**Exploring the Potential of Moringa oleifera and Andrographis paniculata Leaves as Natural Growth Promoters in Broilers**

# ABSTRACT

The broiler industry is presently experiencing a significant transformation, prompted by the global demand for antibiotic-free animal products and the prohibition of antimicrobial growth promoters (AGPs). This chapter examines the potential of Moringa oleifera and Andrographis paniculata as natural feed additives to address challenges related to productivity and health in broiler chickens. Recent research indicates that the bioactive compounds in these plants, including flavonoids, polyphenols, and andrographolides, have been demonstrated to enhance gut health and microbial populations. Notably, they reduce Escherichia coli and Salmonella counts while increasing lactic acid bacteria. Phytochemicals also contribute to improved feed efficiency, and weight gain. Experimental evidence suggests that supplementation with the nano-liquid extract at a concentration of 0.75% is highly effective in optimizing growth performance, feed conversion ratio, production index, and income over feed cost (IOFC). The incorporation of Moringa oleifera and Andrographis paniculata into broiler nutrition represents a viable, sustainable, and health-conscious alternative to synthetic feed additives, thereby supporting animal welfare and consumer safety.

*Keywords: Phytogenic, Antibiotic Free, Moringa, Andrographis, Broiler.*

# 1. INTRODUCTION

The broiler industry is one of the most dynamic sectors in global livestock production and plays a crucial role in increasing demand for animal protein worldwide. Despite its remarkable expansion and contribution to food security, broiler farming continues to face multifaceted challenges that significantly affect production efficiency, animal health, and product quality at the farm level. These challenges arise from a complex interaction of internal factors such as feed quality, genetics, and husbandry practices as well as external pressures including environmental conditions and disease prevalence. The cumulative effects of these elements frequently hinder the realization of optimal broiler performance, thereby necessitating a critical reassessment of conventional management strategies, particularly those related to feed supplementation.

Feed quality remains a fundamental determinant of broiler productivity. As evidenced by [1] the efficiency of nutrient utilization in formulated rations significantly influences growth rates, feed conversion, and overall flock performance. Nutritional imbalances whether due to inaccuracies in protein-to-energy ratios, deficiencies in essential amino acids, vitamins, or minerals, or the presence of anti-nutritional compounds can severely impair metabolic function, leading to stunted growth, reduced carcass quality, and elevated mortality. The selection of high performance broiler strains further compounds this issue. Although modern genotypes exhibit enhanced genetic potential for rapid growth, they are also highly sensitive to stressors and nutritional deficiencies. [2] emphasized that these genetic advancements can only be fully realized under optimal nutritional regimes and precise management systems tailored to the birds’ physiological demands.

Inclusion of AGPs in animal feed has raised profound concerns regarding food safety and public health, particularly in relation to antimicrobial resistance and residual contamination of meat products. Consequently in the numerous countries, including Indonesia, have enacted legislative bans on the use of AGPs. The Indonesian Ministry of Agriculture formally prohibited AGP usage under Regulation No. 14/Permentan/PK.350/5/2017, aligning national policy with the recommendations of international health authorities such as the World Health Organization (WHO) and the World Organisation for Animal Health (OIE) [3, 4]. This move reflects a growing consensus that indiscriminate antibiotic use in animal agriculture contributes to the global crisis of antimicrobial resistance and presents risks to both consumer health and environmental integrity.

The implications of the AGP ban on broiler productivity have been substantial. While initial concerns pointed to possible reductions in performance, empirical evidence from several studies suggests that with strategic adjustments in management and nutrition, equivalent performance outcomes can still be achieved. [5] reported no significant decline in productivity when AGPs were replaced with therapeutic alternatives and improved biosecurity protocols. Nevertheless, the transitional period following the AGP ban posed practical challenges, particularly in systems lacking advanced health monitoring and environmental control. [6] highlighted that in such settings, feed conversion ratios and growth rates were adversely affected, demonstrating the necessity of adopting comprehensive health and welfare programs. The removal of AGPs has prompted a paradigm shift in broiler health and nutrition management. Without the antimicrobial shield provided by AGPs, producers are now compelled to implement more holistic strategies. [7] emphasized that in the absence of AGPs, broilers are increasingly vulnerable to intestinal disorders such as necrotic enteritis, thereby necessitating alternative feed additives with gut health-supportive properties. In this context, phytogenic compounds, organic acids, and probiotics have gained traction as viable non-antibiotic growth promoters.

This transition has underlined the urgency of developing Natural Growth Promoters (NGPs) that can support broiler performance through mechanisms that are both biologically effective and environmentally responsible. NGPs present a multifaceted solution to the challenges posed by AGP withdrawal. Their efficacy stems from several key biological functions, including enhancement of digestive efficiency, modulation of gut microbiota, immunostimulation, and antioxidant activity. Bioactive compounds found in plant extracts and organic acids stimulate digestive enzymes such as amylase and protease, thereby improving nutrient assimilation and overall growth performance [8]. Moreover, NGPs play an essential role in shaping a favorable gut microbial environment. Additives like probiotics, prebiotics, and synbiotics are known to suppress pathogenic bacteria while promoting beneficial microbial populations, thereby enhancing gut integrity and immunity [9]. Beyond their influence on digestion and microbiota, NGPs also exert immunomodulatory effects. Phytogenic compounds can trigger cytokine production and improve mucosal immunity, resulting in greater resistance to infections and better resilience under intensive rearing conditions [10]. Their antioxidant properties, meanwhile, help mitigate oxidative stress a common issue in high density broiler farming thus preserving the structural and functional integrity of the gastrointestinal tract. Technological advancements such as microencapsulation further increase the efficacy of NGPs by protecting sensitive bioactive compounds from degradation during feed processing and digestion. These delivery systems ensure precise, targeted release within the gastrointestinal tract, optimizing bioavailability and improving consistency in performance outcomes. An equally important consideration in the selection of NGPs is their safety profile. Unlike AGPs, which are often associated with residual contamination in meat and adverse environmental effects, NGPs especially those derived from edible plants and naturally occurring microbes are widely regarded as safe. Their integration into feed formulations thus aligns with evolving consumer expectations and regulatory frameworks that emphasize food safety and sustainability.

Among the diverse range of botanical candidates explored for their growth-promoting potential, Moringa oleifera (commonly known as moringa) and Andrographis paniculata (commonly known as andrographis) have emerged as particularly promising. Moringa is noted for its high concentrations of protein, essential vitamins, minerals, and potent antioxidants, making it a valuable nutritional supplement in broiler diets. Moringa leaf powder supplementation improves carcass yield and giblet weight, contributing to enhanced production efficiency. Andrographis, on the other hand, possesses remarkable antimicrobial and immunomodulatory properties.[11] found that andrographis extract significantly reduces bacterial loads such as Escherichia coli in broiler meat, thereby improving product safety and compliance with food hygiene standards such as SNI 7388:2009.

Moringa and andrographis offer considerable economic and logistical advantages. Their adaptability to tropical agroclimatic conditions, including those prevalent in Indonesia, ensures year round availability and supports sustainable local production systems [12]. The affordability and accessibility of these plants also make them attractive for smallholder farmers seeking cost-effective solutions to replace synthetic additives. The synergistic effects of combining andrographis with other herbal ingredients such as turmeric, ginger, and honey, resulting in improved health outcomes, reduced morbidity and mortality, and stabilized performance indicators across broiler flocks. These findings underscore the urgency and feasibility of developing NGPs from locally available herbal resources. The strategic adoption of moringa and andrographis in poultry nutrition represents not only a viable alternative to AGPs but also a forward looking approach that integrates animal health, food safety, environmental sustainability, and rural economic empowerment. As the broiler industry continues to evolve in response to growing consumer demand and regulatory scrutiny, the development and implementation of scientifically validated natural feed additives will be instrumental in shaping the future of sustainable poultry production.

