressful conditions.

Keywords: ***Fenugreek seed powder; Feed Additive; Dexamethasone; FCR; Vencobb broiler.***

1. INTRODUCTION

The broiler industry in India is a vital component of the poultry sector, primarily focused on chicken meat production. The industry has experienced rapid growth, driven by increasing demand for affordable protein sources, urbanization and evolving dietary preferences. India ranks among the world's largest producers of poultry meat, with its growth fueled by the adoption of high-yielding broiler varieties (achieving 2.4–2.6 kg weight within six weeks) and the implementation of standardized practices in nutrition, housing, management and disease control. Over the past three decades, broiler production in India has grown at an impressive annual rate of 8–10%. In the fiscal year 2021–22, India produced 9.29 million tonnes of meat, reflecting an annual growth rate of 5.62% (DAHD, 2022). Of this, poultry meat accounted for approximately 4.2 million tonnes, making up about 45.2% of the country's total meat production. This highlights the significant role of the broiler industry in meeting the nation's meat consumption demands.

Fenugreek (*Trigonella foenum-graecum*) an annual leguminous plant which belongs to the family Fabaceae. It is one of the oldest medicinal plants, originating in India and Northern Africa. It is cultivated worldwide as a semiarid crop and is widely used for human consumption in India as food and as medicine in Ayurveda. Fenugreek seeds are rich in crude protein, dietary fibre, fatty acids, amino acids, and minerals (Pandey and Awasthi, 2015; Nasim et al., 2016). The phytochemical components of Fenugreek seed powder (FSP) are reported to be polysaccharides, flavones, steroidal saponins and alkaloids. FSP is reported to possess many health beneficial properties, such as hypoglycemic (Gad et al., 2006; Lu et al., 2015), hypocholesterolemic (Ramulu et al., 2011; Uemura et al., 2011) anti-oxidation (Abdel-Daim et al., 2015; Goyal et al., 2018) antibacterial (Mozhdeh et al., 2019) anti-inflammatory (Bae et al., 2012; Ahmed et al., 2017) immuno-stimulating activities (Begum et al., 2016; Guardiola et al., 2018) and improve growth performance (Toaha et al., 2016). Fenugreek (*Trigonella foenum-graecum*) seed powder has been reported to enhance appetite and improve gut health in poultry through its bioactive compounds, such as saponins and alkaloids, which influence the nervous system and improve intestinal microbial balance (Kumar et al., 2021).

Physiological stress is one of many concerns facing the modern broiler producer. When a stressor is actually causing a negative impact on the well-being of an animal, this can be defined as distress. Under stress the hypothalamic-pituitary-adrenocortical axis is activated, the hypothalamus produces corticotrophin-releasing factor, which in turn stimulates the pituitary to release adrenocorticotropic hormone (ACTH). Secretion of ACTH causes the cells of the adrenal cortical tissue to proliferate and to secrete corticosteroids. The main active hormone of the axis is corticosterone in birds. In chickens, adrenal corticosteroids are secreted shortly after exposure to stress and elevated plasma levels have been used as an index of the response to stress in poultry. Synthetic corticosteroid like dexamethasone (DEX) administration mimics the negative impacts of increased corticosteroid (Berenjian et al., 2021). Besides inducing stress, corticosteroids can also influence digestive function by markedly decreasing the digestibility of protein and carbohydrates (Scanes, 2016). DEX exhibited modulation in anti-inflammatory, immunomodulatory and antioxidant mediators in chicken splenocytes (Ambwani et al., 2023). DEX was used as the specific stressor in this study to induce physiological stress in Vencobb broiler chickens. Therefore, the objective of this study was to evaluate the effect of fenugreek seed, dexamethasone and their cumulative effect on the FCR, feed intake and body weight gain in Vencobb broilers.

