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Bioactive potential of Okra (*Abelmoschus esculentus* L. Moench) as a feed additive in poultry: A mini review

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ABSTRACT

The global poultry industry has been challenging due to the ban on the use of antibiotic growth promoters (AGPs) and the increasing consumer demand for safe and environmentally friendly natural feed. Okra (*Abelmoschus esculentus* L. Moench) is a potential feed additive candidate because of its high levels of bioactive compounds, such as polyphenols, flavonoids, polysaccharides, and phytosterols, which exhibit antioxidant, antimicrobial, hypolipidemic, and immunomodulatory activities. This mini-review summarizes the latest in vivo research findings on okra supplementation in broiler chickens and laying hens. Among the eight publications analyzed, okra supplementation at low to moderate doses (1–2 g/kg fruit powder, 1–2% seed powder, or 2–5% leaf flour) consistently improved the growth performance, feed efficiency, carcass quality, lipid metabolism, antioxidant status, and gut microbiota balance in broilers. In laying hens, okra supplementation was found to increase egg production and yolk and shell quality, and reduce egg cholesterol levels, primarily mediated by phytoestrogenic and antioxidant activities. Although these results are promising, available research data remain limited and vary in terms of plant parts, processing methods, and supplementation levels. Therefore, standardization, long-term research, and molecular mechanism studies are needed to ensure the effectiveness and safety of okra as a natural feed additive to replace AGP in sustainable poultry farming.

Introduction

The global poultry industry is currently undergoing major changes driven by increasing consumer awareness and stricter regulations regarding efforts to reduce the use of antibiotics as growth promoters (AGPs) in livestock production (Salim *et al.*, 2018). Antibiotics are typically used for disease prevention and treatment as well as growth promoters to enhance poultry productivity (Alagawany *et al.*, 2022). However, their widespread use has led to the emergence of antibiotic-resistant bacteria, which pose health risks to both animals and humans. This led to a global ban on the use of antibiotics in poultry feed, starting in Europe in 2006 (Żbikowska *et al.*, 2020). In response to this challenge, the exploration of natural feed additives as alternatives to antibiotics has increased, one of which is plant-derived feed additives. The presence of polyphenols, flavonoids, alkaloids, and other bioactive compounds in plants has modulatory effects on the gut microbiota, enhances immunity, and improves productivity in poultry (Medina-Larqué *et al.*, 2022).

Okra (*Abelmoschus esculentus* L. Moench) is a promising candidate owing to its rich nutritional content, phytonutrients, and potential pharmacological benefits. Okra contains vitamins, minerals, dietary fiber, protein, fat, polyphenols, flavonoids, polysaccharides, and phenolic acids (Chawla *et al.*, 2025). The pharmacological activities of okra include antidiabetic, hypoglycemic, antihyperlipidemic, antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, neuroprotective, antitumor, and gastroprotective effects (Abdel-Razek *et al.*, 2023; Kwok *et al.*, 2025). Okra has shown potential as a feed additive in poultry, with beneficial effects such as increasing broiler chicken productivity (Ashour *et al.*, 2020; Abbas, 2021), increasing egg production in laying hens (Sobayo *et al.*, 2017; Saleh *et al.*, 2023), and improving antioxidant status while reducing oxidative stress in poultry (Al-Hatchami and Alshukri, 2023a).

Based on a review of the latest literature, the number of in vivo studies that directly evaluate the effects of okra on poultry performance is still relatively limited. These limited data highlight the existence of a broad research gap and underscore the importance of a comprehensive review to identify the potential, limitations, and future research directions related to the use of okra as a poultry feed additive. Therefore, this review aimed to provide a concise yet comprehensive overview of the bioactive potential of okra as a feed additive for poultry. The primary focus is on examining physiological effects, production parameters, product quality, and underlying potential mechanisms. In addition, this review sought to identify existing research gaps and provided directions for further studies, enabling okra to be optimally utilized as a natural feed additive in the sustainable poultry industry as an alternative to antibiotics.

Using of Okra as a feed additive

This review is based on a literature review focused on identifying and analyzing research related to the use of okra (*Abelmoschus esculentus* L. Moench) as an additive in poultry feed. A literature search was conducted using Google Scholar (https://scholar.google.com), Scopus (https://www.scopus.com), and PubMed (https://pubmed.ncbi.nlm.nih.gov) databases, covering publications from 2015 to 2025. The keywords used in the search included combinations such as: "okra," "*Abelmoschus esculentus*," along with "broiler chickens," "laying hens," and "poultry."