**2.** The Potential of Moringa oleifera and Andrographis paniculata as Natural Feed Additives

This subchapter examines the potential of Moringa oleifera and Andrographis paniculata as natural feed additives in poultry nutrition. The analysis is cantered on two primary aspects: the nutritional content and phytochemical composition of Moringa oleifera, and the phytochemical profile of Andrographis paniculata. Both sections offer a comprehensive review of the bioactive compounds and nutrient content that underpin the functional properties of these two plants, which are increasingly acknowledged for their antimicrobial, antioxidant, and growth-promoting effects. The information provided establishes a scientific foundation for understanding the mechanisms by which these plant-based additives enhance poultry health and productivity.

## 2.1 Nutrient Content and Phytochemical Profile of Moringa oleifera

The leaves of Moringa oleifera exhibit a noteworthy phytochemical profile and nutrient composition, rendering them suitable as additives in broiler feed. The phytochemicals present in Moringa leaves encompass significant compounds such as flavonoids, tannins, saponins, and alkaloids. These compounds not only possess antioxidant properties but also contribute to the health and growth of broiler chickens. Empirical studies have demonstrated that the antioxidant content in Moringa leaves can enhance the chickens' resistance to oxidative stress, thereby potentially improving their health and growth performance [13, 14]. The nutritional composition, mineral profile, and antioxidant activity of Moringa oleifera leaves, as detailed in Tables 1, 2, and 3, underscore their abundant content of proteins, essential minerals, and bioactive compounds [13].

**Table 1. Nutrient Content of *Moringa oleifera* Leaf**

| Parameters | Mean Value (g/100g Dry Matter) |
| --- | --- |
| Moisture | 7.23 ± 0.12 |
| Protein | 25.30 ± 0.27 |
| Lipid | 5.75 ± 0.21 |
| Ash | 9.95 ± 0.12 |
| Carbohydrates | 29.80 ± 4.55 |
| Dietary fiber | 24.97 ± 4.55 |

**Table 2. Mineral Content of Moringa oleifera Leaf**

| Minerals | Mean Value (mg/100 g Dry Matter) |
| --- | --- |
| Boron (B) | 3.54 ± 0.01 |
| Calcium (Ca) \* | 1.48 ± 0.01 g |
| Copper (Cu) | 0.45 ± 0.05 |
| Iron (Fe) | 25.14 ± 1.13 |
| Potassium (K) \* | 1.75 ± 0.02 g |
| Magnesium (Mg) | 301.11 ± 2.08 |
| Manganese (Mn) | 7.21 ± 1.03 |
| Sodium (Na) | 133.11 ± 20.09 |
| Phosphorus (P) | 352.39 ± 1.19 |
| Sulphur (S) | 982.49 ± 11.56 |
| Zinc (Zn) | 2.04 ± 0.85 |

*Note: (\*) Values are expressed in g/100 g DM.*

**Table 3. Antioxidant Activity and Total Phenolic Content of Moringa oleifera Leaf**

| Method | Mean ± SD |
| --- | --- |
| Total phenolic content (mg GAE/g) | 32.90 ± 4.38 |
| Ferric Reducing Antioxidant Power (µmol TE/g) | 396.43 ± 17.12 |
| Oxygen Radical Absorbance Capacity (µmol TE/g) | 3197.24 ± 19.65 |
| ABTS Scavenging Activity (%) | 41.40 ± 8.66 |

The nutritional profile of Moringa is notably rich, encompassing a substantial amount of protein, minerals, and antioxidants. The phytochemical and nutrient composition of Moringa contributes to its efficacy as a feed additive. For instance, the saponins found in Moringa leaves can act as fat-binding agents, aiding in the regulation of fat in poultry diets [14]. Furthermore, flavonoids may enhance metabolism and nutrient absorption [13]. Incorporating Moringa leaves into broiler diets can meet the nutritional requirements essential for the growth and development of chickens, while also addressing malnutrition issues [15–17].

Research investigating the incorporation of moringa into broiler diets has demonstrated enhancements in body weight, feed efficiency, and overall health of the chickens [15]. The inclusion of moringa in these diets has been associated with notable growth improvements, as evidenced by enhanced feed conversion rates in chickens receiving moringa-supplemented diets compared to those on control diets without moringa [13, 18]. These findings underscore the potential of moringa to reduce reliance on synthetic additives in poultry feed. Moringa leaves offer a complex array of nutrients, functioning not only as a protein source but also as a health protector for broilers [19].

Despite the many benefits identified in the use of moringa as a chicken feed additive, it is important to continue further research to confirm the long-term effects and metabolic aspects of moringa consumption by broiler chickens. The understanding of these effects may vary depending on practical decisions in chicken rearing. More in-depth research is needed to evaluate the long-term effects of moringa use as a feed additive and to establish quality standards and standardized procedures for its use in the feed industry.

## 2.2 Phytochemical Profile of Andrographis paniculata

*Andrographis paniculata* popularly called the “King of Bitters,” has long been valued in Asian materia medica for treating fever, infections, and hepatobiliary disorders. Modern phytochemical investigations attribute much of this plant’s therapeutic breadth to a constellation of diterpenoid lactones and flavonoids, among which andrographolide is the pre-eminent bioactive molecule [20]. Understanding the chemistry, biological actions, and translational challenges of andrographolide is therefore pivotal to rationalising the evidence-based use of *A. paniculata* in contemporary pharmacotherapy.

*Andrographis  paniculata* its functional prominence in animal nutrition to a dense matrix of bioactive secondary metabolites supported by a modest yet valuable nutrient profile. The signature constituents are labdane type diterpenoids, among which andrographolide (AGL) predominates, accompanied by 14‑deoxyandrographolide and neoandrographolide [21]. These diterpenoids constitute 1.5 – 3.0 % of leaf dry matter and account for more than 60 % of total quantified bioactives in ethanolic extracts [22]. Structural analyses reveal a decalin core bearing a γ‑butyrolactone fused at C‑12/C‑16; polyhydroxy substitutions confer amphipathic characteristics that underpin both membrane interaction and redox modulation [23].

Andrographolide is a bicyclic diterpenoid featuring a labdane skeleton fused into a decalin system with a terminal γ-butyrolactone ring. Three hydroxyl residues positioned at C-3, C-14, and C-19 confer amphipathic characteristics that enhance solubility and facilitate partitioning into biological membranes [20]. These structural attributes not only underpin its broad pharmacodynamic profile but also allow meaningful interactions with intracellular signalling proteins and lipid bilayers. The pharmacological portfolio of andrographolide is remarkably diverse. Anti-inflammatory activity, arguably the most thoroughly characterized property, stems from suppression of nuclear factor-κB translocation and downstream cytokine transcription, thereby attenuating production of TNF-α, IL-1β, and IL-6 [24, 25]. Antimicrobial efficacy has been demonstrated for ethanolic extracts rich in diterpenes, which markedly inhibit *Escherichia coli* and other food-borne pathogens, highlighting potential applications in food safety stewardship [26]. Hepatoprotective effects emerge in chemically induced liver injury models, where andrographolide limits lipid peroxidation and restores antioxidant enzyme activities, safeguarding hepatocyte viability [27, 28]. Anticancer investigations reveal pro-apoptotic and antimitogenic actions across diverse tumour lines effects mediated by reactive oxygen species accumulation and mitochondrial membrane depolarization [29, 30]. Antidiabetic studies in rodent models document improved glycaemic control through enhanced insulin sensitivity and modulation of hepatic gluconeogenesis [31, 32].

At the mechanistic level, andrographolide acts as a pleiotropic modulator of cellular signalling networks. It interferes with Janus kinase/signal transducer and activator of transcription (JAK/STAT) cascades, curbing inflammatory gene expression and dampening aberrant immune activation [24]. Concurrently, its intrinsic antioxidant capacity directly scavenges free radicals while indirectly up regulating endogenous defences such as superoxide dismutase and glutathione peroxidase [25]. The molecule’s amphipathic nature promotes reversible insertion into phospholipid bilayers, subtly altering membrane fluidity and receptor microenvironment an effect postulated to modulate downstream signal transduction [27].