2. MATERIAL AND METHODS

The experiment was conducted at the Instructional Poultry Farm of Govind Ballabh Pant University of Agriculture and Technology, located in Pantnagar, U.S. Nagar, Uttarakhand. All procedures involving birds were reviewed and approved by the Institutional Animal Ethics Committee (IAEC) (IAEC/CBSH/MBGE/407). Two hundred sixteen Vencobb broiler were

randomly allocated to 4 dietary treatments of three replicates of each group in a factorial arrangement (3 X 12).For first 7 days standard diet was provided to acclimatize the birds.Afterwards treatment groups were: T1- Standard feed (control), T2- Standard diet + dexamethasone @ 1mg/kg body wt, T3- Standard diet + dexamethasone@1mg/kg body wt. + fenugreek@ 1percent of diet, T4- Standard diet + fenugreek@ 1percent of diet. Throughout the experimental period, all the broilers were maintained under standard and uniform management conditions to ensure consistency in the study. They were provided ad-libitum access to feed and water, ensuring their nutritional and hydration needs were continuously met. A controlled light period of 18 hours per day was maintained to support optimal productivity and health. The birds received vaccinations according to the routine schedule and prescribed doses, ensuring protection against common diseases. Fenugreek seed were procured from Vegetable Research Center, Pantnagar and the herbarium specimen of the plant was submitted in the Department of Biological Sciences with Herbarium Accession No: GBPU-1023. These seed were dried and powdered for efficient mixing in the feed at the inclusion level of 1 percent. Dexamethasone was administered orally in the feed @ 1mg/kg body wt. A standard basal layer diet was formulated by precisely mixing ingredients to meet the nutrient requirements outlined in the BIS (2007) recommendations, as detailed in Table-1. Additionally, regular health monitoring was conducted to identify and address any potential issues promptly. Environmental conditions such as temperature and humidity were carefully regulated to provide a comfortable and stress-free environment for the birds.

Table 1: Ingredient composition of basal rations (kg/100 kg feed)

S No.	Ingredients	Starter Ration (0-3 weeks)	Finisher Ration (4-6 weeks)
1.	Yellow Maize	45	55
2.	Deoiled Rice Bran	15	11
3.	Soya Bean Meal	18	13
4.	Ground Nut Cake	12	12
5.	Fish meal	8	7
6.	*Mineral & vitamin mixture	2	2
7.	Groundnut oil	0.5	0.5

**Mineral mixture containing kg per 100 kg, lime stone powder 61.540, sterilized bone meal 30.770, common salt 6.950, potassium iodide 0.018, sodium molybdate 0.080, copper sulphate 0.040, manganese sulphate 0.380, ferrous sulphate 0.150, cobalt sulphate 0.030 and zinc carbonate 0.042 and vitamin mixture containing vitamin A 50,00,000 IU, Vitamin D3 10,00,000 IU, Vitamin B2 2 g, Vitamin E 750 units, calcium pantothenate 2.5 g, nicotinamide 10 g, vitamin B12 6g, choline chloride 150 g, calcium 750 g, manganese 275 g, iodine 1 g, iron 7.5 g, vitamin K 1g, zinc 15 g, copper 2 g, cobalt 0.45 g.*

Daily record of feed given to birds of different treatment groups was maintained. Left over of feed was weighed daily. The birds from each replicate were weighed on a weekly basis to determine their body weight gain until six weeks of age. The body weight gain and feed consumption for a particular period (weekly) were used to calculate the feed conversion ratio (FCR).

Statistical Analysis

Statistical analysis of the data obtained during the experiment was performed using the IBM SPSS Statistics 22 software package. The data were initially subjected to descriptive analysis to compute the means (± standard error) of each treatment group at different time intervals. The variability within the groups was assessed through standard deviation, and

95% confidence intervals were calculated to summarize the precision of the estimated means.

The experimental data were further analyzed using One-Way Analysis of Variance (ANOVA) to test for significant differences among the treatment groups. The variance ratio (F-values) was calculated and compared against the critical value at a probability level of 5% ($P < 0.05$). The null hypothesis (H_0) that all group means are equal was tested, and significant differences among treatment means were identified.

Following a significant F-value in the ANOVA, Duncan's New Multiple Range Test (Duncan's Range Test), as modified by Kramer (1957), was applied as a post-hoc analysis to determine the specific differences between treatment means. Duncan's test identifies subsets of means that are significantly different, providing insight into which treatments were most effective or different from others.All statistical analyses were conducted under the assumption that the data met the requirements for ANOVA, including normality and homogeneity of variance. In cases where assumptions were violated, appropriate transformations or alternative tests were considered. Results were reported as significant at $P < 0.05$.

