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A review on the bioactive, nutritional and medicinal properties of *Zanthoxylum species* and its effects on poultry productive performance and health

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Abstract

Plants are globally acknowledged as essential sources of food and medicinal treatments for various health conditions. The secondary metabolites produced by plants significantly influence both toxicity and health benefits. Zanthoxylum species are deciduous shrubs belonging to the Rutaceae family, comprise approximately 250 distinct species. This genus displays a wide array of biological functions due to its broad distribution and abundant bioactive compounds such as terpenoids, flavonoids, and alkaloids, enhancing its importance in medical applications as well as its insecticidal properties (larvicidal, repellent, and anti‑feedant effects). Beyond therapeutic uses, Zanthoxylum species are commonly used as spices in various culinary traditions. In poultry production, Zanthoxylum supplementation has been associated with enhanced growth performance, improved immunity, and better overall well‑being. The bioactive compounds, including antioxidants, alkaloids, and flavonoids, underline the therapeutic effects on growth and immunity. Additionally, antimicrobial and anti‑inflammatory activities help maintain gut health and reduce the need for antibiotics, aligning with the growing trend toward natural and sustainable agriculture. This review critically examines the nutritional composition, bioactive phytochemicals, and documented effects of Zanthoxylum species on poultry growth performance, immune response, health and safety considerations.

Keywords: *Zanthoxylum species*, poultry, growth performance, health, bioactive compounds

Introduction

Poultry production plays a vital role in ensuring global food security, and there is ongoing demand for improvements in feed formulations to enhance both production and health. As the use of antibiotic growth promoters become increasingly restricted, interest in natural alternatives, particularly phytogenic compounds, has grown (Aminullah *et al.*, 2025).

Plants are globally acknowledged as vital sources of food and medicinal treatments for various health conditions. The secondary metabolites produced by plants significantly influence both toxicity and health benefits. *Zanthoxylum species* are deciduous shrubs belonging to the Rutaceae family, comprise approximately 250 distinct species. Bioactive compounds present in *Zanthoxylum* species, including flavonoids, alkaloids, and polyphenols, possess antioxidant and anti-inflammatory properties that may help maintain intestinal mucosal integrity and reduce oxidative stress in broilers. (Hu *et al.*, 2024).

Zanthoxylum are typically dioecious shrubs, trees or woody climbers armed with trichomes. The leaves are arranged alternately and are usually pinnate or trifoliate (Hartley, 2013). The genus *Zanthoxylum Linn* (Rutaceae) is represented in Nigeria by eleven distinct species (Table 1).

All eleven species of *Zanthoxylum* are members of the family *Rutaceae*, specifically grouped within the subfamily *Rutoideae* and the tribe *Zanthoxyleae*, indicating their close botanical relationship and shared characteristics. In common with other African *Zanthoxylum* species, they are identifiable through various taxonomic, anatomical, and morphological traits, particularly those associated with the roots, leaves, fruits, and related plant structures. These species are mainly adapted to forest vegetation and are widely distributed in the southern parts of Nigeria (Olatunji, 1983). *Zanthoxylum gillettii*, *Zanthoxylum tessmannii*, and *Zanthoxylum leprieurii* are tree species commonly found in the wet and dry forest zones of Southern Nigeria. Among them, *Zanthoxylum gillettii* is more abundant in wetter habitats such as riverbanks, streams, and moist valleys. In contrast, *Zanthoxylum zanthoxyloides* is more common in savannah and dry forest areas, occurring mainly in the drier parts of Southwestern Nigeria and extending into Niger State (Adesina, 2005).

Zanthoxylum rubescens occurs as a small tree and is sparsely distributed across the southern forest regions, with some occurrence in northern Nigeria. *Zanthoxylum viridis* has been reported mainly in the drier areas of Oyo and Kwara States, while *Zanthoxylum thomense* is found in Ondo and Edo States. *Zanthoxylum lemairei* occurs in Edo and Benue States, whereas *Zanthoxylum dinklagei* is distributed in Edo and the southeastern region of Nigeria. *Zanthoxylum bouetense* and *Zanthoxylum buesgenii* are restricted to the Oban Forest in south-eastern Nigeria near the Cameroon border (Olatunji, 1983).