Despite these compelling bioactivities, among them is poor oral bioavailability attributable to limited aqueous solubility, presystemic metabolism, and rapid clearance. Nano encapsulation, liposomal delivery, and structural analogues are under active investigation to overcome these barriers [28]. Equally critical is the phytochemical variability driven by genotype, agro-ecological conditions, and extraction technology; rigorous standardisation and quality-control frameworks are required to guarantee consistent andrographolide content [32]. *A. paniculata* embodies a phytochemical arsenal whose flagship compound, andrographolide, manifests anti-inflammatory, antimicrobial, hepatoprotective, anticancer, and antidiabetic properties through multifaceted biochemical routes. Continued research aimed at optimising delivery systems, elucidating structure–activity relationships, and standardising botanical preparations will be indispensable for translating centuries of empirical use into reproducible, safe, and efficacious clinical interventions.

# 3. THE EFFECT OF LIQUID EXTRACT LEVELS OF MORINGA OLEIFERA AND ANDROGRAPHIS PANICULATA ON BROILER PERFORMANCE

This chapter presents and interprets the findings of the study investigating the effects of liquid extract supplementation of Moringa oleifera and Andrographis paniculata at varying levels (0%, 0.25%, 0.50%, and 0.75%) on broiler performance and gut microbiological characteristics. The discussion is structured into sub-sections based on observed production parameters and microbiological profiles, providing a comprehensive and critical analysis based on statistical evidence and relevant literature.

## 3.1. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Broiler Feed Intake

Feed intake in broilers refers to the total amount of feed consumed during a given period. Statistical analysis revealed that varying levels of the liquid extract used as a feed additive significantly affected broiler feed intake (P<0.05). The inclusion of liquid extract in the diet influenced feed efficiency in broilers. The mean feed intake across treatments was as follows: 3470.75 ± 71.76 g/bird (L2 = 0.5%), 3501.5 ± 68.36 g/bird (L0 = 0%), 3557.75 ± 58.76 g/bird (L3 = 0.75%), and 3587.25 ± 71.76 g/bird (L1 = 0.25%). The lowest average feed intake occurred at the 0.50% supplementation level.



**Fig. 1. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Feed Intake**

The trend indicates that higher supplementation levels were associated with decreased feed intake. This may be due to the presence of bioactive compounds such as andrographolide, saponins, flavonoids, and tannins in Andrographis paniculata, which are known to enhance immune response [33].

The main bioactive compounds in *Moringa oleifera* include flavonoids (quercetin, kaempferol), saponins, tannins, alkaloids, and glucosinolates. *Andrographis paniculata* is rich in andrographolide, flavonoids, and terpenoids. Flavonoids and alkaloids stimulate metabolism and appetite, while low concentrations of saponins and tannins may enhance digestive secretions. Despite their bitter nature, these compounds trigger salivary and gastric enzyme secretion, indirectly improving feed intake. These bitter phytochemicals stimulate taste receptors and digestive reflexes, increasing saliva and pancreatic enzyme secretion, which enhances digestive efficiency. Andrographolide also exhibits anti-inflammatory effects that support gut integrity, though high doses may suppress appetite due to antinutritional effects.

Additionally, essential oils and phenolic compounds exert antimicrobial activity by interacting with bacterial cell structures [34]. Simple sugars like rhamnose, glucosinolates, and isothiocyanates in Moringa oleifera contribute to hypotensive, anticancer, and antibacterial effects [35]. Other compounds such as papain, alkaloids, and saponins enhance immune performance [36]. Essential oils and ethanol in Kaempferia rhizomes provide anti-inflammatory benefits [36].

Essential oils (e.g., eugenol, thymol) and phenolic compounds disrupt pathogenic bacterial membranes via protein denaturation and permeability alteration. This suppresses harmful bacteria and supports the growth of beneficial microbiota, leading to improved gut health and feed palatability. Furthermore, xanthorrhizol and curcuminoids in Curcuma xanthorrhiza possess cholagogue properties, promoting bile and pancreatic secretions. Antibacterial properties of phytochemicals in Moringa and Andrographis extracts, particularly those with hydroxyl groups (-OH), can disrupt bacterial membranes via hydrogen bonding, leading to cell lysis and protein coagulation [37]. This antimicrobial effect helps suppress pathogenic bacteria and favors the growth of beneficial gut microbiota, thereby improving nutrient digestion and absorption.

Analysis of variance showed that the 0.25% supplementation level was the most effective in improving feed efficiency. Body weight gains tended to increase with higher supplementation levels (0–0.75%). The bitterness of bioactives such as andrographolide, saponins, flavonoids, and tannins may stimulate salivary secretion, thereby enhancing feed intake. This bitterness is also linked to improved immune responses, including increased antibody production and inhibition of viral attachment [38].

Phenolic compounds like gingerol and shogaol from ginger act as antioxidants, with a positive correlation between total phenol content and antioxidant activity. Besides their antioxidative roles, phenolics exert strong antibacterial effects by disrupting both Gram-negative and Gram-positive bacterial cell walls [39]. A well-functioning immune system is essential for gut health, preventing inflammation and maintaining the integrity of the intestinal mucosa, which in turn supports nutrient uptake and feed utilization.

This is consistent with [40] who noted that the mechanism of antibiotic growth promoters (AGPs) includes protecting feed from microbial degradation, enhancing nutrient absorption via intestinal barrier stabilization, and reducing toxin production and infections in the gut. These mechanisms ultimately improve feed conversion efficiency through better nutrient absorption. Optimal feed intake enhances the availability of essential nutrients for growth and immune response. Nutrients like amino acids, vitamins, and trace minerals support tissue synthesis and antibody production. Additionally, phytogenic additives modulate immune function by increasing intestinal IgA production.

## 3.2. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Broiler Body Weight

Body weight in broilers refers to the live weight measured either during the rearing period or at market age. The statistical analysis presented in Table 4 shows that the inclusion of different levels of liquid extracts as feed additives significantly affected broiler body weight (P<0.05). The inclusion of Moringa oleifera and Andrographis paniculata extract enhanced body weight, indicating improved growth efficiency. The mean body weights observed were 2225.4 ± 68.22 g/bird (L0 = 0%), 2235.22 ± 36.79 g/bird (L1 = 0.25%), 2260.79 ± 30.26 g/bird (L2 = 0.50%), and 2300.82 ± 36.71 g/bird (L3 = 0.75%).



**Fig. 2. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Body Weight**

The significantly higher body weight observed in the 0.75% treatment level aligned with the improved feed intake results. Body weight gain in broiler is strongly influenced by the amount of feed consumed. Feed protein provides essential amino acids required for tissue synthesis. Adequate feed intake ensures the availability of amino acids for muscle and tissue development. Flavonoids, saponins, tannins, alkaloids, and andrographolide are the main phytochemicals. Their antioxidant and anti-inflammatory activities enhance digestive health and nutrient utilization, which promotes body weight gain [36]. An intact mucosal layer ensures effective nutrient absorption and prevents endotoxin translocation. Damage from inflammation or infection reduces nutrient uptake and growth. Herbal supplements help restore mucosal integrity through their bioactive compounds.

Analysis of variance confirmed that the 0.75% inclusion level was most effective in increasing body weight. The positive growth trend observed at higher extract levels may be attributed to the bioactive compounds in the phytogenic extracts, including anti-inflammatory, antioxidant, antibacterial, and immunomodulatory properties. Flavonoids and terpenoids in *Andrographis paniculata* support intestinal mucosal integrity and reduce inflammation caused by pathogenic bacteria, thereby optimizing nutrient absorption.

Antioxidants such as tannins, phenols, and flavonoids help protect cells from damage caused by oxidative stress. Reducing oxidative stress can enhance the integrity of digestive tissues and support more efficient nutrient absorption, directly benefiting body weight gain. broilers are vulnerable to heat-induced stress, which negatively affects nutrient absorption, health, and survival rates, ultimately reducing productivity. Antioxidants play a vital role in mitigating oxidative stress and maintaining cellular oxygen balance.