3. RESULTS AND DISCUSSION

The effect of supplementation of fenugreek and dexamethasone (DEX) in different treatment group namely T1- standard diet (control), T2- standard diet +dexamethasone @ 1mg/kg body wt. T3- standard diet + dexamethasone@1mg/kg body wt. + fenugreek@ 1percent of diet, T4- Standard diet + fenugreek@ 1percent of diet is given below.

Feed Intake and Weight Gain

The mean weight gain values were found to be 337.6679±9.43099, 312.6309±8.82731, 353.7092±9.84708 and 376.1865±10.27129 for T1, T2,T3 and T4, respectively (Table 2). The values of mean feed intake is concerned the subsequent values were as follows 587.6527±20.66253, 562.3381±19.93302, 602.9842±21.02984 and 623.1232±21.3613 for T1,T2, T3 and T4, respectively (Table 3). DEX had substantially decreased ($P < 0.05$) feed intake, feed efficiency, and overall weight gain in the broiler (Rafiqul Islam et al.,2022)

Table 2: Body Weight Gain of birds of different treatment groups during the trial period

WEEK	T1	T2	T3	T4	P-VALUE
I	$108.9047±.09883^{c}$	$99.9908±.10439^{d}$	$112.092±.09676^{b}$	$118.0981±.10097^{a}$	0
II	$208.9936±.09569^{c}$	$193.9889±.10067^{d}$	$219.946±.08228^{b}$	$244.9986±.08945^{a}$	0
III	$325.1692±.10423^{c}$	$295.0353±.10450^{d}$	$347.1614±.08772^{b}$	$370.0797±.09321^{a}$	0
IV	$454.0964±.09597^{c}$	$413.9003±.10032^{d}$	$472.9858±.10802^{b}$	$502.065±.09347^{a}$	0
V	$464.9583±.10875^{c}$	$434.8933±.09605^{d}$	$489.97778±.09414^{b}$	$516.99±.09260^{a}$	0
VI	$463.885±.09513^{c}$	$437.97667±.10043^{d}$	$480.09167±.10875^{b}$	$504.8867±.10167^{a}$	0
Overall	$337.6679±9.43099^{bc}$	$312.6309±8.82731^{c}$	$353.7092±9.84708^{ab}$	$376.1865±10.27129^{a}$	0

Table 3: Mean feed intake of birds of different treatment groups during the trial period

WEEK	T1	T2	T3	T4	P-VALUE

I	119.1683±.09242[c]	114.10389±.09449[d]	122.01889±.09127[b]	124.988±.10285[a]	0
II	311.91889±.10167[c]	300.0361±.10578[d]	321.0142±.10395[b]	345.92056±.09864[a]	0
III	501.0089±.09039[c]	469.9239±.09106[d]	524.9553±.10289[b]	547.9858±.09852[a]	0
IV	764.0358±.09804[c]	724.895±.09352[d]	779.9019±.09469[b]	805.005556±.09696[a]	0
V	879.8597±.10026[c]	845.0205±..09148[d]	904.975±.09244[b]	929.8722±.09668[a]	0
VI	949.9247±.09879[c]	920.0489±.10036[d]	965.0397±.0984[b]	984.9667±.10597[a]	0
OVERALL	587.6527±20.66253	562.3381±19.93302	602.9842±21.02984	623.1232±21.3613	0.208

The result was found statistically insignificant for mean feed intake values. However, on weekly basis the feed intake for all 4- treatment groups were found to be statistically significant indicating that there was subsequent improvement in the feed intake in fenugreek powder treated group (T4) as compared to other treatment groups on weekly basis. Similarly, broiler chicks fed on 0.50% FK diets recorded the lowest feed consumption while the broilers group received 1.0% FL diets recorded the highest value for feed consumption (Abdel-Azeem, et al., 2006). The T2 group was marked by a subsequent dip in feed intake in each week. Similar finding was observed by DEX treatment which resulted in a significant decrease in body weight and feed intake with an increase in FCR (Lv et al., 2018).
Analysis of the results of experiment for body weight gain in grams it was observed that treatment group T2 and T4 differed significantly *(P < 0.05)* indicating that mean values of weight gain for fenugreek seed powder (T4) is higher compared to other treatment groups