A notable feature of these species is the presence of prickles, often referred to as spines, on the trunks, branches, branchlets, petioles, and inflorescence axes (Waterman, 1986). This review critically examines the effects of *Zanthoxylum* species on poultry growth performance, immunity, and general health, while also addressing limitations and safety concerns.

Methodology

This paper is a review of published research findings. The literature search was conducted in the following electronic databases, original journal research articles, conference articles, and systematic reviews published in English; studies reporting on the effect of *Zanthoxylum species'* nutritional composition, phytochemistry on poultry growth, immunity and health.

Nutritional Composition of *Zanthoxylum* Species

Zanthoxylum species, commonly known as prickly ash, include *Zanthoxylum bungeanum, Zanthoxylum alatum,* and *Zanthoxylum armatum,* which are widely valued in Asian cuisines and traditional medicine. These plants are nutritionally dense and rich in bioactive compounds. The pericarp (fruit peel) of *Zanthoxylum bungeanum* contains substantial protein, estimated at 92.32 mg/g (Li *et al.,* 2017). Amino acid analysis across 13 germplasms of Chinese prickly ash identified 17 amino acids, including all essential amino acids except tryptophan. Total amino acid content ranged from 5.82% to 10.9%, with essential amino acids making up 17–33% of the total (Li *et al.,* 2017). Fatty acids are mainly found in the seeds and their oils. The seed oil contains high levels of unsaturated fatty acids, including linoleic, oleic, and α- linolenic acids. Total fatty acid content can reach up to 966.04 mg/g in seed oil, with lower levels in seeds and pericarp (Li *et al.,* 2017). The carbohydrate content, particularly soluble polysaccharides, is also notable in the pericarp, with a value of about 96.33 mg/g (Wang *et al.,* 2017).

Table1: Distribution of *Zanthoxylum species* identified in Nigeria

S/N	*Zanthoxylum* Species	Distribution in Nigeria
1	*Zanthoxylum gillettii*	Common in wet and dry forests of Southern Nigeria; more frequent along rivers, streams, and wet valleys.
2	*Zanthoxylum tessmannii*	Common in wet and dry forest vegetation of Southern Nigeria.
3	*Zanthoxylum leprieurii*	Common in wet and dry forest vegetation of Southern Nigeria.
4	*Zanthoxylum zanthoxyloides*	Predominantly found in savannah and dry forest zones of Southwestern Nigeria extending to Niger State.
5	*Zanthoxylum rubescens*	Sparsely distributed in Southern Forest regions and extending into northern Nigeria.
6	*Zanthoxylum viridis*	Recorded in the drier parts of Oyo and Kwara States.
7	*Zanthoxylum thomense*	Found in Ondo and Edo States.
8	*Zanthoxylum lemairei*	Occurs in Edo and Benue States.
9	*Zanthoxylum dinklagei*	Distributed in Edo State and the south-eastern region of Nigeria.
10	*Zanthoxylum bouetense*	Restricted to the Oban Forest in south-eastern Nigeria near the Cameroon border.
11	*Zanthoxylum buesgenii*	Restricted to the Oban Forest in south-eastern Nigeria near the Cameroon border.

Source: Olatunji, O.A. (1983)

Proximate Composition of *Zanthoxylum* Species

The proximate composition of *Zanthoxylum* species varies by plant part and species. In *Zanthoxylum zanthoxyloides* stem bark, proximate analysis showed high carbohydrate content, moderate protein, and low-fat levels. Specifically, carbohydrates were 81.81 mg/100 g, protein 5.70 mg/100 g, crude fibre 2.22 mg/100 g, and fat 1.03 mg/100 g, indicating a potential source of energy and dietary fibre with low lipid content. Ash content (mineral residue) was also appreciable, reflecting mineral richness (Ezeani, 2025). In the same species studied by another group, *Zanthoxylum zanthoxyloides* stem bark showed moisture 9.47%, crude fat 6.36%, crude protein 11.00%, crude fibre 18.75%, ash 4.29%, and total carbohydrates 50.13%, demonstrating compositional variation due to extraction method, environmental conditions, or analytical protocol (Olushola‐Siedoks *et al.,* 2020). For *Zanthoxylum zanthoxyloides* leafy vegetables, proximate analysis revealed moisture content of 37.7%, fat 3.4%, protein 6.95%, and total carbohydrate 37.91%, indicating substantial water and carbohydrate content in the leaves (David *et al.,* 2024). Table 2 shows the proximate composition of *Zanthoxylum zanthoxyloides* stem bark and leaf.

