

A REVIEW OF POTENTIAL USES OF LEMONGRASS AND FENUGREEK AS ALTERNATIVE ANTIBIOTICS IN RABBIT INDUSTRY IN NIGERIA

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ABSTRACT

The Nigerian rabbit industry is a vital sector for addressing national animal protein deficits; however, its heavy reliance on synthetic antimicrobial growth promoters (AGPs) has worsened the public health crisis of antimicrobial resistance. This literature review evaluates the potential of phytochemical feed additives, specifically lemongrass (*Cymbopogon citratus*) and fenugreek (*Trigonella foenum-graecum*), as sustainable alternatives to conventional antibiotics in rabbit production. Current research indicates that the unique phytochemical profiles of these plants, including the antimicrobial properties of citral in lemongrass and the prebiotic saponins in fenugreek, effectively promoting beneficial gut bacteria by mimicking the growth-promoting effects of synthetic AGPs. Specifically, dietary supplementation with 150 mg/kg of lemongrass oil significantly enhances final live weight, carcass traits, and dressing percentages in growing rabbits (El-Komy *et al.*, 2020). Furthermore, the inclusion of lemongrass extract at 4 g/kg has been documented to boost the relative immune response by significantly increasing blood immunoglobulin G concentrations (Safwat *et al.*, 2021). Fenugreek acts as a potent prebiotic and galactagogue. In vitro characterization shows that 984 g/kg of fenugreek seed gum is fermented by rabbit caecal bacteria, which promotes the production of volatile fatty acids and inhibits pathogens by lowering gut pH (Jihed, 2020). Growth performance trials found that rabbits supplemented with fenugreek achieved a significantly higher average weight gain of 416.00 g compared to 313.83 g in control groups (Olanrewaju *et al.*, 2019). Furthermore, both plants exhibit strong antioxidant properties that enhance the overall immune response and physiological health of weaned rabbits. The review concludes that lemongrass and fenugreek are highly viable, cost-effective, and safe alternative antibiotics. Adopting these natural additives can help the Nigerian rabbit industry mitigate the risks of antimicrobial resistance, reduce feed production cost and transition toward more sustainable and healthy production systems.

Keyword: Lemongrass, Fenugreek, Phytochemical feed additives, Rabbit, Antibiotics, AGPs.

INTRODUCTION

Domestic rabbits are one of the most simple but efficient cellulose converter animal species, ensuring the high production of low-cost meat which has several nutritional benefits, including a high protein content and a low cholesterol level (El-Sabrouh and Aggag, 2018; Siddiqui *et al.*, 2023). Rabbit farming is an increasingly vital sector of the global livestock industry, valued for its high-protein, low-fat meat production, rapid growth rates, high prolificacy, and the ability to convert forage into high-quality protein. Despite a population of over 200 million people, Nigeria remains one of the least consumers of animal protein globally, with per capita consumption well below FAO recommendations (Food and Agriculture Organization, 2023). Rabbit production offers a pragmatic solution to this

deficit due to the animal's short generational interval, small body size, and lack of religious taboos regarding its consumption. However, the industry has historically relied heavily on synthetic antibiotics not only for disease treatment but also as antimicrobial growth promoters (AGPs). This reliance has contributed to the global crisis of antimicrobial resistance, prompting strict regulatory bans on AGPs in the European Union and increasing restrictions worldwide (Abdelsalam and Fathi, 2023). Antibiotics are a class of drugs, which are either naturally occurring or artificially synthesized, that possess antimicrobial activity and are used for treatment or prevention of diseases (Cheesman *et al.*, 2017). In Nigeria, the usage of antibiotics growth promoters is alarming. Recent studies indicated

that antibiotics such as tetracyclines, fluoroquinolones, and beta-lactams are readily available over the counter and are frequently administered without veterinary supervision (Ndahi *et al.*, 2023). Residue of antibiotics is frequently detected in meat products, posing a direct threat to public health. The consumption of antimicrobials has been projected to increase considerably due to the rising number of animals used as food in Nigeria by 163% by 2030 (Anthony *et al.*, 2016). Consequently, research has pivoted toward phytochemicals (plant-derived bioactive compounds) as safe, effective alternatives. Among these, Lemongrass (*Cymbopogon citratus*) and Fenugreek (*Trigonella foenum-graecum*) have emerged as candidates of interest due to their accessibility and complex phytochemical profiles.