WEEK	T1	T2	T3	T4	P-VALUE
I	1.0943±.00132[b]	1.1412±.00163[a]	1.0886±.00138[c]	1.0584±.00121[d]	0
II	1.4925±.00085[b]	1.5467±.00101[a]	1.4595±.00077[c]	1.4119±.00070[d]	0

representing increased feed utilization and efficiency. Likewise, it was observed by the inclusion of 1.5 percent of fenugreek in broiler diet as an herbal feed supplement is beneficial in improving the live weight and weight gain (Gaikwad, B. S. et al., 2018).The marked reduction of the DEX treated group weight gain represent the adverse effect of DEX on the feed efficiency and subsequently weight gain in the treatment group . Similar findings were observed in DEX treatment which resulted in a significant decrease in body weight and feed intake with an increase in FCR (Lv et al., 2018).

Feed Conversion Ratio (FCR)

The FCR mean values for the four-treatment group were found to be 1.6250±. 02083,1.6793±.02097, 1.5944±.02009 and 1.5507±.01951 for T1, T2, T3 and T4; respectively (Table 4).

Table 4: FCR of birds of different treatment groups during the trial period

III	1.5408±.00063[b]	1.5928±.00055[a]	1.5121±.00051[c]	1.4807±.00046[d]	0
IV	1.6825±.00036[b]	1.7514±.00050[a]	1.6489±.00047[c]	1.6034±.00035[d]	0
V	1.8923±.00051[b]	1.9431±.00046[a]	1.847±.00041[c]	1.7986±.00037[d]	0
VI	2.0478±.00039[b]	2.10068±.00053[a]	2.01012±.00051[c]	1.95087±.00047[d]	0
OVERALL	1.6250±.02083[ab]	1.6793±.02097[a]	1.5944±.02009[bc]	1.5507±.01951[c]	0

The use of fenugreek powder improved the FCR by 13.8 % (Weerasingha and Atapattu, 2013) compared to control group. The 1% fenugreek was significantly best than that of control. Feed conversion ratio is affected adversely by the dexamethasone administration. The increase in feed conversion ratio indicates that the administration of dexamethasone-induced physiological stress where glucose metabolism is favoured over protein synthesis which had a negative impact on feed to tissue conversion (Ademu et al.,2018). The mean values of FCR significantly differed *(p<0.05)* for T4 group (fenugreek treated) and T2 group (DEX) indicating a greater feed efficiency for T4 group compared to the T2 group. The lower FCR values for T4 group compared to other group represent better feed utilization and efficiency in this group as compared to the T2 group representing that the supplementation of fenugreek seed powder has positively impacted the FCR value leading to significant reduction ($p<0.05$)compared to other treatment groups. Similar finding was found for the use of fenugreek powder improved the (FCR) by 13.8 % (Weerasingha and Atapattu 2013) compared to control group. The 1% fenugreek was significantly better than that of control. However, high inclusion (3%) level of fenugreek seed powder in the diet gave rise to higher FCR than any other inclusion level of FGS (Toaha et al., 2016).Considering the statistically significant value for T2 group we can conclude that the feed efficiency was decreased and significant increase in the values of FCR was found, study by (Islam et al., 2022) observed that DEX had substantially decreased (*P< 0.05*) feed intake, feed efficiency, and overall weight gain in the broiler. Based on these findings, we conclude that DEX reduces feed intake.Numerous studies have highlighted the biological activities of fenugreek seeds, including their anti-inflammatory (Liu et al., 2012), antidiabetic, antioxidant (Kaviarasan et al., 2007; Belguith-Hadriche et al., 2013), cancer-preventive (Raju et al., 2004), and hypolipidemic effects (Narasimhamurthy et al., 1999). This extensive array of bioactive compounds underpins the wide-ranging therapeutic potential of fenugreek in traditional and modern medicine.

4. CONCLUSION

In conclusion, the study demonstrated that the inclusion of fenugreek seed powder in broiler diets significantly improved feed conversion ratio (FCR), feed efficiency, and weight gain compared to other treatments, particularly the dexamethasone (DEX) group. The T4 group (fenugreek-treated) showed the lowest FCR, indicating better feed utilization, and the highest weight gain, highlighting the positive impact of fenugreek supplementation. These findings align with previous research, which also reported improved FCR and weight gain with fenugreek inclusion. Conversely, the DEX-treated group exhibited reduced feed intake, feed efficiency, and weight gain, further emphasizing the detrimental effects of DEX on broiler performance. Overall, this study supports the use of fenugreek seed powder as a beneficial dietary supplement for enhancing growth performance and feed efficiency in broilers.

