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Review article

The potential use of *Alpinia galanga* and *Piper betle* as growth promoters in the broiler industry: A review

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Abstract

Phytogenic feed additives (PFA) have been studied in many poultry researches primarily as growth promoters due to the growing interest in using natural products in farming. However, few researchers opted to study *Piper betle* (betel) and *Alpinia galanga* (greater galangal) as growth promoters in broilers despite these plants' abundance of beneficial phytoconstituents. Thus, this narrative review aims to provide insights to the readers on the characteristics and properties of *P. betle* and *A. galanga* to be used as growth promoters by supplementation to broiler chicken. Issues and knowledge addressed in this review article help poultry researchers and industry to explore the potential of *P. betle* and *A. galanga* to improve the performance of poultry flocks in the future.

Keywords: Alpinia galanga, Broiler, Growth promoter, Piper betle, Poultry

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INTRODUCTION

The idea of innovating growth promoters in Malaysia should be considered seriously, as it can improve the livestock industry that contributes significantly to the economic growth. In Malaysia, the poultry industry is regarded as one of the most crucial livestock industries that contributed the largest share of gross output value in the livestock sub-sector at 89.9% valued at RM16.8 billion in 2021 (DOSM, 2023). As most of the chicken population nationwide, the broiler industry focuses more on attaining the best growth performance and carcass yield. Therefore, growth promoters are usually incorporated into the broiler diets to boost farm performance and profits.

Phytogenic feed additives **(**PFA**)** have been studied in many poultry researches primarily as growth promoters, due to the growing interest in using natural products in farming. One positive impact of using PFA is improve in growth performance of animals, including broilers (Mehdi et al., 2018; Stevanović et al., 2018; Čabarkapa et al., 2019; Christaki et al., 2019; Jin et al., 2019; Skoufos et al., 2019; Tabashsum and Biswas, 2019; Bhagwat et al., 2021; Krauze, 2021; Kuralkar and Kuralkar, 2021; El-Hack et al., 2022; Rafiq et al., 2022) . Franz et al. (2019) reported that the most commonly used and important plant species used in PFA studies belong to the Lamiaceae, Apiaceae, Asteraceae and Rosaceae families. Other families of plants have also been used, such as Alliaceae, Brassicaceae, Cannabaceae, Fabaceae, Gentianaceae, Lauraceae, Myrtacecae, Papaveraceae, Rutaceae, Solanaceae, and Zingiberaceae, but only involved a few species and not as many as those families mentioned previously.

Among the various herbs used as PFA, greater galangal and betel are not commonly studied as PFA in poultry despite possessing various beneficial properties, which will be discussed later. However, both plants have been used as medicine and health supplement by many communities across Asian countries from ancient times until now, as modern alternative medicine (Shah et al., 2016; Khairullah et al., 2020). They are highly regarded within most Asian communities, having been consumed for generations due to their reputation for being safe and edible.

P. betle or commonly known as betel has also been used extensively in Asian religious or cultural functions and as a breath freshener with benefits for oral health (Shah et al., 2016; Nayaka et al., 2021). The main part of the plant typically used is the glossy heart-shaped leaves. Several studies that used betel leaves as a supplement in broiler diets had recorded significant positive impacts mainly on growth performance and intestinal morphometrics (Oso et al., 2019; Basit et al., 2020a; Basit et al., 2020b; Gannapao and Patagao, 2020; Lodang et al., 2020).

A. galanga or commonly known as galangal has been used as food flavouring to enhance many Asian cuisines due to its distinctive aroma (Khairullah et al., 2020). The most used and researched part of the plant is the galangal rhizome, although the flower part also has some beneficial compounds (Khairullah et al., 2020). As a PFA in broilers, not many works have been done using galangal, but some published works have observed significant positive results on the animals in terms of blood biochemistry and growth performance (Abdel-Azeem and Basyony, 2019; Elghalid et al., 2021).

P. betle and *A. galanga* are two different species of plants that belong to the family Piperaceae and Zingiberaceae respectively. Nevertheless, both of these plants share some similarities that have the potential to be used as efficient growth supplements in broilers either separately or in combination. In terms of phytochemical constituents, both plants contain major phytochemicals that are mainly terpenes and phenolic compounds that possess various documented health benefits (Khairullah et al., 2020; Biswas et al., 2022). Moreover, these two botanical specimens are extensively and conveniently grown in the Southeast Asian region (Khairullah et al., 2020; Biswas et al., 2022; Carsono et al., 2022; Mandal et al., 2023), thereby enhancing the accessibility of the plant resources for local agricultural practitioners and mitigating expenses associated with imports.