Moreover, the antibacterial compounds in *Moringa* and *Andrographis* help maintain a healthy gut microbiota by suppressing pathogens. They work by damaging the bacterial cell wall and causing cell death, thus creating favorable conditions for beneficial bacteria to thrive, further improving nutrient utilization. Increased feed intake and efficient protein utilization from herbal supplementation led to better muscle development. Enzymes like papain also aid protein breakdown and absorption, promoting growth.

## 3.3. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Feed Conversion Ratio (FCR) in Broilers

The Feed Conversion Ratio (FCR) is a crucial indicator representing the amount of feed required by broiler chickens to gain one kilogram of body weight. Statistical analysis revealed that the application of various levels of liquid extract feed additives had a significant effect (P<0.05) on the FCR of broilers. This result indicates that the inclusion level of the Moringa and Andrographis liquid extract in feed influenced the efficiency with which broilers converted feed into body mass.



**Fig. 3. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Feed Conversion Ratio (FCR)**

The lowest FCR was achieved at the 0.75% supplementation level, indicating superior feed efficiency at this dose. This significant difference is likely attributable to the direct relationship between feed consumption, body weight gain, and FCR. FCR values are determined by the balance between the feed intake and the resulting body weight gain. An increased feed intake without a corresponding increase in body weight will lead to a higher (poorer) FCR, while proportional weight gain will maintain or reduce FCR, signifying more efficient feed utilization.

Analysis of variance confirmed that the 0.75% extract level was the most effective in reducing FCR. This implies that increasing the extract level up to 0.75% can significantly enhance feed efficiency. This improvement may be attributed to the presence of bioactive compounds such as essential oils, phenolic compounds, saponins, tannins, and curcumin in the extract, which have been shown to possess strong antibacterial properties. These compounds help regulate the intestinal microbial population, particularly by reducing the presence of pathogenic bacteria that can compromise nutrient digestion and absorption.

Antibacterial compounds exert their effects by disrupting bacterial cell wall synthesis, altering membrane functions, and inhibiting protein and nucleic acid synthesis in pathogenic microbes [41]. Additionally, the phytogenic extract may contain beneficial actinomycetes (e.g., Streptomyces), which are known to produce antibacterial, antifungal, and antiparasitic substances. These metabolites support the growth of beneficial gut bacteria such as Bacteroidetes, which can hydrolyze undigestible polysaccharides like cellulose and produce organic acids (e.g., propionate and succinate) with anti-inflammatory and gut-protective functions [42].

Moreover, the presence of antioxidant compounds in the liquid extract helps neutralize free radicals and alleviate oxidative stress, particularly in gastrointestinal tissues. This supports nutrient absorption and utilization. Turmeric (a source of curcuminoids and essential oils) provides antioxidative, anti-inflammatory, and antibacterial effects, improves digestive enzyme secretion, and promotes tissue regeneration [43]. The essential oils in the extract are responsible for a broad range of biological activities, including antioxidant, antifungal, antiviral, antiparasitic, antibacterial, and anti-inflammatory actions, all of which contribute to lower FCR and better feed efficiency in broilers.

## 3.4. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on the Production Index (IP) of Broilers

The Production Index (IP) is a composite performance indicator that reflects the overall efficiency and productivity of broiler chickens. It encompasses key performance metrics, including growth rate, feed efficiency, survivability, and body weight. Statistical analysis demonstrated that the inclusion of liquid extracts at different levels significantly influenced (P<0.05) the IP of broilers.

The highest production index was obtained with a 0.75% inclusion level of the liquid extract. The significant differences in IP were closely related to the variations in body weight and FCR, which were also significantly affected by the extract supplementation. This confirms the close interrelation between growth performance, feed efficiency, and overall production output.



**Fig. 4. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Production Index (IP)**

The higher the body weight achieved within a given time frame, the more favorable the IP value, reflecting better growth performance. Moreover, FCR efficiency directly affects production costs [44]. A lower FCR implies more efficient feed utilization, reducing the cost per unit of body weight gained and enhancing IP scores.

Analysis of variance further showed that supplementation with 0.25% and 0.75% extract levels was effective in improving broiler IP. The data suggests that increasing the extract concentration leads to better broiler performance across the production cycle. Typical IP values for broilers in open-house systems range between 260 and 370, while closed-house systems can achieve IPs of 400 to 420 [45]. In the present study, only the 0.25% and 0.75% extract levels exceeded the IP standard for closed-house rearing, confirming their effectiveness in enhancing broiler performance.

These improvements may be linked to the presence of papain, an enzyme known for its protein-digesting ability as well as its antimicrobial and antioxidant properties. Papain enhances nutrient absorption, supports intestinal health, and reduces infections, all of which contribute to increased body weight and feed efficiency. Papain at 2.5% concentration effectively inhibits *Staphylococcus aureus* by breaking down microbial proteins into simpler dipeptides and amino acids [46]. Thus, the bioactivity of the extract not only supports digestion but also protects gut health, enhancing overall productivity.

## 3.5. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on IOFC in Broilers

Income Over Feed Cost (IOFC) represents the net income derived from the sale of broilers after accounting for feed expenses. It is a key economic indicator in poultry production. Statistical analysis showed that the inclusion of different levels of liquid extracts significantly affected broiler IOFC (P<0.01). The findings suggest that varying the concentration of Moringa and Andrographis liquid extract in the feed can enhance the economic efficiency of broiler production.

The highest IOFC was achieved at the 0.75% supplementation level. The highly significant increase in IOFC is likely due to the improvements observed in body weight gain and feed conversion, which were also significantly influenced by the treatment. IOFC is closely tied to FCR values. Efficient feed conversion translates to better economic returns, as it reduces the cost of producing each kilogram of broiler meat. Calculating IOFC requires considering feed cost, total feed intake, and the selling price of the chickens. Efficient feed utilization—achieved when feed is converted into body mass effectively—improves IOFC. Conversely, poor FCR leads to higher feed expenses and reduced income. Drop in IOFC directly reduces gross income.



**Fig. 5. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Income Over Feed Cost (IOFC)**

The analysis also indicated that the 0.75% extract inclusion was the most effective in enhancing IOFC. A linear improvement was observed across the range from 0% to 0.75%, suggesting that higher extract concentrations in the diet increase the bioactive content consumed, which in turn improves nutrient absorption, digestion, and body weight gain. IOFC improves when feed costs are minimized without compromising feed quality, and body weight gains are maximized. Higher extract levels increase the presence of functional phytochemicals, enhancing feed utilization efficiency. Similarly, a combination of red ginger, turmeric, and *Phyllanthus niruri* powders at 16 g/kg feed significantly improved protein digestion [47]. The essential oils in red ginger and turmeric stimulate pancreatic enzyme secretion (protease, amylase, lipase), which are vital for digesting proteins, carbohydrates, and fats.

In conclusion, enhancing IOFC through the addition of herbal extracts is feasible and economically beneficial, especially at the 0.75% inclusion level, which offers the highest return on feed investment without additional feed cost burden.

**4. The Impact of Moringa (Moringa oleifera) and Sambiloto (Andrographis paniculata) on Gut Microbiota of Broiler Chickens**

This subchapter elucidates and interprets the findings regarding the impact of Moringa oleifera and Andrographis paniculata on gut microbiota composition. The discussion is organized into three subsections: the role of these phytogenic feed additives in modulating populations of Lactobacillus, Escherichia coli, and Salmonella spp. within the gastrointestinal tract. Each section is structured with a critical analysis supported by experimental findings and relevant scientific literature, highlighting the functional benefits of incorporating Moringa and Andrographis extracts into chicken feed.

## 4.1 Role in Gut Microbiota: Modulation of *Lactobacillus*, *Escherichia coli*, and *Eimeria* spp. Populations

Moringa and sambiloto exhibit significant potential as natural feed additives due to their capacity to modulate the gut microbiota composition in broiler chickens. These herbal additives can substantially influence the populations of key microbial groups, including beneficial bacteria such as Lactobacillus, opportunistic pathogens like Escherichia coli, and protozoan parasites such as Eimeria spp. By fostering the proliferation of probiotics and inhibiting harmful microorganisms, both plants contribute to enhanced intestinal health, improved immune responses, and increased disease resistance in broiler chickens.