Inclusion criteria were in vivo research articles on poultry using okra plant parts (leaves, fruit, seeds, stems, or extracts) as a single feed additive or in combination. Studies that only reported in vitro research, experiments on non-poultry animals, or general reviews without applicable data on poultry were excluded from analysis. Of the 44 articles obtained, only eight matched the criteria. The collected data are presented in a summary table and then described narratively.

Effects of okra supplementation on broiler chickens and laying hens

Based on a literature review, several studies have been found that examined the effects of okra supplementation on broiler chickens and laying hens. These studies utilized different parts of the okra plant, such as

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the leaves, fruits, and seeds, in the form of dried powder or fresh extract. The dosage also varied, ranging from low (1 g/kg feed or 1%) to high (10 g/kg of feed) levels. A comprehensive summary of the administration form, dosage, type of poultry, observed parameters, and main results of each study is shown in Table 1.

From the data presented in Table 1, although the parts and forms of administration, as well as the doses used, vary, there is a general pattern that is quite consistent. In general, okra feeding in broilers focuses more on growth performance, feed efficiency, carcass quality, and physiological response to heat stress. Meanwhile, in laying hens, research has focused on productivity, egg quality, and yolk lipid profiles. To facilitate understanding of the general trends in all research results, a combined analysis was conducted to summarize the optimal dose, the most effective form of administration, and the dominant physiological and production effects reported. The results of this analysis are presented in Table 2.

As shown in Table 2, okra supplementation at low to medium doses gave the most consistent results, both in broilers and layers. In broilers, a dose of 1-2 g/kg dried fruit powder or 1-2% seed powder increases body weight, improves feed conversion, and reduces abdominal fat. In laying hens, a dose–2-5% leaf powder or 2-4 g/kg fruit powder increased

Table 1. Various studies on the use of okra in poultry.

Part and Form of Administration	Dosage	Type of Poultry	Research Parameters	Main Results	References
Leaves, dried & ground into leaf meal	0, 2.5, 5, 7.5, 10% feed	Laying hens (Black Harco)	Final weight, weight gain, feed consumption, hen-day production, internal & external egg quality, egg lipid profile	5% leaf meal → highest final weight & egg production; improved yolk color & weight; decreased cholesterol, triglycerides, LDL, increased HDL	(Sobayo *et al.*, 2017)
Fresh fruit (pods), aqueous extract	5 ml/L drinking water (with neem or combination)	Broiler (Cobb-500)	Body weight gain, mortality	Combined extract of neem + okra → highest body weight (2116.58 g), low mortality (2-4%) compared to control (13%)	(Islam *et al.*, 2020)
Dried fruit, powder	0, 2, 4 g/kg feed	Laying hens	Hen-day production, egg weight, egg mass, serum triglycerides, MDA, GSH, estrogen	2 g/kg → lowest triglycerides; MDA down & GSH up; estrogen up at 2-4 g/kg	(Saleh *et al.*, 2023)
Dried fruit, powder	0, 1, 2, 3 g/kg feed	Broiler (Ross)	Growth, feed consumption, feed conversion, carcass fat percentage, liver enzymes, meat quality	1 g/kg → highest body weight & weight gain, lowest abdominal fat, low urea & creatinine, better meat quality during storage	(Ashour *et al.*, 2020)
Seeds, powder (OSP)	0, 1, 2, 4% feed	Broiler (Ross 308)	Final body weight, FCR, internal organs, serum cholesterol, ALT, gut microbes	1-2% → best weight & FCR, decreased cholesterol & ALT, increased lactic acid bacteria, decreased *E. coli*	(Abbas, 2021)
Dried fruit, powder + Vitamin C/E	0, Vit C 250 mg/kg, Vit E 200 mg/kg, Okra 2 g/kg, Okra 4 g/kg	Laying hens (Lohmann Brown-Lite)	Relative weight of egg components, shell thickness, peroxide number, egg estrogen	Okra 4 g/kg → lowest peroxide number, increased egg estrogen; increased shell thickness in all treatments	(Allaw *et al.*, 2023)
Seed powder, fruit powder, or combination	5-10 g/kg feed	Broiler (Rose 308)	Blood quality (SOD, MDA, H/L ratio, glucose, total protein, cholesterol)	Okra 10 g/kg (fruit) → lowest blood glucose; seed+fruit combination → lowest blood cholesterol & high SOD, low MDA	(Al-Hatchami and Alshukri, 2023b)
Seed powder, fruit powder, or combination	5-10 g/kg feed	Broiler (Rose 308)	Body weight, feed consumption	Okra fruit 10 g/kg → highest weight gain; combination of seed+fruit → increased feed consumption	(Al-Hatchami and Alshukri, 2023a)

Table 2. Combined analysis of various studies on okra feeding in poultry.