1.1 PHYTOGENICS IN LIVESTOCK INDUSTRY

Phytochemical feed additives (PFAs) are products of plant origin including herbs, seeds, and fruits incorporated into animal diets to enhance productivity and health (Sychoy *et al.*, 2024). As the global market increasingly shifts toward organic, antibiotic-free agriculture, these natural additives have become a crucial component of modern livestock nutrition strategies (Sychoy *et al.*, 2024; Shahbakht *et al.*, 2024). Phytochemical substances can be used as an antioxidant in small animal and poultry nutrition without adverse effects on performance and also assist in overcoming heat stress (Mohamed and Hassan, 2022). El-Shall *et al.* (2020) reported that providing broiler chickens with drinking water supplemented with a blend of key essential oil, such as oregano (carvacrol), thyme (thymol), eucalyptus (eucalyptol), along with an acacia-based surfactant, enhanced immune responses following Newcastle disease (ND) and infectious bursal disease vaccination, and also showed antiviral activity against the ND virus. Hussein *et al.* (2021) found that dietary combinations of peppermint, chamomile, and probiotic yeast cell wall were comparably effective to salinomycin in mitigating the reduction in body weight gain and overall performance in coccidiosis-challenged broiler chickens. Alagbe and Oluwafemi (2019) found that ginger and garlic extracts stimulate intestinal tract activity, leading to improved digestive secretions, nutrient absorption, and metabolism. No effect of Cinnamon and Bishop's weed essential oils, Bitter vine and *Garcinia lanceifolia* blend was reported on growth performance, however, it showed an

improvement in lipid profile, immunity and gut integrity in piglets (Samanta *et al.*, 2021). PFAs possess multifaceted biological roles, including antimicrobial, antioxidant, and anti-inflammatory properties that improve disease resistance and growth rates (Shahbakht *et al.*, 2024). They enhance nutrient digestibility, support a healthy immune system and serve as eco-friendly alternatives to antibiotic growth promoters (Attia *et al.*, 2025). Their use can mitigate energy losses and reduce environmental pollution associated with livestock production (Mobashar, 2025). There exists, however, certain limitations in the applications of PFAs. According to Yang *et al.* (2015), doses are currently given in high dosages (1-2% or higher) and the highly lipophilic nature of certain essential oils can limit their delivery to specific pathogens in the gut with offensive odours can occasionally impacting feed palatability and acceptability (Ibeagha-Awemu *et al.*, 2025). The minimal inhibitory concentration of PFAs required for controlling enteric pathogens may not guarantee the feed efficiency, balanced immunity of animals and cost-effectiveness of production (Yang *et al.*, 2015). The efficacy of PFAs is affected by genetic variation in the plant, maturity stage, harvest time, and extraction method.

1.2 THE ROLE OF PHYTOGENICS IN RABBIT INDUSTRY

Feed additives are products used in animal nutrition to improve the efficiency of feed utilization and reduce the high cost of feed. The continued use of conventional feed additives in rabbit diets, whether derived from plant or animal sources, has become a critical issue (El-Sabrouy *et al.*, 2023). The authors further reiterated that there is a global trend toward finding natural alternatives to synthetic drugs, such as antibiotics, in rabbit farms. Plant nutraceuticals are naturally occurring chemical substances that positively influence animal physiological and productive abilities. Nutraceuticals can be added to rabbit diets, as a natural antioxidant and immunological stimulant, to improve rabbit growth performance and health (El-Sabrouy *et al.*, 2023). The use of plant extracts is an alternative way to reduce the problem of overdose of antibiotics and circumvent the current drug resistance of important micro-organisms (Adukwu *et al.*, 2012). Different natural feed additives have been investigated by several studies for example blue

agave stem powder, Ginger and Rosemary, Goji berry fruit (Cremonesi *et al.*, 2022; Elazab *et al.*, 2022; Martinez *et al.*, 2022). Table 1 presents outcomes of some previous researches, show extent of research observations on the potency of herbs additives in rabbit's feeds. Celia *et al.* (2016) observed unaffected feed intake when rabbits were fed diets containing a mixture of essential oils, herbs, spices and extract. There have been studies where fenugreek and lemongrass where 1.0% to 1.5% fenugreek or lemongrass powder was used to enhance growth performance and meat traits without adverse effects (Hasan, 2022; Mohamed and Hassan, 2022).