The gastrointestinal tract of broiler chickens constitutes a complex habitat for diverse microorganisms that play critical roles in animal health and performance. The composition of the gut microbiota is affected by various factors, including feed type, additives used, and environmental conditions. The application of natural feed additives such as moringa leaves (Moringa oleifera) and andrographis (Andrographis paniculata) has been demonstrated to modulate the gut microbiota of broiler chickens, particularly impacting three major groups of microorganisms: beneficial bacteria (Lactobacillus), opportunistic pathogens (Escherichia coli), and protozoan parasites (Eimeria spp.). Lactobacillus, recognized as a probiotic, plays a crucial role in maintaining gut health and enhancing nutrient absorption, while E. coli and Eimeria spp. are identified as potential pathogens that can adversely affect poultry health.

Moringa leaves are abundant in bioactive compounds, including flavonoids, tannins, saponins, and phenolic acids, which possess antibacterial and antioxidant properties. These compounds inhibit the proliferation of pathogenic microorganisms through mechanisms such as the disruption of cell wall synthesis, alteration of membrane permeability, and inactivation of metabolic enzymes. Furthermore, complex polysaccharides and prebiotic compounds present in Moringa oleifera and Andrographis paniculata act as fermentation substrates for probiotic bacteria, thereby fostering the growth of lactic acid bacteria.

Moringa oleifera extract has demonstrated antimicrobial activity that enhances gut health in broiler chickens. The plant's high phytochemical content, particularly flavonoids and polyphenols, supports the proliferation of beneficial microflora such as Lactobacillus while inhibiting the growth of pathogenic organisms like E. coli and Eimeria spp. Studies have indicated that the inclusion of moringa in poultry feed significantly increases Lactobacillus populations in the gut, correlating with a reduction in the prevalence of E. coli and Eimeria spp. [48–51].

Andrographis paniculata, commonly known as sambiloto, contains andrographolide, a diterpenoid lactone with recognized antiparasitic and immunomodulatory properties. In the context of Eimeria spp. infections—the primary cause of coccidiosis in broiler chickens—sambiloto extract has been shown to reduce oocyst counts in feces. Its anti-inflammatory and antimicrobial activities further enhance its positive effects on the gut microbiota [52]. These findings underscore the potential of sambiloto as a natural alternative to synthetic coccidiostats.

The combined use of moringa and sambiloto fosters a healthier intestinal environment by increasing beneficial bacterial populations, suppressing enteric pathogens, and controlling protozoal infections. This phytogenic intervention not only supports gut health but also improves feed conversion efficiency and overall growth performance in broiler chickens. The integration of these herbal additives into poultry feed has been associated with enhanced intestinal health, better feed utilization, and improved meat quality, particularly during the growth and finishing phases [53, 54].

### 4.1.1 Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Escherichia coli Counts in Broiler Intestines

*Escherichia coli* (*E. coli*) is a rod-shaped bacterium belonging to the *Enterobacteriaceae* family. While *E. coli* normally exists as a commensal organism in the intestines of humans and warm-blooded animals, certain strains can act as pathogens, affecting poultry health and productivity. Statistical analysis showed that varying the levels of liquid extract supplementation significantly affected (P<0.01) *E. coli* populations in broiler digesta.



**Fig. 6. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Escherichia coli Counts**

The lowest *E. coli* population was observed at the 0.75% extract supplementation level, indicating a 19.2% reduction from the control. This significant decline in *E. coli* levels is likely attributable to the antibacterial properties of the phytogenic and probiotic compounds found in the extract. These compounds can disrupt bacterial cell membranes, cause leakage of intracellular contents, and ultimately lead to cell death.

Bioactive compounds such as eugenol and various terpenoids (e.g., seychellene, pogostol, pogostone) possess strong antibacterial and antifungal activity. These substances interact with membrane proteins and disrupt cell integrity, effectively suppressing bacterial growth. Probiotics such as EM-4—which contain Lactobacillus, yeast, actinomycetes, and photosynthetic bacteria (Rhodopseudomonas palustris)—support feed efficiency by enhancing the digestion of fats, crude fiber, and proteins while producing antibacterial metabolites that inhibit pathogenic microbes.

Analysis of variance confirmed that supplementation with 0.75% extract was the most effective in lowering E. coli counts. As the concentration of the extract increased, so did the availability of bioactive compounds such as curcumin, essential oils, phenolics, saponins, and tannins—all known for their antibacterial effects.

Papain at a concentration of 2.5% inhibited Staphylococcus aureus by digesting microbial proteins into simpler peptides and amino acids. Additionally, curcumin has multiple bioactive functions, including antibacterial properties, with proven safety at high doses, low cost, and wide availability—making it a promising alternative to conventional antibiotics [54].

Moreover, lactic acid bacteria (LAB) produce lactic acid, which lowers intestinal pH and creates an inhospitable environment for pathogens like E. coli. Reductions in pH across the duodenum, jejunum, ileum, and cecum effectively suppress E. coli and Salmonella populations in broilers [55]. This acidic shift, driven by LAB activity, is a key mechanism in maintaining intestinal microbial balance and enhancing broiler gut health.

### 4.1.2 Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Salmonella sp. Counts in Broiler Intestines

*Salmonella* spp. are pathogenic bacteria belonging to the *Enterobacteriaceae* family and are well-known for causing infections in both humans and animals. In poultry, *Salmonella* can impair health, reduce productivity, and pose a significant risk of contamination in food products. Statistical analysis revealed that different levels of liquid extract supplementation significantly influenced (P<0.01) the population of *Salmonella sp.* in the digesta of broiler chickens.

The lowest *Salmonella* count was observed at the 0.50% supplementation level, indicating that intermediate inclusion was most effective in suppressing this pathogenic bacterium. The significant differences among treatment levels suggest a correlation with the increased presence of lactic acid bacteria (LAB), which was also observed in this study. LABs are known to produce lactic acid, lowering gut pH and creating an unfavorable environment for the growth of *Salmonella sp.*



**Fig. 7. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Salmonella sp. Counts**

A decrease in gut pH—especially in the duodenum, jejunum, ileum, and cecum—can promote the growth of non-pathogenic bacteria such as *Lactobacillus* while suppressing *Escherichia coli* and *Salmonella*. An acidic gut environment inhibits pathogen proliferation, and LABs contribute to this by producing bacteriocins—antimicrobial compounds that inhibit or kill *Salmonella* spp.

The presence of LABs is vital due to the high pathogenic potential of *Salmonella* and *E. coli*. Antimicrobial activity against such pathogens is essential not only for improving poultry performance but also for preventing contamination in animal-derived food products [21]. Analysis of variance further confirmed that the 0.50% inclusion level of the herbal liquid extract was the most effective in reducing *Salmonella* populations. As the level of extract supplementation increased up to 0.50%, a clear decline in *Salmonella* counts was observed—from 4.36 ± 0.06 Log CFU/mL (L0) to 3.43 ± 0.06 Log CFU/mL (L2). This significant reduction was attributed to the increased concentration of antimicrobial compounds found in phytogenic and probiotic elements of the extract.

Flavonoids significantly reduce pathogenic bacteria in the broiler intestine [55]. Flavonoids disrupt bacterial function by coagulating cellular proteins, which undergo denaturation and subsequently lose their biological activity. Essential oils interfere with bacterial protein structures via denaturation and coagulation, impairing bacterial viability.

In summary, liquid extract supplementation at 0.50% was most effective in reducing *Salmonella sp.* levels in broiler intestines, likely due to the synergistic antibacterial actions of flavonoids, essential oils, and low pH from LAB activity.

### 4.1.3 Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Lactic Acid Bacteria (LAB) Counts in Broiler Intestines

Lactic Acid Bacteria (LAB) are beneficial microorganisms capable of fermenting carbohydrates—particularly glucose—into lactic acid. They are naturally found in organic-rich environments such as the gastrointestinal tracts of animals, fermented foods, and plants. In broilers, LAB contribute significantly to gut health and the suppression of pathogenic microbes. Statistical analysis demonstrated that supplementation with different levels of *Moringa oleifera* and *Andrographis paniculata* liquid extracts significantly influenced (P<0.01) LAB populations in the intestinal digesta of broilers.