Parameter	Trends from All Studies	Optimal Dose (Range)	Most Effective Part & Form	Main Physiological/Productive Effects	Important Notes	References
Broiler Growth	Optimal weight gain at low-medium doses; too high doses sometimes do not improve performance	1-2 g/kg (dried fruit powder) or 1-2% (seed powder)	Dried fruit powder (DOFP) or seed powder (OSP)	FCR improved, final body weight increased, abdominal fat decreased	High doses (≥4% seed) may reduce performance	(Abbas, 2021; Ashour *et al.*, 2020)
Egg Production	Increased hen-day production and egg weight at moderate doses	2-5% dry leaf powder (AELM) or 2-4 g/kg fruit powder	Dried leaf powder or dried fruit powder	Egg yolk weight increased, yolk color more intense, egg triglyceride decreased	The effects on yolk color and quality were obvious at intermediate doses	(Saleh *et al.*, 2023; Sobayo *et al.*, 2017)
Egg Quality	Shell thickness and internal quality improved	4 g/kg fruit powder + Vit C/E gave the best antioxidant effect	Dried fruit powder + vitamins	Decreased peroxide number, increased egg estrogen	Okra antioxidants work synergistically with vitamin C/E	(Allaw *et al.*, 2023)
Blood Lipid Profile	Cholesterol and triglycerides decreased at moderate doses	2-4 g/kg fruit powder or 1-2% seed powder	Dried fruit powder or seed powder	Total & LDL cholesterol down, HDL up	The hypocholesterolemic effect is consistent across several studies	(Abbas, 2021; Sobayo *et al.*, 2017)
Antioxidants & Heat Stress	SOD activity increased, MDA decreased, H/L ratio improved	10 g/kg fruit powder or fruit+seed combination 5+5 g/kg	Dried fruit powder, fruit+seed combination	Increase endogenous antioxidants, reduce oxidative stress	Effective in heat stress conditions	(Al-Hatchami and Alshukri, 2023b, 2023a)
Gut Microbiota	Lactic acid bacteria population increased, E. coli decreased	1-2% seed powder	Seed powder (OSP)	Improvement of gut microbial balance	Supports digestive tract health	(Abbas, 2021)
Impact on Mortality	Mortality was lower in the okra group	Fruit extract 5 ml/L drinking water (neem + okra combination)	Fresh fruit extract	Mortality 2-4% vs 13% in control	Synergistic effect of herbs with other plants	(Islam *et al.*, 2020)

egg production, improved yolk quality, and lowered egg cholesterol. Additional effects recorded were improved blood lipid profiles, improved antioxidant status, and reduced mortality.

Overall, the results of the literature review indicated that feeding okra to poultry has the potential to provide a wide range of benefits, from increasing production performance to improving the quality of livestock products. Variations in the form, dose, and plant parts used resulted in different responses, but the general trend was consistent in favor of using okra as a natural additive in poultry diets. These findings provide an important basis for further discussion of the mechanisms, practical implications, and comparative effects of okra feeding in broilers and layers, which will be outlined in the Discussion section.

The earliest effects of okra supplementation in broiler chickens were observed in the balance of digestive tract microbiota. Research has shown that okra seed powder (OSP) can increase the population of lactic acid bacteria, while reducing the number of *Escherichia coli*. This change in microbiota is important because it supports gastrointestinal health and improves feed digestibility (Abbas, 2021). This is most likely influenced by the content of soluble polysaccharides, such as pectin or mucilage, which act as prebiotic substrates, help the growth of good bacteria, and support the integrity of the intestinal mucosa. Soluble polysaccharides such as pectin are resistant to poultry digestive enzymes and reach the lower intestine, where beneficial bacteria ferment. This fermentation process produces short-chain fatty acids (SCFAs) such as lactate, acetate, and propionate. The production of SCFAs during the fermentation of soluble polysaccharides lowers the pH of the intestinal environment, thus creating unfavorable conditions for pathogenic bacteria such as *E. coli* (Tingirikari, 2019). An acidic environment inhibits the growth and colonization of pathogenic bacteria, thereby improving gut health and reducing the incidence of disease. These mechanisms lead to improvements in gut morphology such as increased villus length and improved nutrient absorption (De Maesschalck *et al*., 2015).