Rabbits possess a unique and sensitive caecal fermentation system. This system makes the administration of broad-spectrum antibiotics influences the destruction of beneficial gut flora. This can paradoxically lead to fatal enterotoxemia, where resistant pathogens like *Clostridium* proliferate in the vacuum left by the antibiotic treatment (Sreepian and Sreepian, 2025). Phytogenics emerge as the ideal physiological solution; unlike AGPs that disrupt the gut microbiome, phytogenics often exert selective bacteriostatic pressure while actively preserving, the healthy fermentative flora required for rabbit survival (Cremonesi *et al.*, 2022).

Table 1: Evaluations of previous work done and their discoveries

AUTHOR(S) & YEAR	PRIMARY FOCUS / ADDITIVE	KEY SUBMISSIONS & DIFFERENCES IN FINDINGS
El-Sabroun <i>et al.</i> (2023)	General Plant Nutraceuticals	Established phytochemicals as natural antioxidants and immunological stimulants that holistically improve both growth and health.
Adukwu <i>et al.</i> (2012)	General Plant Extracts	Focused primarily on the antimicrobial resistance; submitted that extracts are the primary alternative to circumvent drug resistance from antibiotic overdosing.
Celia <i>et al.</i> (2016)	Digestarom® 1315	Reported that these mixtures had no effect on the feed conversion ratio, weight gain and mortality rate
Hasan (2022); Mohamed & Hassan (2022)	Fenugreek & Lemongrass	Provided specific quantitative inclusion rates (1.0% to 1.5%); submitted that these directly enhance growth performance and physical meat traits without adverse effects.
Martinez (2022); Elazab (2022); Cremonesi (2022)	Blue Agave, Ginger, Rosemary, Goji Berry	Submitted that these phytochemicals can modulate the gut microbe and increase caecal fermentation.

2.0 LEMONGRASS (*Cymbopogon citratus*) AS AN ANTIMICROBIAL AND IMMUNOMODULATORY AGENT

Lemongrass, *Cymbopogon citratus*, is a perennial aromatic plant from the family Poaceae which was formerly known as Gramineae (Herbs, 2000). It is extensively cultivated in tropical and subtropical regions. It is widely used as a phytogenic supplement in tropical countries and is of particular interest in this review. It has been historically utilized in home remedies to treat various ailments such as malaria, coughs and pneumonia. Lemon grass (*Cymbopogon*