**Fig. 8. Effect of Liquid Extract Levels of Moringa oleifera and Andrographis paniculata on Lactic Acid Bacteria (LAB) Counts**

The highest LAB count was observed in broilers receiving the 0.75% extract supplementation level. The increasing trend in LAB populations with higher extract levels is likely attributed to the presence of nutrients and probiotic-supporting compounds in the extract—such as photosynthetic bacteria that provide nitrogen, a critical nutrient for LAB growth. Both organic and inorganic nitrogen sources are essential for the proliferation of LAB, along with carbohydrate substrates [56].

The variance analysis confirmed that the 0.75% inclusion level was the most effective for boosting LAB counts. This aligns with the findings of [57], who noted that supplementation with 1.5% Moringa leaf powder enhanced LAB populations in the gut. Antioxidants in Moringa can disrupt pathogenic bacteria by denaturing their membrane proteins, thereby reducing their metabolic activity and allowing beneficial bacteria like LAB to dominate.

Additionally, fermented fungi such as Aspergillus are known to produce weak organic acids like citric, oxalic, and gluconic acids [58]. These acids contribute to lowering intestinal pH by releasing hydrogen ions (H⁺) during short-chain fatty acid dissociation. This creates an acidic environment in the gut, which is favorable for LAB proliferation [59]. LAB growth is optimal in low pH conditions and is essential for non-ruminant animals like broilers, as it plays a critical role in pathogen suppression and overall digestive health. Importance of maintaining a large LAB population in the gut to outcompete and suppress harmful bacteria. As the LAB population increases, the presence of pathogens like E. coli and Salmonella tends to decrease, resulting in improved nutrient absorption and enhanced animal productivity. The higher LAB levels correlate with better poultry performance due to their role in enhancing gut integrity and immune function.

In conclusion, the supplementation of *Moringa* and *Andrographis* liquid extracts at 0.75% effectively increases LAB counts in the broiler gut, promotes a balanced microbiota, and supports better nutrient utilization and growth performance.

**4. Conclusion**

Moringa oleifera and Andrographis paniculata provide more than just essential nutrients for broiler chickens. The bioactive compounds found in these plants contribute to enhanced gut health, strengthened immune function, and improved meat quality. Supplements derived from these botanical sources lead to increased broiler performance, including feed intake, body weight, FCR, and IOFC. These plants offer a sustainable alternative to antibiotic growth promoters; however, further research is necessary to determine optimal dosages, feeding strategies, and to assess long-term effects.

**References**

1. Magothe, T. M., Okeno ,T.O., Muhuyi ,W.B., & and Kahi, A. K. (2012). Indigenous chicken production in Kenya: I. Current status. *World’s Poultry Science Journal*, *68*(1), 119–132. https://doi.org/10.1017/S0043933912000128

2. Vasdal, G., Granquist, E. G., Skjerve, E., de Jong, I. C., Berg, C., Michel, V., & Moe, R. O. (2019). Associations between carcass weight uniformity and production measures on farm and at slaughter in commercial broiler flocks. *Poultry Science*, *98*(10), 4261–4268. https://doi.org/10.3382/ps/pez252

3. Mairizal, M. (2013). Pengaruh Penggantian Sebagian Ransum Komersil dengan Bungkil Kelapa Hasil Fermentasi dengan Effective Microorganism-4 (Em-4) terhadap Bobot Karkas Ayam Pedaging. *Jurnal Peternakan Indonesia (Indonesian Journal of Animal Science)*, *15*(1), 46–51. https://doi.org/10.25077/jpi.15.1.46-51.2013

4. Rahman, R., Wahyono, T., Hidayat, C., Krisnan, R., & Malalantang, S. S. (2017). Penerapan Recursive Linear Model (Rlm) Dalam Pendugaan Berat Badan Ayam Broiler Dan Ayam Lokal. *Jurnal Ilmu dan Teknologi Peternakan Tropis*, *4*(3), 26–33. https://doi.org/10.33772/jitro.v4i3.3650

5. Maron, D. F., Smith, T. J. S., & Nachman, K. E. (2013). Restrictions on antimicrobial use in food animal production: an international regulatory and economic survey. *Globalization and Health*, *9*, 48. https://doi.org/10.1186/1744-8603-9-48

6. Gadde, U., Kim, W. H., Oh, S. T., & Lillehoj, H. S. (2017). Alternatives to antibiotics for maximizing growth performance and feed efficiency in poultry: a review. *Animal Health Research Reviews*, *18*(1), 26–45. https://doi.org/10.1017/S1466252316000207

7. Gomez-Osorio, L.-M., Yepes-Medina, V., Ballou, A., Parini, M., & Angel, R. (2021). Short and Medium Chain Fatty Acids and Their Derivatives as a Natural Strategy in the Control of Necrotic Enteritis and Microbial Homeostasis in Broiler Chickens. *Frontiers in Veterinary Science*, *8*. https://doi.org/10.3389/fvets.2021.773372

8. Adu, O. A., Gbore, F. A., Oloruntola, O. D., Falowo, A. B., & Olarotimi, O. J. (2020). The effects of Myristica fragrans seed meal and Syzygium aromaticum leaf meal dietary supplementation on growth performance and oxidative status of broiler chicken. *Bulletin of the National Research Centre*, *44*(1), 149. https://doi.org/10.1186/s42269-020-00396-8

9. Krumbeck, J. A., Maldonado-Gomez, M. X., Martínez, I., Frese, S. A., Burkey, T. E., Rasineni, K., … Walter, J. (2015). In Vivo Selection To Identify Bacterial Strains with Enhanced Ecological Performance in Synbiotic Applications. *Applied and Environmental Microbiology*, *81*(7), 2455–2465. https://doi.org/10.1128/AEM.03903-14

10. Li, H.-Y., Zhou, D.-D., Gan, R.-Y., Huang, S.-Y., Zhao, C.-N., Shang, A., … Li, H.-B. (2021). Effects and Mechanisms of Probiotics, Prebiotics, Synbiotics, and Postbiotics on Metabolic Diseases Targeting Gut Microbiota: A Narrative Review. *Nutrients*, *13*(9), 3211. https://doi.org/10.3390/nu13093211

11. Stopponi, S., Fotio, Y., Cifani, C., Li, H., Haass-Koffler, C. L., Cannella, N., … Ciccocioppo, R. (2021). Andrographis paniculata and Its Main Bioactive Ingredient Andrographolide Decrease Alcohol Drinking and Seeking in Rats Through Activation of Nuclear PPARγ Pathway. *Alcohol and Alcoholism*, *56*(2), 240–249. https://doi.org/10.1093/alcalc/agaa136

12. Zhang, H., Huang, L., Hu, S., Qin, X., & Wang, X. (2023). Moringa oleifera Leaf Powder as New Source of Protein-Based Feedstuff Improves Growth Performance and Cecal Microbial Diversity of Broiler Chicken. *Animals*, *13*(6), 1104. https://doi.org/10.3390/ani13061104

13. Peñalver, R., Martínez-Zamora, L., Lorenzo, J. M., Ros, G., & Nieto, G. (2022). Nutritional and Antioxidant Properties of Moringa oleifera Leaves in Functional Foods. *Foods*, *11*(8), 1107. https://doi.org/10.3390/foods11081107

14. Prayitno, S. A., Patria, D. G., Mardiana, N. A., Utami, D. R., Kusumawati, R., Rochma, N. A., & Niam, M. K. (2022). Fortification of Moringa oleifera Flour on Quality of Wet Noodle. *Food Science and Technology Journal (Foodscitech)*, 63–70. https://doi.org/10.25139/fst.v5i1.4236

15. Abbas, T. E. (2013). The use of Moringa oleifera in poultry diets. *Turkish Journal of Veterinary & Animal Sciences*, *37*(5), 492–496. https://doi.org/10.3906/vet-1211-40