ETHICAL APPROVAL

The due approval of this study was procured from Institutional Animal Ethics Committee, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand,India (IAEC/CBSH/MBGE/407)

REFERENCES

1. Abdel-Azeem, F. (2006). Effect of using fenugreek and fennel seeds as natural feed additives on performance of broiler chicks. Egyptian Journal of Nutrition and Feeds, 9(2), 277-297.
2. Abdel-Daim, M. M., Abd Eldaim, M. A., & Hassan, A. G. (2015). *Trigonella foenum-graecum* ameliorates acrylamide-induced toxicity in rats: Roles of oxidative stress, proinflammatory cytokines, and DNA damage. Biochemistry and Cell Biology, 93(3), 192-198.
3. Ademu, L. A., Erakpatobor-Iyeghe, G. T., Barje, P. P., Daudu, O. M., &Wafar, R. J. (2018). Response of broiler chickens under dexamethasone induced stress conditions. Asian Journal of Research in Animal and Veterinary Sciences, 1(1), 1-9.
4. Adil, S., Qureshi, S., &Pattoo, R. A. (2015). A review on positive effects of fenugreek as feed additive in poultry production. International Journal of Poultry Science, 14(12), 664.
5. Ahmed, E. S., Fatma, A., Osama, A., & Mohamed, E. B. (2017). Fenugreek (*Trigonella foenumgraceum*) extract mitigates the cyclophosphamide induced immunosuppression, oxidative stress and genotoxicity in rats. AustVasc Access Soc, 4, 110-132.
6. Ambwani, S., Dolma, R., Sharma, R., Kaur, A., Singh, H., Ruj, A., &Ambwani, T. K. (2023). Modulation of inflammatory and oxidative stress biomarkers due to dexamethasone exposure in chicken splenocytes. Veterinary Immunology and Immunopathology, 262, 110632.
7. Bae, M. J., Shin, H. S., Choi, D. W., & Shon, D. H. (2012). Antiallergic effect of *Trigonella foenum-graecum* L. extracts on allergic skin inflammation induced by trimellitic anhydride in BALB/c mice. Journal of Ethnopharmacology, 144(3), 514-522.
8. Begum, M., Hossain, M. M., & Kim, I. H. (2016). Effects of fenugreek seed extract supplementation on growth performance, nutrient digestibility, diarrhoea scores, blood profiles, faecal microflora and faecal noxious gas emission in weanling piglets. Journal of Animal Physiology and Animal Nutrition, 100(6), 1121-1129.
9. Berenjian, A., Sharifi, S. D., Mohammadi-Sangcheshmeh, A., &Bakhtiarizadeh, M. R. (2021). Omega-3 fatty acids reduce the negative effects of dexamethasone-induced physiological stress in laying hens by acting through the nutrient digestibility and gut morphometry. *Poultry Science*, *100*(3), 100889.
10. Gad, M. Z., El-Sawalhi, M. M., Ismail, M. F., & El-Tanbouly, N. D. (2006). Biochemical study of the anti-diabetic action of the Egyptian plants Fenugreek and Balanites. Molecular and Cellular Biochemistry, 281, 173-183.
11. Gaikwad, B. S. (2018). Effect of fenugreek (*Trigonella foenum-graceum* L.) seed powder as a natural feed additive on growth performance of broilers (Doctoral dissertation, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani).
12. Goyal, S., Gupta, N., Kumar, A., Chatterjee, S., & Nimesh, S. (2018). Antibacterial, anticancer and antioxidant potential of silver nanoparticles engineered using Trigonella foenum- graecum seed extract. IET Nanobiotechnology, 12(4), 526-533.