Using betel and galangal as dietary supplements or feed additives is not foreign to poultry farmers in Asia, as some did execute it in their operations. Nevertheless, these two plants are not popular among researchers that study PFA in broilers. As of 6th August 2023, the keywords search based on the search statement, "(betle OR betel) AND (broiler OR chicken)" resulted in 26 results in Scopus, 5 results in PubMed and 19 results in Web of Science in the span of the year 2005 to 2023. Meanwhile for galangal, the keywords search based on the search statement, "(galanga OR galangal) AND (broiler OR chicken)" had yield in 17 results in Scopus, 5 results in Pubmed and 11 results in Web of Science in the span of the year 1999 to 2023. *In-vivo* studies on polyherbal formulations that combine only these two local plants as growth promoters in broilers are non-existent. Furthermore, review on *A. galanga* and *P. betle* specifically, as growth promoter supplements in broilers, have never been done before this publication. Hence, this review aims to elaborate on the potential use of *A. galanga* and *P. betle* and as growth promoter supplements in broilers.

GROWTH PROMOTER IN POULTRY INDUSTRY

Toldra and Reig (2016) explained that growth promoters are typically used in livestock due to several goals: to promote growth, to improve fat and protein distribution and accelerate feed-to-muscle conversion rate. Growth promoters improve protein deposition by inhibiting the muscle protease enzymes, which leads to an enhanced feed conversion rate. As a result, connective tissue production and collagen cross-linking create leaner and tougher meat yield. Growth promoters are orally activated and can be consumed by the animals from the feed, drinking water, or via a subcutaneous route at the ears for some hormones.

The mechanisms of action of growth-promoting agents are either direct or indirect. Direct acting growth promoting agents are mostly anabolic that are added to increase the lean to fat ratio to achieve higher feed conversion efficiency. The main groups under this criterion are steroid hormones, substances that have hormonal action, resorcylic acid lactones, stilbenes, antithyroid agents, b-agonists and glucocorticoids. Next, the indirect-acting growth promoters are antimicrobials that enhance the nutrients available to the animals instead of the gut bacteria (Toldra and Reig, 2016).

One of the issues concerning growth promoters is the residues in animal products due to the possibility of containing carcinogenic, genotoxic and other undesirable harmful substances that create public fear and awareness of growth promoter usage in livestock (Toldra and Reig, 2016). Eventually, after years of the application under strict conditions and considering withdrawal periods, growth promoters with anabolic effects are banned (Toldra and Reig, 2016). Residues of substances that have hormonal or thyreostatic effects or beta agonists are being monitored in animal products (Toldra and Reig, 2016). Whereas substances which exert growth-promoting effects, such as antimicrobials, are still being utilised and established with maximal residue limits (Toldra and Reig, 2016). Nevertheless, this practice leads to the issue of global health concerns due to antimicrobial resistance.

For years, antimicrobials have been used within the poultry industry to improve feed conversion, promote growth rate and disease prevention (Mehdi et al., 2018). Antibiotic administration under subtherapeutic doses has been used to promote growth and improve immunity by controlling gastrointestinal infections and modifying intestinal microbiomes (Mehdi et al., 2018). Although the mechanisms are still studied occasionally, the actions are thought to involve remodeling intestinal microbial diversity and relative abundance to create an optimum microbiome for growth.

However, according to Huyghebaert et al. (2010), prolonged use of antimicrobial growth promoters (AGP) in poultry had led to the emergence of resistant bacterial strains, subsequently leading to the ban of common feed antibiotics by the European Union. Due to this constraint, the alternatives for AGP have become the subject of interest since a decade ago. A good AGP alternative needs to perform at least similar to the performance of the AGP that helps the animal growth in different outcomes, which include reduced incidence and severity of subclinical infections, reduced microbial use of nutrients, improved nutrient absorptions due to intestinal wall thinning and reduced growth depressing metabolites amount produced by Gram-positive bacteria. This is supported by another study by Brown et al. (2017), that emphasised the necessity of searching for alternatives that mimic the physiological responses of AGP. The study shared similar sentiment by agreeing that AGP functions are not only limited to affecting enteric microbial populations but also to immunomodulatory functions and concluded with an emphasis on understanding the mechanism of actions of AGP to develop an effective alternative. Mehdi et al. (2018) added that alternatives for AGP must maintain a low mortality rate and high animal yield while safeguarding the environment and consumer health.