Table 2: Proximate Composition of *Zanthoxylum zanthoxyloides*

Plant Part	Moisture (%)	Protein (%)	Fat (%)	Crude Fibre (%)	Ash (%)	Carbohydrates (%)	Reference
Stem bark	6.33	5.70	1.03	2.22	2.91	81.80	Ezeani (2025)
Stem bark	9.47	11.00	6.36	18.75	4.29	50.13	Olushola‑ Siedoks *et al.* (2020)
Leaf	37.70	6.5	3.40	6.25	7.75	37.91	David *et al.* (2024)

Note: Values are reported on a dry weight basis unless otherwise specified. Variations reflect differences in geographical origin, harvest time, and analytical methods.

Phytochemicals and Bioactive Compounds

Zanthoxylum species contain flavonoids and phenolics, such as quercetin, rutin, and kaempferol derivatives. The ethyl acetate fraction of pericarp extracts had the highest total phenolic content (97.29 mmol GAE/100 g) and flavonoid content (67.93 mmol QE/100 g) with high antioxidant capacity (Zhang *et al.*, 2014). The anesthetic activity typical of prickly ash is brought about by amide compounds like hydroxy‑ α‑ sanshool and hydroxy‑ β‑ sanshool.
Hydroxy‑ α‑ sanshool content in the pericarp ranged from 24.38 to 66.24 mg/g depending on region and species (Zheng *et al.*, 2023). The seeds also contain about 3.94 mg/g of nucleosides, which are utilized for cellular metabolism and signaling (Wang *et al.*, 2017).

Alkaloids

Alkaloids have been found in all plant organs and are particularly prevalent in the bark of the trunk and roots of most *Zanthoxylum* species. Two classes isoquinolines and quinolines make up most of the identified alkaloids. These include benzophenanthridine, aporphine, benzylisoquinoline protoberberine, berberine, and benzylisoquinoline (Patino *et al.*, 2012). Benzophenanthridines are highly renowned for their diverse biological activities, with a primary focus on anticancer activity (Adesina, 2005). They also possess activity against malaria, nematodes, leukemia, microbes, oxidative stress, HIV, bacteria, and fungi (Okagu *et al.*, 2023). Quinoline alkaloids (furoquinolines and pyranoquinolines) are frequently found, and some, such as zhantosimulin and huajiaosimulim, exhibit apoptotic action (Patino *et al.*, 2012). Canthin‑ 6‑ one alkaloids, prized for leishmanicidal activity, have been reported in *Zanthoxylum rugosum*, *Zanthoxylum chiloperone*, and *Zanthoxylum budrunga* (Ahmad *et al.*, 1993; Adesina, 2005).

Flavonoids

Flavonoids are widely distributed in *Zanthoxylum* species and contribute significantly to antioxidant defense. Their biological activities include anti‑ inflammatory, antioxidant, antithrombotic, antiseptic, antihepatotoxic, cancer‑ preventing, antihypertensive, antiviral, antiallergic, and estrogenic effects (Adesina, 2005). Flavonoids occur mostly as glycosides of flavones, flavanols, and flavanones, distinguished by polymethoxylation a feature shared with other Rutaceae genera.

Terpenoids, Essential Oils, and Phenolics

Terpenoids (monoterpenes and

sesquiterpenes such as limonene and β‑caryophyllene) contribute to the aromatic nature and possess antimicrobial and anti‑inflammatory properties (Wang *et al.*, 2019). Essential oils from leaves and fruit peels contain limonene, β‑pinene, and geraniol, with high antimicrobial activity (Rao *et al.,* 2018). Phenolic compounds, including gallic acid, caffeic acid, chlorogenic acid, and related flavonoids, have been identified in several *Zanthoxylum* species and are associated with antioxidant and anti-inflammatory activities (Phuyal *et al.,* 2020). Amides (e.g., β‑sanshool) exhibit insecticidal, sialogogue, antitussive, and analgesic properties (Kaleeswaran *et al.*, 2019; Patino *et al.*, 2012). Sterols (stigmasterol, β‑sitosterol) and coumarins (auraptene, collinine, psoralen) show antioxidant, anti‑thrombotic, and monoamine oxidase inhibitory activities (Adesina, 2005; Okagu *et al.*, 2023). Lignans such as syringaresinol and sesamin provide antimicrobial, antioxidant, and antitumor benefits.