Subsequent effects occur on lipid metabolism and liver function. Okra seed supplementation can improve liver enzyme activity (ALT and AST), reduce total cholesterol, triglyceride, and LDL levels, and increase HDL levels (Abbas, 2021). The decrease in blood cholesterol and triglyceride levels may be related to bioactive compounds, such as flavonoids and polyphenols, in okra. Flavonoids and polyphenols exhibit antioxidant and anti-inflammatory activities, which help to reduce oxidative stress and inflammation in the liver. This may improve liver function, activity, and enzyme levels(Santos-Sánchez and Cruz-Chamorro, 2025). It also modulates lipid metabolism by affecting the activity of enzymes involved in lipid synthesis and degradation, as well as by inhibiting lipid absorption in the gut. This modulation helps lower total cholesterol, triglyceride, and LDL levels, thereby reducing the overall lipid levels in the bloodstream (Yu *et al*., 2021). Bioactive compounds may also enhance the reverse cholesterol transport mechanism, which helps increase HDL levels. This process involves the transportation of cholesterol from the peripheral tissues back to the liver for excretion (Prakash, 2023).

Furthermore, okra also plays a role in improving the antioxidant status and immune response to stress. Research (Al-Hatchami and Alshukri, 2023b) reported that administration of okra fruit powder or a combination of seeds and fruit can increase SOD activity, reduce MDA, and improve the heterophil/lymphocyte ratio. Polyphenolic compounds are known to interact directly with superoxide dismutase (SOD), thereby increasing the superoxide radical scavenging activity and reducing oxidative stress levels. In addition, flavonoids such as quercetin can increase the expression of various antioxidant enzymes, including SOD, catalase, and glutathione peroxidase (GSH-Px), which collectively strengthen oxidative defense mechanisms (Al-Khalaifah *et al*., 2024; El-Ghareeb *et al*., 2023; Tang *et al*., 2024).

Flavonoids and polyphenols also have strong antioxidant properties, which play a role in reducing the formation of reactive oxygen species (ROS) and suppressing lipid peroxidation, thereby reducing malondialdehyde (MDA) levels as a marker of oxidative damage to lipids. This decrease in MDA reflects the protection of cell membrane integrity, which is achieved through the upregulation of antioxidant enzymes that neutralize ROS before they trigger further lipid peroxidation (Zhang and Kim, 2020). In addition to their antioxidant effects, flavonoids also exhibit anti-inflammatory properties by modulating the expression of pro-inflammatory cytokines, such as TNF-α, IL-1β, and IL-6, thus reducing systemic inflammation, as reflected in the improved heterophil/lymphocyte ratio. Overall, the antioxidant and anti-inflammatory effects of flavonoids and polyphenols play an important role in reducing stress responses in poultry, especially under conditions of heat stress and high rearing density, which in turn supports a more balanced immune response and optimal physiological performance (Insawake *et al*., 2025).

Improvements in the physiological conditions, including reduced mortality, are reflected in the general health of poultry. Supplementation with okra fruit extract in drinking water, especially when combined with neem, was shown to reduce mortality to 2-4%, much lower than the control (13%) (Islam *et al*., 2020). The series of effects of the microbiota level, metabolism, and antioxidant system ultimately lead to increased productivity. Studies have reported that supplementation of dried fruit powder (DOFP) and okra seeds at low to moderate doses (1-2 g/kg or 1-2% of feed) can increase final body weight, improve feed conversion (FCR), and reduce abdominal fat(Abbas, 2021; Ashour *et al*., 2020).