citratus) has been valued for its aromatic and medicinal properties. Thus, natural alternatives like lemon grass, are rich in essential oils (such as citral α , citral β , geraniol, citronellal, terpinolene, geranyl acetate, myrcene and terpinol methylheptenone), flavonoids, terpenoids and phenolic compounds (Shah *et al.*, 2011). It offers various biological activities such as antibacterial, antidiarrheal, antifungal, antioxidants, and as a growth promoter (Aglipay *et al.*, 2025). The therapeutic properties credited to lemon grass are analgesic, antidepressant, antimicrobial, antipyretic, antiseptic, bactericidal, diuretic, fungicidal, insecticidal, nervous system sedative and tonic (Mmereole, 2010). Lemon grass leaves and stems are very good in folic acid content. Fresh or dried lemon grass are rich sources of minerals like magnesium, potassium, copper, zinc, calcium, iron and manganese, zinc. Fresh lemon grass also contains vitamins such as vitamin C and vitamin A and small amounts of anti-oxidant. Lemon grass decoction and essential oil extracts contain bio compounds, non-toxic and non-mutagenic (Olorunnisola *et al.*, 2014). The major chemical ingredient found in all varieties of essential oils of lemongrass is citral or lemonal and 1 to 2% essential oil on a dry basis (Aziz, 2011). Other uncommon component of lemon grass includes limonene, citronella, β -myrcene and geraniol. Lemon Grass also contains anthraquinones, alkaloids, saponins, tannins and steroids (Nambiar *et al.*, 2012). Literatures provided contradicting results on the use of lemon grass as feed supplement/additive. There are some research studies on the use of lemon grass or its secondary metabolites for performance enhancing particularly of chickens (Mmereole, 2010; Mukhtar *et al.*, 2012; Thayalini *et al.*, 2011). Mmereole (2010) and Mukhtar *et al.* (2012) confirmed in their study that lemon grass could be a replacement to antibiotics. Some literatures provided contradicting results on the use of lemon grass as feed supplement/additive like Thayalini *et al.* (2011) who declared that lemon grass did not improve or decreased the growth performance. According to Safwat *et al.*, 2021, lemongrass extract powder enhanced the anti-oxidative status and relative immune response of growing rabbits and can be used as a natural phytogenic feed additive in the growing rabbit diets. Presence of essential oils, tannins and other plant secondary metabolites in the lemongrass can improve or decrease the palatability of feeds which has an influence on feed intake and weight

gain (Gidenne *et al.*, 2010; Abu Hafsa *et al.*, 2016; Zeng *et al.*, 2015). Lemongrass essential oil has been proven to serve as a feasible alternative for combating methicillin-resistant *Staphylococcus aureus* (MRSA) infections and biofilm-associated resistance (Sreepian and Sreepian, 2025). This mechanism is particularly effective against the common pathogens responsible for rabbit skin and respiratory infections (Valková *et al.*, 2022). The strong antimicrobial activity of lemongrass has been attributed to a high citral content (Adukwu *et al.* 2012). In a study involving weaned rabbits, supplementation linearly increased glutathione peroxidase activity and immunoglobulin G (IgG) levels, indicating an enhanced immune response capable of warding off sub-clinical infections without synthetic drugs (Safwat *et al.*, 2021). Furthermore, the essential oil's modulation of gut microflora reduces the load of pathogenic *E. coli* while sparing beneficial lactic acid bacteria, thereby mimicking the growth promotion effect of conventional antibiotics (Abdelsalam and Fathi, 2023).



Figure 1: A Lemongrass plant

2.1 Effect on Growth Performance and Nutrient Digestibility

In livestock, lemongrass leaf meal has been documented as a viable supplement for improving growth performance in broiler chicks (Mmereole, 2010). In rabbit production,

phytochemicals generally act as digestive stimulants (Assan, 2018). They improve nutrient digestibility by stimulating natural digestive enzymes and inducing positive alterations in gut histology, which allows for better absorption of dietary components (Abdel-Raheem *et al.*, 2025; Assan, 2018). Al-Sagheer *et al.* (2017) reported that supplementation of growing New Zealand rabbit diets with lemon grass oil increased live body weight and daily body weight gain and improved feed conversion ratio. It has been reported that the dietary supplementation with 150 mg/kg of lemongrass oil significantly enhances final live weight, carcass traits, and dressing percentages in growing rabbits (El-Komy *et al.*, 2020).

2.2 Effect on Carcass Quality and Organ Characteristics

Phytogenic supplementation serves as a primary solution for enhancing the quality of animal products (Assan, 2018). Studies suggest these additives act as product quality enhancers by improving production indices (Anaso *et al.*, 2025). In the Nigerian context, they are particularly valued for improving animal performance and meat output in hot environmental conditions (Anaso *et al.*, 2025). Supplementing growing rabbit diets with lemongrass oil significantly increased dressing, carcass and total edible parts according to El Komy *et al.*, 2020.

