Original Research Article

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

ABSTRACT

Aim: The study aimed to evaluate the impact of fenugreek seed powder supplementation on the growth performance of commercial broilers exposed to dexamethasone, a synthetic corticosteroid known to induce stress and suppress growth.

Study design: A total of 144 day-old broiler chicks (Vencobb) were randomly allocated to four treatment groups, each with three replicates of 12 birds, for a 42-days trial, receiving different dietary treatments, including a control diet, dexamethasone treatment and diets supplemented with fenugreek seed powder (FSP).

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: 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). Growth parameters such as body weight gain, feed intake and feed conversion ratio (FCR) were measured over a period of 42 days of all the four groups.

Results: The results demonstrated that dexamethasone treatment in the T2 group led to a noticeable reduction in weight gain. On the other hand, broilers in the T3 and T4 groups, supplemented with 1% FSP, showed significant improvements in feed intake, weight gain and feed conversion efficiency compared to those without FSP or subjected to dexamethasone alone ($P < 0.05$).

Conclusion: Dexamethasone exposure significantly reduced growth performance, while fenugreek seed powder supplementation mitigated these negative effects. Broilers receiving FSP demonstrated improved body weight gain and FCR compared to the dexamethasone-only and control groups. 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. Further research on optimal dosage and long-term effects is recommended.

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.

Trigonella foenum-graecum (Fenugreek) an annual leguminous plant which belongs to the family Fabaceae, 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; Singh *et al*., 2021). The phytochemical components of Fenugreek seed powder (FSP) are reported to be polysaccharides, flavones, steroidal saponins and alkaloids (Kumar *et al*., 2021). 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; Kumar *et al*., 2021) 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). One hundred forty four broilers (Vencobb) were randomly allocated to 4 dietary treatment groups with three replicates of 12 birds in 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. + FSP @ 1percent of diet, T4- Standard diet + FSP @ 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 seeds 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. A standard basal broiler 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.*

Feed intake was recorded daily for each treatment group and the remaining feed was measured to calculate consumption. Weekly body weights of birds in each replicate were recorded throughout the six-week experimental period to assess growth performance.

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. + FSP @ 1percent of diet, T4- Standard diet + FSP @ 1percent of diet is given below.

Feed Intake and Weight Gain

The mean weight gain values were found to be $108.9047\pm.09883^{c}$, $99.9908\pm.10439^{d}$, $112.092\pm.09676^{b}$, $118.0981\pm.10097^{a}$ for T1, T2, T3, T4, respectively in first week, which are statistically significant ($P<0.05$). The values of mean weight gain were found lowest in T2 group in the first week due to the administration of dexamethasone and similar trends were observed in the subsequent weeks. DEX had substantially decreased ($P <0.05$) feed intake, feed efficiency and overall weight gain in the broilers (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	$108.9047\pm.09883^{c}$	$99.9908\pm.10439^{d}$	$112.092\pm.09676^{b}$	$118.0981\pm.10097^{a}$	0
II	$208.9936\pm.09569^{c}$	$193.9889\pm.10067^{d}$	$219.946\pm.08228^{b}$	$244.9986\pm.08945^{a}$	0
III	$325.1692\pm.10423^{c}$	$295.0353\pm.10450^{d}$	$347.1614\pm.08772^{b}$	$370.0797\pm.09321^{a}$	0
IV	$454.0964\pm.09597^{c}$	$413.9003\pm.10032^{d}$	$472.9858\pm.10802^{b}$	$502.065\pm.09347^{a}$	0
V	$464.9583\pm.10875^{c}$	$434.8933\pm.09605^{d}$	$489.97778\pm.09414^{b}$	$516.99\pm.09260^{a}$	0
VI	$463.885\pm.09513^{c}$	$437.97667\pm.10043^{d}$	$480.09167\pm.10875^{b}$	$504.8867\pm.10167^{a}$	0

^{a,b,c,d} Means with no common superscripts within the rows of each classification are significantly different ($P<0.05$).

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

WEEK	T1	T2	T3	T4	P-VALUE
I	$119.1683\pm.09242^{c}$	$114.10389\pm.09449^{d}$	$122.01889\pm.09127^{b}$	$124.988\pm.10285^{a}$	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

[a,b,c,d] Means with no common superscripts within the rows of each classification are significantly different (P<0.05).

The feed intake on first week for all 4- treatment groups (T1, T2, T3, T4) were found to be 119.1683±.09242[c],114.10389±.09449[d], 122.01889±.09127[b],124.988±.10285[a], respectively, which are statistically significant (P<0.05); indicating that there was subsequent improvement in the feed intake in FSP treated group (T4) as compared to other treatment groups. Likewise trends were observed in the subsequent weeks.

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).

Upon analyzing the results of experiment for body weight gain, it was observed that treatment groups differed significantly (P < 0.05) indicating that mean values of weight gain for FSP (T4) is highest compared to other treatment groups representing increased feed utilization and efficiency. It was reported that 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, *et al*., 2018). The marked reduction of the DEX treated group weight gain represent the adverse effect of DEX on the feed efficiency and subsequent 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 were found to be 1.0943±.00132[b], 1.1412±.00163[a], 1.0886±.00138[c], 1.0584±.00121[d] for T1, T2, T3, T4, respectively for the first week, which are statistically significant (P<0.05), indicating that there was subsequent improvement in the feed conversion ratio in FSP treated group (T4) as compared to other treatment group. Similar trends were observed in the subsequent weeks.