P. BETLE AS BROILER DIET SUPPLEMENT

Taxonomy and Distribution

Based on the Integrated Taxonomic Information System (ITIS) in 2023, the taxonomy for the betel is as follows:

Kingdom: Plantae
Phylum: Tracheophyta
Class: Magnoliopsida
Order: Piperales
Family: Piperaceae
Genus: *Piper* L.
Species: *P. betle* L.

The betel leaves are widely distributed in Asia and East Africa, mostly in hot and moist regions such as Malaysia, Indonesia, India, Sri Lanka and Bangladesh (Shah et al., 2016; Abdullah et al., 2019; Basit et al., 2020b).

Morphology

As for the physical appearance of betel, Shah et al. (2016) described it to be similar to pepper in terms of growth habits due to the climbing manner of the green leafy vine as a ground cover. The betel vine grows as a small climber that can reach 10 to 15 feet high. Whereas for the leaves, the heart-shape appearance is cover with a glossy and white catkin. Biswas et al. (2022), added a lengthier and more detailed description of the betel. Betel leaves were described as simple blade, alternate, spiral and ex-spitulate. The petioles are 2 to 5 mm in length, pubescent and channeled. The blades of betel leaves are glabrous, coriaceous, fleshy, green-yellow in colour, glossy, broadly ovate, with the size measured 7 to 8.5 cm width, 9 to 11cm length. Betel leaves also have a cordate base, acuminate apex, with an entire margin and narrowly recurved. Leaf veins are reticulate venation, with seven to nine veins in two or three pairs originating from the mid rib, and singular pair from the base. For the inflorescence or the flower head, the axillary could spike to 5.5 cm. The shape of the male inflorescence forms a cylindrical pendulous catkin measuring length of 10cm and diameter of 2 cm. Meanwhile, the female spikes are cylindrical and pendulous, measuring 2.5 to 4 cm long and 0.5 cm diameter. There are also minute, reduced and unisexual individual flowers formed from a couple of stamens and stigmas in the axil of each bract. The bracts are described as orbicular, peltate in the arrangement of a thickly crowded spiral. Mature inflorescence possesses a strong aroma. The measurement for most fruiting spikes is 3 to 5 cm long, in orange and dripping manner entrenched on the rachis of mature inflorescence. Betel stems appear stout, terete, flat shaped, light greenish when young, zed by the short, raised, whitish streaks and with pink stripes across the node with the internodes measured at 12 cm length and 1.2 cm diameter.

Nutritional and Phytochemical Properties

The summary of nutritional values of *P. betle* can be found in Table 1. Meanwhile, the phytochemical constituents summary is presented in Table 2 and Table 3.

Despite the abundance of phytoconstituents that the betel plant

Table 1 Nutritional composition of *Piper betle*

	Piper betle leaves	Dried *Piper betle* leaves powder
References Method	Shah et al. (2016) Review paper	Vijayanchali, (2018) Anthrone method (carbohydrate), Lowry method (protein), Soxhlet (fat), Association of Official Analytical Chemists, (1990) (ash, fibre)
Moisture (%)	85 - 90	84.5
Protein (%)	3 - 3.5	2.9
Ash (%)	-	1.2
Oil (%)	0.08 - 0.2	-
Carbohydrate (%)	0.5 - 6.1	5.6
Fat (%)	0.4 -1.0	0.5
Fibre (%)	2.30	2.0

Table 2 Phytochemical Constituents of *Piper betle* from Review Articles

***Piper betle* (Betel)**	
Author	**Findings**
Azahar et al. (2020)	Major components of *Piper betle* are tannins, flavonoids (quercetin), eugenol, hydroxychavicol and chavibetol.
Biswas et al. (2022)	Key constituents of betel leaves oil, including safrole (48.7%), chavibetol acetate (12.5%), allylpyrocate choldiacetate (34.0%), as well as ρ–cymene, 4-terpinol, eugenol, and β-caryophyllene. Another study reviewed by Biswas et al. (2022) identified the primary compounds in betel leaves oil, including two sesquiterpenes, cadinene and caryophyllene, safrole (52.7%), eugenyl acetate (5.8%), allylpyrocatecholdiacetate (15.4%), and eugenol (6.4%).
Nayaka et al. (2021)	The content of essential oil in betel leaves was 0.15% to 0.2%. The GC-MS analysis of the essential oil from betel leaves identified phenylpropanoid groups as the major components, including acetyl eugenol, eugenol, chavicol, and safrole. The essential oil from betel leaves contained approximately 40% eugenol, a combination of carvacrol and chavicol at nearly 40%, with chavibetol as a marker compound.