13. Guardiola, F. A., Bahi, A., & Esteban, M. A. (2018). Effects of dietary administration of fenugreek seeds on metabolic parameters and immune status of gilthead seabream (Sparus aurata L.). Fish & Shellfish Immunology, 74, 372-379.
14. Gupta, S. K., Behera, K., Lone, S. A., & Behera, D. (2015). Influence of stocking density on growth performance of Vencobb broiler.
15. Islam, M. R., Nasirin, S., Rekha, R. D., Sonali, B., Anisuzzaman, Z. H., & Mohammed, R. I. (2022). Effects of dexamethasone induced stress on the intestinal morphology and morphometry in broiler chicken. Journal of Advances in Biotechnology, 5(2), 394-407.
16. Islam, R., Sultana, N., Ayman, U., Islam, M. R., & Hashem, M. A. (2022). Role of steroid growth promoter on growth performance and meat quality traits in broiler. Poultry Science, 101(7), 101904.
17. Khorshidian, N., Yousefi Asli, M., Arab, M., Adeli Mirzaie, A., &Mortazavian, A. M. (2016). Fenugreek: Potential applications as a functional food and nutraceutical. Nutrition and Food Sciences Research, 3(1), 5-16.
18. Pardeep Kumar, Rohit Walia, Sunil Punia, Sushil Kumar and Sajjan Sihag. Fenugreek as a phytogenic feed additive in poultry feed- A review. The Pharma Innovation Journal. 2021; 10(12s): 33-38.
19. Lu, F., Cai, Q., Zafar, M. I., Cai, L., Du, W., Jian, L., ... & Gao, F. (2015). 4-Hydroxyisoleucine improves hepatic insulin resistance by restoring glycogen synthesis in vitro. International Journal of Clinical and Experimental Medicine, 8(6), 8626.
20. Lv, Z. P., Peng, Y. Z., Zhang, B. B., Fan, H., Liu, D., & Guo, Y. M. (2018). Glucose and lipid metabolism disorders in the chickens with dexamethasone- induced oxidative stress. Journal of Animal Physiology and Animal Nutrition, 102(2), e706-e717.
21. Mozhdeh, S., Ali, M., Sara Sadat, N., Pouya, F., & Amir Hossein, B. (2019). Comparison of the efficacy of oral fenugreek seed extract and azithromycin in the treatment of acne vulgaris: A randomized, triple-blind controlled pilot clinical trial. Iranian Journal of Dermatology, 22(2), 58-64.
22. Paneru, D., Tellez-Isaias, G., Romano, N., Lohakare, G., Bottje, W. G., &Lohakare, J. (2022). Effect of graded levels of fenugreek (*Trigonella foenum-graecum* L.) seeds on the growth performance, hematological parameters, and intestinal histomorphology of broiler chickens. Veterinary Sciences, 9(5), 207.
23. Pandey, H., & Awasthi, P. (2015). Effect of processing techniques on nutritional composition and antioxidant activity of fenugreek (*Trigonella foenum-graecum*) seed flour. Journal of Food Science and Technology, 52, 1054-1060.
24. Ramulu, P., Giridharan, N. V., &Udayasekhararao, P. (2011). Hypolipidemic effect of soluble dietary fiber (galactomannan) isolated from fenugreek seeds in WNIN (GR-Ob) obese rats. Journal of Medicinal Plants Research, 5(19), 4804-4813.
25. Scanes, C. G. (2016). Biology of stress in poultry with emphasis on glucocorticoids and the heterophil to lymphocyte ratio. Poultry Science, 95, 2208-2215.
26. Siegel, H. S. (1995). Stress, strains, and resistance. British Poultry Science, 36, 3–22.
27. Smith, M. (2003). Therapeutic applications of fenugreek. Alternative Medicine Review, 8(1), 20-27.
28. Toaha, S. M., Mollah, B. R., & Ahammad, M. U. (2016). Use of dietary fenugreek (*Trigonella foenum-graecum* L.) seed for the production of safe broiler lean meat. Research in Agriculture Livestock and Fisheries, 3(2), 305-314.
29. Uemura, T., Goto, T., Kang, M. S., Mizoguchi, N., Hirai, S., Lee, J. Y., ... & Kawada, T. (2011). Diosgenin, the main aglycon of fenugreek, inhibits LXRα activity in HepG2 cells and decreases plasma and hepatic triglycerides in obese diabetic mice. The Journal of Nutrition, 141(1), 17-23.

30. Yang, L., Chen, L., Zheng, K., Ma, Y. J., He, R. X., Arowolo, M. A., ... & He, J. H.(2022). Effects of fenugreek seed extracts on growth performance and intestinal health of broilers. Poultry Science, 101(7), 101939.

1