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

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
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

[a,b,c,d] Means with no common superscripts within the rows of each classification are significantly different (P<0.05).

The use of fenugreek powder @1% improved the FCR by 13.8 % (Weerasingha and Atapattu, 2013) compared to the control group. Similarly, Gaikwad *et al*. (2018) demonstrated that herbal feed additives like fenugreek enhance weight gain and feed utilization efficiency, consistent with the results for the fenugreek-treated groups here. Paneru *et al*. (2022) reported the effect of graded levels of FSP on the growth performance, and intestinal histomorphology of broiler chickens. 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 FSP has positively impacted the FCR value leading to significant reduction ($P<0.05$) compared to other treatment groups. 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 which could be corroborated to a study by Islam *et al*. (2022) reported that DEX had substantially decreased ($P< 0.05$) feed intake, feed efficiency, and overall weight gain in the broiler. Based on these findings, it could be concluded that DEX reduces feed intake. Numerous studies have highlighted the biological activities of fenugreek seeds which could be due to bioactive phytoconstituents. This extensive array of bioactive compounds underpins the wide-ranging therapeutic potential of fenugreek in traditional and modern medicine.

This study builds upon the findings of Lv *et al*. (2018), who identified the detrimental effects of dexamethasone-induced stress on feed intake and weight gain. Unlike previous studies, this research demonstrates that dietary supplementation of FSP (T3 and T4 groups) effectively mitigates these negative impacts, suggesting a novel approach to managing stress in broilers. Herbal plants exhibit their medicinal and health benefits due to presence of various phytochemicals present in them (Ambwani *et al*., 2018; Pandey and Ambwani, 2022). Additionally, the observed improvements may be attributed to the immunomodulatory and antioxidant effects of fenugreek, as documented by Begum *et al*. (2016), Guardiola *et al*. (2018) and Singh *et al*. (2021). These comparisons further validate the utility of fenugreek as a dietary intervention for stressed broilers.

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. While the results are promising, cost implications of FSP supplementation and potential effects on digestive tolerance need further evaluation. Future studies should address these factors to ensure its practical application. Overall, this study supports the use of fenugreek seed powder as a beneficial dietary supplement for enhancing

growth performance feed efficiency and combat against glucocorticoid mediated oxidative stress 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)

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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 foenum graceum*) extract mitigates the cyclophosphamide induced immunosuppression, oxidative stress and genotoxicity in rats. Aust Vasc Access Soc, 4, 110-132.
6. Ambwani, S., Tandon, R., Ambwani T. K., & Malik Y. S. (2018). Current knowledge on nanodelivery systems and their beneficial applications in enhancing the efficacy of herbal drugs. Journal of Experimental Biology and Agricultural Science, 6(1), 87-107.
7. 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.

8. 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.
9. 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.
10. 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.
11. 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.
12. 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).
13. 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.
14. 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.
15. Gupta, S. K., Behera, K., Lone, S. A., & Behera, D. (2015). Influence of stocking density on growth performance of Vencobb broiler.
16. 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.
17. 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.
18. 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.
19. Kumar, N., Ahmad, A. H., Singh, S. P., Pant, D., Prasad, A., & Rastogi, S. K. (2021). Phytochemical analysis and antioxidant activity of Trigonella foenum-graecum seeds. *Journal of Pharmacognosy and Phytochemistry*, *10*(1), 23-26.
20. Kumar, N., Kumar, M., Verma, M. K., Ramanarayanan, S., Ranjan, A., & Ranjan, R. (2021). Bioactive effects and safety profiles of fenugreek (Trigonella foenum-graecum L.) for pharmaceutical and medicinal applications. *Pharma innov*, *10*(12), 912-919.
21. 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.
22. Pandey, Y., & Ambwani, S. (2022). Nano Metal based Herbal theranostics for Cancer management: coalescing nature's boon with nanotechnological advancement. Current Pharmaceutical Biotechnology, 23(1), 30-46.
23. 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.

24. 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.
25. 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.
26. 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.
27. 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.
28. 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.
29. Scanes, C. G. (2016). Biology of stress in poultry with emphasis on glucocorticoids and the heterophil to lymphocyte ratio. Poultry Science, 95, 2208-2215.
30. Siegel, H. S. (1995). Stress, strains, and resistance. British Poultry Science, 36, 3–22.
31. Singh, H., Ambwani, S. Ambwani, T. K., Agrawal S., & Gaur A. K. (2021). Assessment of Antioxidative Potential of seeds extract of Trigonella foenum-graecum. Advances in Bioresearch. 12(6), 140-145
32. Smith, M. (2003). Therapeutic applications of fenugreek. Alternative Medicine Review, 8(1), 20-27.
33. 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.
34. 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.
35. 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.