Table 3 Phytochemical Constituents of *Piper betle* from Research Articles

Author	Study	Result
Das et al. (2019)	Analysed the effect of different extracting methods (sonication, Soxhlet, maceration) using acetone (100%, v/v). on the polyphenolic content and antioxidant activities in *Piper betle* leaves.	• Total phenolic content was higher in the sonication extract followed by maceration and Soxhlet. In contrast, the total flavonoid content was also higher in the sonication extract followed by Soxhlet and maceration. • The phenolic content (mg GAE/10 mg extract) of sonication, maceration and Soxhlet extraction methods were 57.60, 53.20 and 50.00, respectively. • The flavonoid content (mg GAE/10 mg extract) of sonication, maceration and Soxhlet extraction methods were 49.79, 32.10 and 40.89, respectively. • The eugenol content (%) of sonication, maceration and Soxhlet extraction methods were 0.32, 0.18 and 0.16, respectively. • The eugenol acetate content (%) of sonication, maceration and Soxhlet extraction methods were 0.376, 0.369 and 0.315, respectively.
Karak et al. (2019)	Analysed phytochemical composition of two solvent fractions, chloroform fractions (CF) and ethyl acetate fractions (EF) of the aqueous extracts obtained from eight varieties of *P. betle* leaves	• Thirty compounds comprising 8 organic acids, 4 fatty acids, 11 phenols, 3 sugars, 2 sugar alcohols, and 2 other organic compounds were detected from CFs. • A total of 64 compounds consisting of 3 amino acids, 20 organic acids, 4 fatty acids, 22 phenols, 6 sugars, 5 sugar alcohols, 1 terpenoid, and 3 other organic compounds were detected from the EFs. • CFs contained a lesser number of metabolites than EFs. • HPTLC analysis confirmed hydroxychavicol is the major compound present at 30% to 40% in the chloroform fraction of seven of eight varieties.
Nguyen et al. (2020)	Codetermination of highly bioactive com- pounds, namely, hydroxychavicol, eugenol, and gallic acid in the *Piper betle* leaf extract by high-performance liquid chromatography method	• The methanol extract contained the highest amounts of hydroxychavicol and gallic acid, thus offering the strongest antioxidant activity in 1,2-diphenyl-2-picrylhydrazyl free radical scavenging assay. • All three compounds were found at low levels in the hexane extract. • The solvent type did not significantly affect the concentration of extracted eugenol. • Ethyl acetate is a good choice to produce a highly antibacterial extract, but methanol and ethanol are more suitable when the antioxidant activity of the extract is more concerned.

possesses, this article would like to focus on the major components of the betel plant that were reported by various studies in recent years. Azahar et al. (2020) reported that the major components of *P. betle* are tannins, flavonoids (quercetin), eugenol, hydroxychavicol and chavibetol. Meanwhile Nguyen et al. (2020) highlighted that hydroxychavicol, eugenol and gallic acid were successfully quantified through high performance liquid chromatography (HPLC) analysis among many phenolic compounds that betel possessed.

Nayaka et al. (2021) reported that the content of essential oil in betel leaves was 0.15% to 0.2% that were grouped as monoterpenes, sesquiterpenes, phenylpropanoids and aldehydes. The gas chromatography mass spectrometry (GC-MS) analysis of the essential oil from betel leaves identified phenylpropanoid groups as the major components, including acetyl eugenol,

eugenol, chavicol, and safrole. The essential oil from betel leaves contained approximately 40% eugenol, a combination of carvacrol and chavicol at nearly 40%, with chavibetol as a marker compound.