Extracts from *Zanthoxylum bungeanum* have demonstrated strong antioxidant activity, primarily due to their phenolic content. The pericarp and leaves showed significant free radical scavenging in DPPH and ABTS assays (Zhang *et al.*, 2014). In hypoglycemic studies, polyphenolic extracts of the pericarp exhibited potent α‑glucosidase inhibitory activity, reducing fasting blood glucose by up to 64.2% in diabetic mice (Liang *et al.*, 2023). Additionally, supercritical CO_2 extracts from plant residues contain antimicrobial agents effective against foodborne pathogens such as *Vibrio parahaemolyticus* and *Aeromonas hydrophila* (Zhao *et al.*, 2021).

Effects of *Zanthoxylum* Species on Growth Performance of Poultry

The growth-promoting effects of *Zanthoxylum* species in poultry are primarily attributed to their bioactive compounds, especially antioxidant activity, which mitigates oxidative stress and enhances nutrient utilization. Hu *et al.* (2024) reported that inclusion of *Zanthoxylum bungeanum* in broiler feed significantly improved average daily weight gain (ADWG) and feed conversion ratio (FCR). Flavonoids and alkaloids improve nutrient absorption and utilization, leading to better weight gain and reduced feed wastage.

Additionally, antioxidants reduce free radical damage that would otherwise impair metabolic processes and growth (Li *et al.*, 2020), attributed to the regulation of gut microbiota and digestive enzyme activity. *Zanthoxylum* also stimulates appetite and improves feed intake.

Hu *et al.* (2024) reported that broiler chicks fed diets containing *Zanthoxylum* leaf meal had significantly higher body weight gain and improved feed efficiency compared to controls. Phytogenic feed additives like *Zanthoxylum* have been reported to enhance intestinal villus development and nutrient digestibility in broiler chickens, thereby improving nutrient absorption efficiency and gut functionality.

Studies have shown that replacement of soybean meal with *Zanthoxylum bungeanum* seed meal has been reported to improve dry matter digestibility, crude protein utilization, and growth performance in broiler chickens (Chen *et al.*, 2024). Broilers fed 5–10% *Zanthoxylum* species showed higher average daily gain (ADG) and average daily feed intake (ADFI) during both starter and grower periods compared to controls (Chen *et al.*, 2024). Increased breast meat and carcass yield have also been reported, indicating improved muscle development and growth quality (Chen *et al.*, 2024).

Supplementation with *Zanthoxylum* extract has been associated with mild enlargement of immune organs such as the bursa of fabricius, which plays a critical role in B‐cell maturation and antibody production (Chen *et al.,* 2024). Dietary inclusion of *Zanthoxylum bungeanum* seed meal increased serum immunoglobulin G (IgG) concentrations in broiler chickens, suggesting enhanced immune function. Furthermore, *Zanthoxylum* species enhance antioxidant enzyme activity (e.g., superoxide dismutase, SOD) and reduce malondialdehyde (MDA) content, a marker of oxidative stress. This antioxidant effect improves immunity by preventing oxidative damage to immune cells (Chen *et al.,* 2024).

Phytogenic compounds rich in alkaloids and flavonoids, like those present in *Zanthoxylum* species, have demonstrated anticoccidial activity against *Eimeria* species in broiler chickens, reducing faecal oocyst shedding and intestinal lesions. Such phytogenic additives may serve as potential alternatives to conventional anticoccidial drugs and could help mitigate concerns associated with antimicrobial resistance. (Hascoët *et al.,* 2025).

Substituting soybean meal with 5–10% *Zanthoxylum bungeanum* seed meal in broiler diets significantly improved ADG and ADFI across different growth phases (1–21 days, 22–42 days, and overall, 1–42 days) (Chen *et al.,* 2024). Serum biochemical indicators also showed reduced serum lipoprotein and total cholesterol levels, correlating with a decrease in abdominal fat rate, suggesting improved lipid metabolism. Liver health markers improved, with reduced activities of glutamic pyruvic transaminase and glutamic oxaloacetic transaminase, indicating less liver stress or damage (Chen *et al.,* 2024).