Effect of okra feeding on laying hens

The initial effect of okra feeding on laying hens can be seen in hormonal regulation, especially the hormone estrogen. Providing okra fruit powder at a dose of 2-4 g/kg feed can increase plasma estrogen levels, which is a key hormone in the regulation of egg production (Saleh *et al*., 2023). This increase in estrogen levels is a biological foundation that supports ovarian and oviductal activity, potentially increasing the number of eggs produced. This study showed that okra contains phytoestrogens that have a structure similar to that of natural estrogen, so it can stimulate estrogen receptors and increase ovarian activity. Phytobiotics containing phytoestrogens work by interacting with estrogen receptors, increasing the expression of reproductive hormone-related genes, and regulating various hormones to increase plasma estrogen levels in laying hens, ultimately improving reproductive performance and egg production (İpçak *et al*., 2025).

In addition to hormonal influences, okra also contributes to the improvement of antioxidant status, which has a direct impact on egg quality. Supplementation with okra fruit powder in combination with vitamins C and E was reported to reduce peroxide number, increase shell thickness, and improve internal egg quality (Allaw *et al*., 2023). This antioxidant activity plays an important role in protecting the integrity of egg components from oxidative damage, thus supporting egg quality, both freshly produced and during storage. Improvements in egg quality, such as peroxide reduction and shell thickness, are due to the abundance of natural flavonoids in okra. Flavonoids and phenolic compounds are known for their ability to neutralize free radicals that are responsible for oxidative stress and lipid peroxidation. This activity helps reduce peroxide formation (Das, 2022). Additionally, phytobiotics, such as quercetin, enhance the metabolism of amino acids, such as glycine, serine, and threonine, which are important for the synthesis of eggshell matrix proteins. This increase in amino acid metabolism supports the biomineralization process, resulting in thicker and stronger eggshells (Wei *et al*., 2025).

Metabolic effects were also evident in lipid profiles. Research has shown that supplementation with okra leaves and fruits reduces serum triglyceride and yolk cholesterol levels, while increasing HDL fractions (Saleh *et al*., 2023; Sobayo *et al*., 2017). These improvements not only benefit chicken health but also result in healthier eggs for consumers. Phytobiotics, owing to their antioxidant properties, help reduce oxidative stress and lipid peroxidation. This reduction in oxidative stress can lower serum triglyceride and cholesterol levels (Wang *et al*., 2021). Flavonoids can also alter the expression of genes related to cholesterol transport, thereby reducing cholesterol transport to the yolk (Zou *et al*., 2025). In addition, the improvement of the lipoprotein profile by increasing HDL levels and decreasing LDL levels by phytobiotics can be achieved through modulation of lipid metabolism and increased antioxidant enzyme activity. Such processes help to maintain higher HDL levels by protecting lipoproteins from oxidative damage (Wang *et al*., 2021).

These mechanisms ultimately lead to an increase in productivity. Feeding 5% okra leaf powder in laying hen feed has been shown to produce the highest final weight and egg production, as well as improve color and yolk weight (Sobayo *et al*., 2017). Similar results were also reported in another study, which found that supplementation with okra fruit powder increased egg weight and daily egg mass (Saleh *et al*., 2023).

Conclusion

Based on a review of the literature, okra supplementation in poultry diets shows multifunctional potential benefits for the poultry industry. In broilers, the main benefits are related to increased growth, improved feed efficiency, decreased abdominal fat, improved blood lipid profile, and improved antioxidant status, particularly under heat stress conditions. In laying hens, okra has been shown to increase egg productivity, improve internal and external egg quality, and lower yolk cholesterol levels. Hormonal effects in the form of increased estrogen level are also important mechanisms that support increased egg production. In general, low to medium doses (1-2 g/kg fruit powder, 1-2% seed powder, or 2-5% leaf powder) provided the most consistent and optimal results. Therefore, okra has great prospects as a natural feed additive that is economical, environmentally friendly, and relevant to the demands of the modern poultry industry, which emphasizes animal health and food product safety.

Conflict of interest

The authors have no conflict of interest to declare.

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References

Abbas, R.J., 2021. Effect of supplementing different levels of okra seed (*Abelmoschus esculentus* L.) powder on growth performance, carcass characteristics, blood parameters and gut microbial populations in broiler chickens. Basrah J. Agric. Sci. 34, 29–41.

Abdel-Razek, M.A.M., Abdelwahab, M.F., Abdelmohsen, U.R., Hamed, A.N.E., 2023. A Review: Pharmacological activity and phytochemical profile of *Abelmoschus esculentus* (2010-2022). RSC Adv. 13, 15280–15294.