16. Dhakar, R., Pooniya, B., Gupta, M., Maurya, S., Bairwa, N., & Sanwarmal. (2011). Moringa : The herbal gold to combat malnutrition. *Chronicles of Young Scientists*, *2*(3), 119. https://doi.org/10.4103/2229-5186.90887

17. Fatima, S., Usmani, M. A., Srivastava, A. K., Fatima, S., Usmani, M. A., & Srivastava, A. K. (2024). Nutritional Value Addition of Bread, Pasta, and Noodles by Incorporating Leaves of Moringa oleifera. *Cureus*, *16*. https://doi.org/10.7759/cureus.75793

18. Qumar, N., & Fatima, N. (2022). Nutritional analysis and sensory evaluation of food products enriched with Moringa oleifera leaves. *International Journal of Horticulture and Food Science*, *4*(1), 93–97. https://doi.org/10.33545/26631067.2022.v4.i1b.90

19. Sultana, S. (2020). Nutritional and functional properties of *Moringa oleifera*. *Metabolism Open*, *8*, 100061. https://doi.org/10.1016/j.metop.2020.100061

20. Li, J., Liu, X., Li, J., Han, D., Li, Y., & Ge, P. (2023). Mechanism of andrographis paniculata on lung cancer by network pharmacology and molecular docking. *Technology and Health Care*, *31*(4), 1407–1427. https://doi.org/10.3233/THC-220698

21. Tan, Y., & Chang, S. K. C. (2017). Digestive enzyme inhibition activity of the phenolic substances in selected fruits, vegetables and tea as compared to black legumes. *Journal of Functional Foods*, *38*, 644–655. https://doi.org/10.1016/j.jff.2017.04.005

22. Stajčić, S. M., Čanadanović-Brunet, J. M., Ćetković, G. S., Tumbas-Šaponjac, V. T., Vulić, J. J., & Šeregelj, V. N. (2021). Simulated gastrointestinal digestion and storage stability of tomato waste encapsulates. *Acta Periodica Technologica*, (52), 239–252.

23. Nur-e-Alam, M., Parveen, I., Wilkinson, B., Ahmed, S., Hafizur, R. M., Bari, A., … Al-Rehaily, A. J. (2021). A neoclerodane orthoester and other new neoclerodane diterpenoids from Teucrium yemense chemistry and effect on secretion of insulin. *Scientific Reports*, *11*(1), 8074. https://doi.org/10.1038/s41598-021-87513-3

24. Lee, K.-C., Chang, H.-H., Chung, Y.-H., & Lee, T.-Y. (2011). Andrographolide acts as an anti-inflammatory agent in LPS-stimulated RAW264.7 macrophages by inhibiting STAT3-mediated suppression of the NF-κB pathway. *Journal of Ethnopharmacology*, *135*(3), 678–684. https://doi.org/10.1016/j.jep.2011.03.068

25. Mussard, E., Jousselin, S., Cesaro, A., Legrain, B., Lespessailles, E., Esteve, E., … Toumi, H. (2020). Andrographis paniculata and Its Bioactive Diterpenoids Against Inflammation and Oxidative Stress in Keratinocytes. *Antioxidants*, *9*(6), 530. https://doi.org/10.3390/antiox9060530

26. Anumihe, O., Etim, G., Ihejieto, N., Azubuike, C., Chibu-Ikwuagwu, G., & Ahamefula, C. (2023). Antimicrobial properties and medicinal effects of Andrographis paniculata. *International Journal of Agriculture Extension and Social Development*, *6*(1), 107–109. https://doi.org/10.33545/26180723.2023.v6.i1b.183

27. Li, X., Yuan, W., Wu, J., Zhen, J., Sun, Q., & Yu, M. (2022). Andrographolide, a natural anti-inflammatory agent: An Update. *Frontiers in Pharmacology*, *13*. https://doi.org/10.3389/fphar.2022.920435

28. Maiti, K., Mukherjee, K., Murugan, V., Saha, B. P., & Mukherjee, P. K. (2010). Enhancing bioavailability and hepatoprotective activity of andrographolide from Andrographis paniculata, a well-known medicinal food, through its herbosome. *Journal of the Science of Food and Agriculture*, *90*(1), 43–51. https://doi.org/10.1002/jsfa.3777

29. Phetruen, T., van Dam, B., & Chanarat, S. (2023). Andrographolide Induces ROS-Mediated Cytotoxicity, Lipid Peroxidation, and Compromised Cell Integrity in Saccharomyces cerevisiae. *Antioxidants*, *12*(9), 1765. https://doi.org/10.3390/antiox12091765

30. Rajeswari, S., Vidya, R., & Amudha, P. (2022). GCMS ANALYSIS ON ANDROGRAPHIS PANICULATA SEED EXTRACT AND ITS ANTICANCER ACTIVITY. *International Journal of Applied Pharmaceutics*, 84–88. https://doi.org/10.22159/ijap.2022.v14ti.5

31. Nugroho, A. E., Andrie, M., Warditiani, N. K., Siswanto, E., Pramono, S., & Lukitaningsih, E. (2012). Antidiabetic and antihiperlipidemic effect of Andrographis paniculata (Burm. f.) Nees and andrographolide in high-fructose-fat-fed rats. *Indian Journal of Pharmacology*, *44*(3), 377. https://doi.org/10.4103/0253-7613.96343

32. Tajidin, N. E., Shaari, K., Maulidiani, M., Salleh, N. S., Ketaren, B. R., & Mohamad, M. (2019). Metabolite profiling of Andrographis paniculata (Burm. f.) Nees. young and mature leaves at different harvest ages using 1H NMR-based metabolomics approach. *Scientific Reports*, *9*(1), 16766. https://doi.org/10.1038/s41598-019-52905-z

33. Teli, D., Vaghela, D. A., Chaudhri, A., Solanki, H. K., Jetha, K., & Chavda, V. P. (2024). Andrographolide: A Review on Experimental Clinical Trials and Applications. *Journal of Experimental and Clinical Application of Chinese Medicine*, 55–72. https://doi.org/10.62767/jecacm501.5474

34. Cruz, A. P. M., Nishimura, F. G., Santos, V. C. O. dos, Steling, E. G., Von Zeska Kress, M. R., Marins, M., & Fachin, A. L. (2024). Essential Oil-Based Soap with Clove and Oregano: A Promising Antifungal and Antibacterial Alternative against Multidrug-Resistant Microorganisms. *Molecules*, *29*(19), 4682. https://doi.org/10.3390/molecules29194682

35. Wen, Y., Li, W., Su, R., Yang, M., Zhang, N., Li, X., … Tian, Y. (2022). Multi-Target Antibacterial Mechanism of Moringin From Moringa oleifera Seeds Against Listeria monocytogenes. *Frontiers in Microbiology*, *13*. https://doi.org/10.3389/fmicb.2022.925291

36. Siahaan, T. N., Basuki, & Hamzah, A. (2023). Phytochemical Screening and Chemical Compounds of Moringa Oleifera Leaf Hot Water Extract. *International Journal of Ecophysiology*, *5*(2), 1–7. https://doi.org/10.32734/ijoep.v5i2.13410

37. Umare, F., Muhammad, M., Maiturare, H., Abubakar, H., Binji, Z., & Inuwa, F. (2022). Antibacterial Activity, Phytochemical and Proximate Analysis of Moringa Oleifera Seeds Against Clinical Isolates. *Caliphate Journal of Science and Technology*, *4*(1), 27-32`. https://doi.org/10.4314/cajost.v4i1.4

38. Kawabata, F., Dey, B., Yoshida, Y., Nishimura, S., & Tabata, S. (2020). Bitter Taste Receptor Antagonists Inhibit the Bitter taste of Canola Meal Extract in Chickens. *The Journal of Poultry Science*, *57*(3), 223–228. https://doi.org/10.2141/jpsa.0190099