Effects of *Zanthoxylum* Species on the Health and Immune Response of Poultry

The bioactive compounds of *Zanthoxylum* species show many medicinal effects. Essential oils possess antimicrobial activities that suppress pathogenic bacteria and maintain gut health (Okagu *et al.,* 2021). Alkaloids such as chelerythrine exhibit anti‐inflammatory activities, suppressing inflammation‐related poultry diseases (Okagu *et al.*, 2021).

Zanthoxylum species extracts possess broad‐spectrum antimicrobial potential against enteric pathogens such as *Clostridium perfringens* and *Eimeria species*, which are common causes of enteric infections in poultry. This antimicrobial property helps reduce the pathogenic load in the gut, thereby improving intestinal wellness and reducing disease prevalence (Chen *et al.,* 2024). *Zanthoxylum* also provides antioxidant and anti‐inflammatory benefits, reducing oxidative stress and protecting hepatic and intestinal tissues. It promotes healthy gut microbiota, prevents pathogenic bacteria, reduces the severity of enteric infections, and supports liver function by limiting lipid peroxidation and aiding detoxification processes.

Studies involving *Zanthoxylum bungeanum* supplementation in broiler diets have demonstrated improvements in immune-related indices, including increased serum immunoglobulin G concentrations and enhanced superoxide dismutase activity (Chen *et al.,* 2024). Anti‐inflammatory activity, via cytokine modulation, reduces unnecessary inflammation, a common complication in intensive chicken rearing (Zheng *et al.,* 2023).

Phytogenic feed additives containing bioactive plant compounds similar to those present in *Zanthoxylum* species have been reported to enhance humoral immune responses and vaccine responsiveness in broiler chickens. Through improved gut health and microbiota balance, *Zanthoxylum* indirectly enhances mucosal immunity and gut‐associated lymphoid tissue (GALT) Naveed *et al.* (2020).

Limitations and Safety Considerations of *Zanthoxylum* species

Despite the promising results, several limitations and safety concerns must be acknowledged:

1. **Potential toxicity:** Some *Zanthoxylum* species contain toxic heavy metals (e.g., Pb, Cd, As, Hg) as documented in *Zanthoxylum acanthopodium* (Sari *et al.*, 2023). Without proper sourcing and processing, heavy metal accumulation in poultry products could pose food safety risks.
2. **Anti‑nutritional factors:** The presence of tannins, phytates, or other anti‑nutrients in *Zanthoxylum* leaves and bark may reduce protein digestibility or mineral bioavailability if included at high levels. No long-term studies have evaluated these effects.
3. **Lack of dose‑response standardisation:** Most studies used arbitrary doses (e.g., 2.5%, 5%, 10%) without determining optimal or safe upper limits. Overdosing might cause adverse effects such as reduced feed intake due to pungent compounds (sanshools).
4. **Species and part variability:** The composition and bioactivity vary dramatically between species (e.g., *Zanthoxylum bungeanum* vs *Zanthoxylum zanthoxyloides*) and plant parts (pericarp, seed, leaf, bark). Results from one species cannot be generalized to others.
5. **Short‑term studies only:** The majority of studies lasted 21–42 days. No long‑term (multiple cycles) or layer studies have thoroughly evaluated chronic effects on egg production, egg quality, or reproductive health.

Conclusion and Recommendations

Zanthoxylum species offer multiple benefits for poultry production, including enhanced growth performance, improved immunity, and better overall well‑being. Their bioactive compounds, antioxidants, alkaloids, and flavonoids underlie these therapeutic effects. Additionally, antimicrobial and anti‑inflammatory activities help maintain gut health and reduce antibiotic use, aligning with natural and sustainable agriculture trends.

However, significant knowledge gaps remain. Most studies have focused on short‑term outcomes; extensive long‑term experiments are needed to ascertain the full benefits and potential risks in commercial poultry diets. Future research should:

i. Determine optimal dosages for different *Zanthoxylum* species and plant parts.

ii. Compare effects across different poultry types (chicken, quail, turkeys).

Generally, *Zanthoxylum* species represent a valuable addition as natural supplements for promoting poultry health and productivity, provided that safety considerations are addressed.

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