Biswas et al. (2022) described the key constituents of betel leaves oil, including safrole (48.7%), chavibetol acetate (12.5%), allylpyrocate choldiacetate (34.0%), as well as ρ–cymene, 4-terpinol, eugenol, and β-caryophyllene. Another study reviewed by Biswas et al. (2022) identified the primary compounds in betel leaves oil, including two sesquiterpenes, cadinene and caryophyllene, safrole (52.7%), eugenyl acetate (5.8%), allylpyrocatecholdiacetate (15.4%), and eugenol (6.4%). Variety of betel phytochemicals depends on the botanical origin and solvent used for extraction. Similarly, the constituents of the betel leaf essential oil depend on the botanical origin, plant age and harvest time. Due to the variety of compounds in the essential oil, the aroma, taste and bioactivity may also be affected.

Nayaka et al. (2021) reported that the phenol content of betel differs by gender. The male plants contain triple the amount of total phenols and twice the amount of thiocyanate than female plants. Other factors that affect the compound concentrations are the different plant varieties, season, climate, geographical location, soil, humidity, agricultural practices and rainfall. Khairullah et al. (2020) reported similarly by mentioning geographical distribution as a factor that influences terpenes and phenolic compounds distribution in betel.

Beneficial Chemical Compounds to Broilers

The beneficial chemical compounds of *Piper betle* to broilers are summarised in Table 4.

Generally, alkaloids and flavonoids were proven to have antimicrobial,

Table 4 Beneficial Chemical Compounds of *Piper betle* to Broilers

Chemical group/ compound	Effect	Reference
Alkaloid	Antimicrobial, anti-inflammatory and antioxidant effects to the animals	Basit et al. (2020a) Basit et al. (2020b)
Eugenol	Improve biological developments in chicken via inhibiting microbial growth through the free hydroxyl group, stimulating the appetite of chickens, triggering pancreatic function and digestive enzymes, enhancing growth performance, increasing digestibility, improving serum total antioxidant capacity and reducing proinflammatory cytokine (IL-18) expression.	Basit et al. (2020a) Basit et al. (2020b) Nguyen, et al. (2020)
Flavonoid	Antimicrobial, anti-inflammatory and antioxidant effects to the animals	Basit et al. (2020a) Basit et al. (2020b)
Gallic acid	Possesses anti-inflammatory, antimutagenic and antioxidative properties	Nguyen, et al. (2020)
Hydroxychavicol	Avoid infection due to the antimicrobial and anti-inflammatory effects	Basit et al. (2020a) Basit et al. (2020b) Nguyen, et al. (2020)
Quercetin	Improve biological development of broilers via growth hormone upregulation with hepatic growth hormone receptors, which consequently leads to higher insulin-like growth factor-1 concentration. Improved growth performance, reduced oxidative stress and proinflammatory cytokines like TNF-a, cyclooxygenase-2 interleukin 6 and cyclooxygenase-2	Basit et al. (2020a) Basit et al. (2020b)
Tannin	In low doses, is able to positively modulate the gut and its ecosystem, antimicrobial, anti-inflammatory and antioxidative properties, improves nutrient absorption via protein and enzyme complexation which lead to better growth performance	Basit et al. (2020a) Basit et al. (2020b)

anti-inflammatory and antioxidant effects to the animals (Basit et al., 2020a; Basit et al., 2020b). The hydroxychavicol in betel is beneficial to avoid infection due to the antimicrobial and anti-inflammatory effects. (Basit et al., 2020a; Basit et al., 2020b; Nguyen, et al., 2020). Betel also contains tannin, which in low doses, is able to positively modulate the gut and its ecosystem, antimicrobial, anti-inflammatory and antioxidative properties, improves nutrient absorption via protein and enzyme complexation which lead to better growth performance (Basit et al., 2020a; Basit et al., 2020b). Eugenol, an amphipathic hydroxyphenyl propene was proven to improve biological developments in chicken via inhibiting microbial growth through the free hydroxyl group, stimulating appetite of chickens, triggering pancreatic function and digestive enzymes, enhancing growth performance, increasing digestibility, improving serum total antioxidant capacity and reducing proinflammatory cytokine (IL-18) expression (Basit et al., 2020a; Basit et al., 2020b; Nguyen, et al., 2020). Quercetin, a type of flavonoid was reported to improve biological development of broilers via growth hormone upregulation together with hepatic growth hormone receptors, which consequently lead to higher insulin-like growth factor-1 concentration (Basit et al., 2020a; Basit et al., 2020b). Quercetin also improved growth performance, reduced oxidative stress and proinflammatory cytokines like TNF-a, cyclooxygenase-2 interleukin 6 and cyclooxygenase-2 (Basit et al., 2020a; Basit et al., 2020b). Gallic acid, which is a natural polyphenol possesses anti-inflammatory, antimutagenic and antioxidative properties (Nguyen, et al., 2020). Likewise, Oso et al. (2019) mentioned that gallic acid was proven to be anti-inflammatory, antibacterial, antiviral, and anticancer, in addition to its benefits in cardiovascular disease treatments.