2.3 Effect on Sensory Evaluation and Meat Keeping Quality

Lemongrass function as antioxidants that address the challenges of lipid peroxidation, which is a primary cause of meat degradation and spoilage in the tropics (Anaso *et al.*, 2025; Assan, 2018). Lemongrass essential oil specifically demonstrates strong antibacterial and anti-biofilm efficacy against pathogens like *Staphylococcus aureus*, which contributes to cleaner carcasses and reduced microbial load during processing (Sreepian and Sreepian, 2025).

2.4 Effect on Gut Morphology and Microbiota

The inclusion of phytobiotics contributes significantly to the stability of the rabbit microbiome (Abdel-Raheem *et al.*, 2025). By stabilizing the gut flora, these additives reduce the presence of microbial toxins and lower intestinal inflammation (Abdel-Raheem *et al.*, 2025). This modulation redirects protein

utilization away from immune responses and toward tissue growth (Abdel-Raheem *et al.*, 2025). Furthermore, lemongrass bio-actives provide a feasible alternative for combating antibiotic-resistant infections that often disrupt gut health in weaned rabbits (Sreepian and Sreepian, 2025).

3.0 FENUGREEK (*Trigonella foenum-graecum*) AS A PREBIOTIC AND PHYSIOLOGICAL ENHANCER

Fenugreek is known as “Eru” in Yoruba, “Kimba” in Hausa, "Mkpuru oka oyibo" in Igbo. *Trigonella foenum-graecum* L. is an annual plant of the *Papilionaceae-Leguminosae* family that is widely grown as a food crop in the Mediterranean regions, North Africa, India, and Yemen (Barakat *et al.*, 2018). Ancient civilisation utilized fenugreek for different medicinal purposes including digestive issues, respiratory problems, skin inflammation and ancient Ayurvedic medicine. Protein is richly found in it along with some important amino acids, like folate and ascorbate, which have nutritive and restorative characteristics, and have been shown to increase blood hemoglobin levels (Khan *et al.*, 2018).

A study by Zemzmi *et al.* (2020) characterized fenugreek seed gum as a potential prebiotic, suggesting it to be totally fermented by rabbit caecal bacteria. This fermentation promotes the production of volatile fatty acids (VFAs), which lower caecal pH which is unfavourable for the proliferation of pathogens like *Clostridium* and *Salmonella*. Fenugreek extracts demonstrate significant inhibition of *E. coli* and *Pseudomonas* species, likely due to the membrane-disrupting properties of its saponins (Raji-Idowu, 2023 and Bentaher, 2024). It was further reported that rabbits fed diets supplemented with 4g to 8g of fenugreek seed powder exhibited significantly improved blood profiles, including higher hemoglobin and red blood cell counts, which correlates with better general health and disease resilience (Bentaher, 2024). Fenugreek seeds also contain silver nanoparticles that have antibacterial activity against both gram-positive and gram-negative bacteria (Deshmukh *et al.*, 2019). Alkaloids, flavonoids, tannins, saponins, steroids and terpenoids, coumarins, diosgenin either alone or in combination, may contribute to fenugreek's antibacterial properties (Khursheed *et al.* 2012; Tak *et al.*, 2024). The excellent nutritional profile and bioactive components in fenugreek give it medicinal and pharmacological properties including antibacterial,

anticholesterolemic, carminative, restorative, uterine tonic, anti-carcinogenic, anti-inflammatory, antiviral, antioxidant, and hypotensive effects (Ranade and Mudgalkar, 2017). Gaikwad *et al.* (2019) reported that adding 1% fenugreek (*Trigonella foenum-graecum*) seed powder to broiler diets as a natural feed additive enhanced growth performance and feed conversion. Similarly, Ali *et al.* (2021) found that dietary supplementation with 1.5% fenugreek seed meal significantly increased body weight gain and feed efficiency relative to the control group.