Al-Hatchami, A.F., Alshukri, A.Y.A., 2023a. Effect of ration treated with powdered okra seeds or fruits on productivity indicators of broilers under heat stress. In: IOP Conf. Ser. Earth Environ. Sci., Fourth International Conference of Modern Technologies in Agricultural Sciences, Kufa, Iraq, pp. 072059.

Al-Hatchami, A.F., Alshukri, A.Y.A., 2023b. Effect of diet fortified with okra powder on blood quality in broiler chickens under heat stress conditions. In: IOP Conf. Ser. Earth Environ. Sci., Fourth International Conference of Modern Technologies in Agricultural Sciences, Kufa, Iraq, pp. 072060.

Al-Khalaifah, H.S., Ibrahim, D., Kamel, A.E.-S., Al-Nasser, A., Abdelwarith, A.A., Roushdy, E.M., Sheraiba, N.I., Shafik, B.M., El-Badry, S.M., Younis, E.M., Mamdouh, M., Yassin, E.M.M., Davies, S.J., Kishawy, A.T.Y., 2024. Enhancing impact of dietary nano formulated quercetin on laying performance: egg quality, oxidative stability of stored eggs, intestinal immune and antioxidants related genes expression. BMC Vet. Res. 20, 494.

Alagawany, M., Abd El-Hack, M.E., Saeed, M., Khan, M.S., Kamboh, A.A., Siddique, F., Raza, A., Farag, M.R., Mahgoub, S., 2022. Hazards of Using Antibiotic Growth Promoters in the Poultry Industry, in: Antibiotic Alternatives in Poultry and Fish Feed. Bentham Science Publishers, pp. 1–18.

Allaw, A.A., Taha, A.T., Saleh, Z.M., 2023. Effect of adding okra powder and vitamin C or E to the diet on some qualitative characteristics and oxidation indices in the eggs of lohmann brown-lite hens. In: IOP Conf. Ser. Earth Environ. Sci., Fifth International Conference for Agricultural and Environment Sciences, Al Qasim, Iraq, pp. 052013.

Ashour, E.A., Bin-Jumah, M., Abou Sayed-Ahmed, E.T., Osman, A.O., Taha, A.E., Momenah, M.A., Allam, A.A., Swelum, A.A., Abd El-Hack, M.E., 2020. Effects of dried okra fruit (*Abelmoschus esculentus* L.) powder on growth, carcass characteristics, blood indices, and meat quality of stored broiler meat. Poult. Sci. 99, 3060–3069.

Chawla, N., Kaur, S., Shakya, S., 2025. Nutritional Quality of Okra: A Global Overview, in: Okra: Status, Challenges and Opportunities. Springer, Singapore, pp. 269–278.

Das, J. 2022. Bioactive Flavonoids as Phytoantioxidants, in: Phytoantioxidants and Nanotherapeutics. John Wiley & Sons, Inc., New Jersey, USA, pp. 99–119.

De Maesschalck, C., Eeckhaut, V., Maertens, L., De Lange, L., Marchal, L., Nezer, C., De Baere, S., Croubels, S., Daube, G., Dewulf, J., Haesebrouck, F., Ducatelle, R., Taminau, B., Van Immerseel, F., 2015. Effects of xylo-oligosaccharides on broiler chicken performance and microbiota. Appl. Environ. Microbiol. 81, 5880–5888.

El-Ghareeb, W.R., Kishawy, A.T.Y., Anter, R.G.A., Aboelabbas Gouda, A., Abdelaziz, W.S., Alhawas, B., Meligy, A.M.A., Abdel-Raheem, S.M., Ismail, H., Ibrahim, D., 2023. Novel antioxidant insights of myricetin on the performance of broiler chickens and alleviating experimental infection with Eimeria spp.: crosstalk between oxidative stress and inflammation. Antioxidants 12, 1026.

Insawake, K., Songserm, T., Songserm, O., Theapparat, Y., Adeyemi, K.D., Rassmidatta, K., Ruangpanit, Y., 2025. Flavonoids, isoquinoline alkaloids, and their combinations affect growth performance, inflammatory status, and gut microbiome of broilers under high stocking density and heat stress. Animals 15, 71.