39. Khatri, D., & Chhetri, S. B. B. (2020). Reducing Sugar, Total Phenolic Content, and Antioxidant Potential of Nepalese Plants. *BioMed Research International*, *2020*, 7296859. https://doi.org/10.1155/2020/7296859

40. Ty, M., Taha-Abdelaziz, K., Demey, V., Castex, M., Sharif, S., & Parkinson, J. (2022). Performance of distinct microbial based solutions in a Campylobacter infection challenge model in poultry. *Animal Microbiome*, *4*(1), 2. https://doi.org/10.1186/s42523-021-00157-6

41. Liu, H., Hu, J., Mahfuz, S., & Piao, X. (2020). Effects of Hydrolysable Tannins as Zinc Oxide Substitutes on Antioxidant Status, Immune Function, Intestinal Morphology, and Digestive Enzyme Activities in Weaned Piglets. *Animals: an open access journal from MDPI*, *10*(5), 757. https://doi.org/10.3390/ani10050757

42. Satessa, G. D., Tamez-Hidalgo, P., Kjærulff, S., Vargas-Bello-Pérez, E., Dhakal, R., & Nielsen, M. O. (2020). Effects of Increasing Doses of Lactobacillus Pre-Fermented Rapeseed Product with or without Inclusion of Macroalgae Product on Weaner Piglet Performance and Intestinal Development. *Animals : an Open Access Journal from MDPI*, *10*(4), 559. https://doi.org/10.3390/ani10040559

43. Imarenezor, E. P. K., Abhadionmhen, O. A., Brown, S. T. C., Briska, J., Shinggu, P. P., Danya, S., … Danya, S. (2022). Effects of seed extracts of turmeric (Curcuma longa linn) on Escherichia coli and Streptococcus species isolated from urine of patients in Wukari, Taraba State, North East, Nigeria: Prospective antimicrobial alternative for Urinary Tracts Infections. *World Journal of Biology Pharmacy and Health Sciences*, *9*(1), 013–019. https://doi.org/10.30574/wjbphs.2022.9.1.0021

44. Collins, J. B., Jordan, B., Vidyashankar, A. N., Castro, P. J., Fowler, J., & Kaplan, R. M. (2021). Impact of fenbendazole resistance in Ascaridia dissimilis on the economics of production in turkeys. *Poultry Science*, *100*(11), 101435. https://doi.org/10.1016/j.psj.2021.101435

45. Susanti, H. I. (2023). A Study of Closed-House Systems in Broiler Production. *JIA (Jurnal Ilmiah Agribisnis) : Jurnal Agribisnis dan Ilmu Sosial Ekonomi Pertanian*, *8*(3), 214–219. https://doi.org/10.37149/jia.v8i3.188

46. Laosam, P., Panpipat, W., Yusakul, G., Cheong, L.-Z., & Chaijan, M. (2021). Porcine placenta hydrolysate as an alternate functional food ingredient: In vitro antioxidant and antibacterial assessments. *PloS One*, *16*(10), e0258445. https://doi.org/10.1371/journal.pone.0258445

47. Widjastuti, T., Garnida, D., Tanwiriah, W., & Balia, R. L. (2020). Mixed Red Ginger (Zingiber offinale var rubrum) with Turmeric (Curcuma longa) as Feed Additive to Improve Conversion Meat Protein Broiler. *Journal of Agricultural Sciences – Sri Lanka*, *15*(2), 244–249. https://doi.org/10.4038/jas.v15i2.8807

48. Abu Hafsa, S. H., Ibrahim, S. A., Eid, Y. Z., & Hassan, A. A. (2020). Effect of dietary Moringa oleifera leaves on the performance, ileal microbiota and antioxidative status of broiler chickens. *Journal of Animal Physiology and Animal Nutrition*, *104*(2), 529–538. https://doi.org/10.1111/jpn.13281

49. Balarabe, S., Jibir, M., Duru, S., & Abdu, S. B. (2021). Evaluation of moringa (Moringa oleifera) leaf meal for broiler chicken performance and meat quality. *ADAN JOURNAL OF AGRICULTURE*, *2*(1), 189–201. https://doi.org/10.36108/adanja/1202.20.0181

50. Karwanti, N. W., Arumdani, D. F., Yulianto, A. B., Marbun, T. D., Sherasiya, A., Arif, M. A. A., … Lokapirnasari, W. P. (2023, February 27). Efficacy of *Moringa oleifera* Lam. extracts &nbsp;and *Pediococcus pentosaceus, Lactobacillus acidophilus, Lactobacillus plantarum* probiotic during starter period on growth performance of male broiler chicken. F1000Research. https://doi.org/10.12688/f1000research.130072.1

51. Lungu, N. S., Maina, J. G., Dallimer, M., & van Marle-Köster, E. (2024). The Potential of Moringa oleifera as a Sustainable Broiler Feed Additive: Investigating Awareness, Perceptions and Use by Broiler Farmers and Moringa Farmers in South Africa. *Sustainability*, *16*(5), 2208. https://doi.org/10.3390/su16052208

52. Hussein, H. M., Ali, N. A.-L., & Al-Jebory, H. H. (2024). The Evaluation of the Nutritional Effectiveness of Nano-Alcoholic Extract of Moringa oleifera Leaves added to Drinking Water on the Productive Traits of Broilers: Evaluation of the Nutritional Effectiveness of Nano-Alcoholic Extract of Moringa oleifera Leaves added to Drinking Water on the Productive Traits of Broilers. *International Journal of Life Science and Agriculture Research*, *3*(2), 56–63. https://doi.org/10.55677/ijlsar/V03I2Y2024-01

53. Abdel-Wareth, A. A. A., & Lohakare, J. (2021). Moringa oleifera Leaves as Eco-Friendly Feed Additive in Diets of Hy-Line Brown Hens during the Late Laying Period. *Animals*, *11*(4), 1116. https://doi.org/10.3390/ani11041116

54. Zhang, J., Zhang, R., Jin, S., & Feng, X. (2024). Curcumin, a plant polyphenol with multiple physiological functions of improving antioxidation, anti-inflammation, immunomodulation and its application in poultry production. *Journal of Animal Physiology and Animal Nutrition*, *108*(6), 1890–1905. https://doi.org/10.1111/jpn.14029

55. Nurliana, N., Siregar, B. H., Sari, W. E., Helmi, T. Z., & Sugito, S. (2022). Identification of cellulolytic lactic acid bacteria from the intestines of laying hens given AKBISprob based on 16S ribosomal ribonucleic acid gene analysis. *Veterinary World*, 1650–1656. https://doi.org/10.14202/vetworld.2022.1650-1656

56. Yin, M., Weil, M., Avallone, S., Lebrun, M., Conejero, G., In, S., & Bohuon, P. (2022). Impact of cooking and drying operations on color, curcuminoids, and aroma of Curcuma longa L. *Journal of Food Processing and Preservation*, *46*(5), e16643. https://doi.org/10.1111/jfpp.16643

57. Kusmayadi, A., & Rahayu, N. (2020). Total Lactic Acid Bacteria and Coliform of Cihateup Ducks Intestine that Given Feed Containing the Combination of Mangosteen Peel and Turmeric Flour. *Jurnal Ilmu dan Teknologi Peternakan (JITP)*, *8*(1). Retrieved from https://journal.unhas.ac.id/index.php/peternakan/article/view/8197

58. Wisda, H., Sediawan, W. B., & Sarto. (2016). Pengaruh Aerasi Pada Fermentasi Padat Tandan Kosong Kelapa Sawit Oleh Aspergillus Niger Terhadap Produksi Gula Sederhana. *Jurnal Teknik Kimia USU*, *5*(3), 12–16. https://doi.org/10.32734/jtk.v5i3.1539

59. Krismaputri, M. E., Suthama, N., & Pramono, Y. B. (2016). Pemberian Soybean oligosaccharides Dari Ekstrak Bungkil dan Kulit Kedelai Terhadap pH Usus, Populasi E. coli, dan PBBH Pada Broiler. *MEDIAGRO: journal of agricultural sciences*, *12*(2). https://doi.org/10.31942/mediagro.v12i2.1615