Fenugreek has significant anti-nutritional factors, primarily saponins and alkaloids, when supplemented at high concentrations. Olayeni *et al.* (2025) recorded a decrease in the weight gain of broilers at the starter phase due to low acceptability and reduced feed intake. The main constituents of fenugreek seeds that cause a reduced acceptability of the feed are volatile oils and alkaloids (Ahmad *et al.*, 2016). Furthermore, high dietary levels of fenugreek seeds (e.g., 5 g to 10 g/kg) have been shown to negatively affect intestinal histomorphology, resulting in significantly shorter villi and deeper crypts in the jejunum and ileum, which ultimately impairs nutrient digestion and absorption (Paneru *et al.*, 2022). The toxic effects of high steroidal saponin and saponin levels contained can intensify these adverse responses in the gastrointestinal tract, leading to a linear decrease in early growth performance and an increased white blood cell count. Therefore, careful dose optimization is strictly required to prevent these detrimental physiological and palatability effects when applying fenugreek to animal diets.



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Figure 2: Fenugreek seed

3.1 Effect on Growth Performance and Weight Gain

Recent trials consistently demonstrate that fenugreek supplementation leads to superior weight gain and final body weights in growing rabbits. In a 35-day study, rabbits supplemented with fenugreek seed powder achieved an average weight gain of 416.00 g, which was significantly higher than the 313.83 g observed in the control group (Adejola *et al.*, 2019). Supplementing diets with 0.5% fenugreek seeds has been shown to significantly increase both final body weight and body weight gain compared to rabbits on basal diets (Elwardany *et al.*, 2022). Fenugreek also improves the growth rates of suckling kits, with daily weight gains reaching 13 g/d compared to 11.7 g/d in control batches (Boukhechem *et al.*, 2021).

3.2 Effect on Nutrient Digestibility and Feed Efficiency

Fenugreek significantly improves the efficiency with which rabbits process their feed. Dietary inclusion of 1.0% fenugreek seeds has been associated with the highest digestibility values for Dry Matter, Organic Matter, Crude Protein, Ether Extract, and Nitrogen-Free Extract (El-Latif *et al.*, 2019). Similar studies using 0.5% fenugreek confirmed significantly higher nutrient digestibility across DM, CP, Crude Fiber, and EE, alongside a significant improvement in the Feed Conversion Ratio (Elwardany *et al.*, 2022).

3.3 Effect on Influence on Lactation and Reproduction

Fenugreek is a potent galactagogue, making it particularly valuable for rabbit does. Supplementing the diets of Californian rabbit does with sprouted fenugreek improved dairy performance, reaching an average peak lactation of 287 g/d compared to 236 g/d in control groups (Boukhechem *et al.*, 2021). The addition of 6% fenugreek seeds (or a 3% fenugreek and 3% anise mixture) significantly increased milk production during the second and third weeks of lactation (Sallam *et al.*, 2019).

3.4 Effect on Carcass Characteristics and Meat Quality

Beyond growth, fenugreek influences the physical attributes of the final product. Rabbits fed diets supplemented with 0.5% fenugreek achieved a significantly better dressing percentage compared to control groups

(Elwardany *et al.*, 2022). Supplementation at a 1% level has been shown to produce carcasses with a higher percentage of the fore and hind parts compared to rabbits fed a standard control diet (Pałka *et al.*, 2021). While it enhances yield, the addition of 1% fenugreek seeds typically has a non-significant effect on meat texture traits such as shear force, hardness, springiness, and chewiness (Pałka *et al.*, 2021).

3.5 Effect on Physiological Responses and Economic Efficiency

Supplementing with 1.0% fenugreek significantly decreases triglyceride levels in growing rabbits, though it typically does not cause significant changes in red blood cell counts, Hemoglobin percentage (Hb%), or Packed Cell Volume (PCV%) (El-Latif *et al.*, 2019). Due to the improved growth rates and FCR, the use of fenugreek as a feed additive has been shown to result in better economic efficiency for rabbit producers (Elwardany *et al.*, 2022).

3.6 Effect on Gut Morphology and Microbiota

Fenugreek exerts significant beneficial effects on the gastrointestinal tract through its dual action as a prebiotic fiber and a modulator of intestinal structure. These effects are particularly relevant for rabbit nutrition, where gut health is critical for optimal performance. Fenugreek supplementation induces positive morphological changes in the intestinal tract, enhancing the absorptive surface area and digestive efficiency.