İpçak, H.H., Denli, M., Yokuş, B., Bademkıran, S., 2025. The impact of dietary encapsulated fennel seed (*Foeniculum vulgare Mill.*) essential oil inclusion levels on performance, serum hormone profiles, and expression of reproductive axis-related genes in the early and late laying phases of hens. Vet. Med. Sci. 11, e70150.

Islam, M.Z., Islam, J., Talukdar, M.L., Haque, M.N., Jahan, S.S., and Islam, M.S., 2020. Potentiality of antibiotic free broiler meat production using alternatives to antibiotics in Bangladesh. Bangladesh J. Agric. Life Sci. 1, 29–32.

Kwok, C.T., Ng, Y.-F., Chan, H.-T.L., Chan, S.-W., 2025. An overview of the current scientific evidence on the biological properties of *Abelmoschus esculentus* (L.) Moench (Okra). Foods 14, 177.

Medina-Larqué, A.-S., Rodríguez-Daza, M.-C., Dudonné, S., Roy, D., Jacques, H., Desjardins, Y., Marette, A., Roquim, M., Pilon, G., Levy, É., 2022. Cranberry polyphenols and agave agavins impact gut immune response and microbiota composition while improving gut barrier function, inflammation, and glucose metabolism in mice fed an obesogenic diet. Front. Immunol. 13, 871080.

Prakash, J., 2023. Secondary Metabolites from Plants for Cardiovascular Disease, in: Pharmacological Benefits of Natural Agents. IGI Global Scientific Publishing, Pennsylvania, USA, pp. 155–171.

Saleh, Z.M., Taha, A.T., Allaw, A.A., 2023. Productive and physiological performance of laying hens under different levels of okra powder. In: IOP Conf. Ser. Earth Environ. Sci., Fifth International Conference for Agricultural and Environment Sciences, Al Qasim, Iraq, pp. 52007.

Salim, H.M., Huque, K.S., Kamaruddin, K.M., Beg, M.D.A.H., 2018. Global restriction of using antibiotic growth promoters and alternative strategies in poultry production. Sci. Prog. 101, 52–75.

Santos-Sánchez, G., Cruz-Chamorro, I., 2025. Plant-derived bioactive peptides and protein hydrolysates for managing MAFLD: A systematic review of in vivo effects. Food Chem. 481, 143956.

Sobayo, R.A., Sanwo, K.A., Muhammad, S.B., Adegbenjo, A.A., Oso, A.O., Sogunle, O.M., Fafiolu, A.O., Adeyemi, O.A., 2017. Effect of dietary *Abelmoschus esculentus* leaf meal on performance and egg quality indices of laying hens. Niger. J. Anim. Prod. 44, 290–298.

Tang, N., Xu, X., Guo, Z., Meng, X., Qian, G., Li, H., 2024. Preparation of safflower fermentation solution and study on its biological activity. Front. Microbiol. 15, 1472992.

Tingirikari, J.M.R., 2019. In-vitro prebiotic analysis of microbiota accessible pectic polysaccharides. Curr. Microbiol. 76, 1452–1460.

Wang, Y., Yang, Q., Lin, P., Li, C., Lu, Y., Daijun, S., 2021. The effect of supplementing tea polyphenols in diet of laying hens on yolk cholesterol content and production performance. Brazilian J. Poult. Sci. 23, eRBCA-2020.

Wei, Y., Liu, Y., Lei, J., Jiang, Q., Geng, X., Guo, Y., Zhang, B., 2025. Quercetin-based treatment improves eggshell quality in aged laying hens by modulating immune response, eggshell gland health and serum metabolome. J. Sci. Food Agric. 105, 5674–5684.

Yu, H., Zheng, R.-F., Su, W.-L., Xing, J.-G., Wang, Y., 2021. Metabolism characteristics and pharmacological insights of flavonoids based on the intestinal bacteria. Yaoxue Xuebao 56, 1757–1768.

Żbikowska, K., Michalczuk, M., Dolka, B., 2020. The use of bacteriophages in the poultry industry. Animals 10, 872.

Zhang, S., Kim, I.H., 2020. Effect of quercetin (flavonoid) supplementation on growth performance, meat stability, and immunological response in broiler chickens. Livest. Sci. 242, 104286.

Zou, C., Jiang, H., Wu, X., Gao, J., Ma, W., 2025. Integrative analysis of metabolomics and transcriptomics reveals alterations in egg quality and hepatic lipid metabolism in hens supplemented with curcumin. Anim. Nutr. 21, 302–314.