In broiler studies, fenugreek oil supplementation significantly increased villi height in the duodenum from $1055.00 \pm 25.50 \mu\text{m}$ to $1530.00 \pm 26.69 \mu\text{m}$, along with improvements in mucosa layer thickness and epithelium thickness (Ezzat, 2023). Similarly, dietary inclusion of fenugreek powder at 2 g/kg and 4 g/kg altered intestinal morphology by increasing the height of the villi relative to the depth of the crypts (Al-Abbas *et al.*, 2025). The morphological changes induced by fenugreek are associated with enhanced feed conversion ratios, which may be linked to structural improvements in the gastrointestinal tract tissues (Mohamed and Hassan, 2022). These alterations increase the absorptive surface area, allowing for more efficient nutrient uptake. While moderate levels of fenugreek (2-4 g/kg) improve gut morphology, higher inclusion levels (5-10 g/kg) in broilers have been shown to reduce

villus height and the villus height: crypt depth ratio, indicating that optimal dosage is critical for maximizing benefits (Paneru *et al.*, 2022). In vitro characterization shows that 984 g/kg of fenugreek seed gum is fermented by rabbit caecal bacteria, which promotes the production of volatile fatty acids and inhibits pathogens by lowering gut pH (Jihed, 2020).

3.6.1 Gut Microbiota

Fenugreek functions as a potent prebiotic, modulating the gut microbial ecosystem through its high galactomannan content. The galactomannan extracted from fenugreek seeds is non-digestible by gastric acid and pancreatic enzymes but is fermented by beneficial bacteria such as *Bacillus coagulans*, with 71.4% utilization observed in vitro (Majeed *et al.*, 2018). This fermentation produces significant amounts of short-chain fatty acids and competitively inhibits *Escherichia coli* growth (Majeed *et al.*, 2018). Defatted fenugreek seed flakes (Fenuflakes™) demonstrated prebiotic efficacy by increasing beneficial SCFAs and promoting the enrichment of several beneficial colonic bacteria while maintaining normal colonic pH and producing less gas than inulin (Thakurdesai *et al.*, 2024). Fenugreek extracts have been shown to contain high levels of *Lactobacillus spp.*, lactic acid bacteria, and *Bifidobacterium spp.*, indicating a favourable shift in microbial composition (Thakurdesai *et al.*, 2024).

Fenugreek seed gum, rich in galactomannan, satisfies two essential conditions of prebiotic effect for rabbit diets: resistance to in vitro enzymatic digestion and complete fermentation by caecal bacteria (Zemzmi *et al.*, 2020). In vitro studies showed that pure fenugreek seed gum was minimally dissolved during the enzymatic phase (145 g/kg) but almost completely disappeared (984 g/kg) during the fermentation phase by caecal bacteria (Zemzmi *et al.*, 2020). Fenugreek-derived fiber enhances intestinal barrier integrity and promotes colonic fermentation to SCFAs, with particular emphasis on butyrate production, which is crucial for maintaining gut health (Kavitha and Krishnan, 2026). These combined effects make fenugreek a valuable phyto-genic additive for improving gut health, nutrient digestibility, and overall performance in livestock, with specific relevance to rabbit production where caecal fermentation plays a crucial role in nutrition.

CONCLUSION

The escalating threat of antimicrobial resistance and the alarming rate of unregulated antibiotic use in Nigeria necessitate an urgent transition toward natural alternatives in rabbit production. This review of current literature clearly establishes that phyto-genic feed additives, specifically lemongrass and fenugreek, offer highly promising and effective solutions. Their diverse reservoirs of bioactive compounds demonstrate substantial capacity to modulate the sensitive rabbit gut microbiota, enhance the immune system, and improve overall physiological health without the adverse effects associated with synthetic antimicrobials. By harnessing the antimicrobial and prebiotic properties of these plants, producers can successfully inhibit pathogen proliferation while maintaining optimal growth performance. Ultimately, integrating readily available and cost-effective phyto-genics like lemongrass and fenugreek provides a strategic, sustainable framework for the Nigerian rabbit industry to meet growing protein demands, eliminate harmful drug residues in meat, and protect public health.

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