In-vivo Studies on *P. betle* as Dietary Supplement in Broiler

Several studies that involve the supplementation of *P. betle* in the diets of broilers in Asia has been published. The *in-vivo* studies on *Piper betle* as dietary supplement in broiler are shown in Table 5.

P. betle was included as one of the plants in phytogenic blend to

Table 5 *In-vivo* Studies on *Piper betle* as Dietary Supplement in Broiler

Method of Supplementation	Plant form	Result	Reference
Broiler feed supplemented with phytogenic blend of *Aerva lanata*, *Piper betle*, *Cynodon dactylon*,and *Piper nigrum* at 1% and 2%	Powder	Improves growth performance, intestinal morphology, and apparent ileal digestibility of organic matter and tryptophan in a dose-dependent manner with the best response at 1% inclusion level	Oso et al. (2019)
Drinking water supplemented with 2% and 4% extract of betel leaf	Extract	Extract of betel leaf water at 4% increased carcass weight and reduced the number of broiler gastrointestinal bacteria.	Lodang et al. (2020)
Broiler feed supplemented with 4%, 8%, and 12% of *Piper betle*	Soilage	12% *Piper betle* consistently outgrown the broilers fed with 8% 4% and control in terms of body weight, feed consumption, gain in weight, and income overfeeds, soilage, chick cost, and miscellaneous cost	Gannapao and Patagao, (2020)
Broiler feed supplemented with 2 g/kg, 4 g/kg and 8 g/kg *Piper betle*	Powder	4 g/kg betel supplement in the feed had improved the microscopic intestinal structure, nutrient digestibility, and the growth performance of broiler chickens that yielded the highest body weight gain	Basit et al. (2020a)
Broiler feed supplemented with 4 g/kg *Piper betle*	Powder	4 g/kg betel supplement in the feed resulted in improvements in gut morphology, caecal microbiota dynamics, nutrient digestibility and growth performance in broilers	Basit et al. (2020b)

study the effect on growth performance, ileal nutrient digestibility, intestinal morphology and caecal microflora in broilers (Oso et al., 2019). The body weight gain of the broiler chicks was shown to be significantly increased as the percentage of phytogenic blend increased. During the grower stage, the 1% phytogenic blend supplement managed to gain similar body weight gain as the antibiotic supplement and successfully resulted in the highest body weight gain throughout the study overall. The 1% phytogenic blend supplement also showed the most excellent feed conversion ratio result significantly compared to non-supplemented and antibiotic supplemented broilers. The non-supplemented broiler had the highest mortality rate in the study. Significant increase of ileal organic matter digestibility had been observed in 1% and 2% supplemented broilers, but reduced in antibiotic supplemented broilers. The 1% supplement showed the highest result of tryptophan in the ileal digestibility test. The intestinal morphology of the supplemented broilers showed longer duodenal villi height compared to non-supplemented, and similar results with the antibiotic supplemented group. However, the phytogenic supplemented broilers surpass the antibiotic supplemented group for jejunal villi height. Regarding gut microflora, the *Bifidobacterium* concentration in the caecal content of phytogenic supplemented broilers showed an increase in line with the inclusion levels of the phytogenic blend. The study summed up the results by highlighting the best response for broiler growth performance, intestinal morphology and apparent ileal digestibility of organic matter and tryptophan was achieved best in 1% inclusion level of the phytogenic blend.

Another study by Lodang et al. (2020) discussed the effect of administering betel leaf extract via drinking water on broiler production and carcass quality. A total of 2% and 4% betel leaf extract were given via drinking water to observe the performance, nutrient digestibility, and total faecal bacteria. Significant results were obtained for the carcass weight, total plate count, coliform and *Escherichia coli.* However, negative results were observed for ration and water consumption, body weight gain, feed conversion ratio, initial body weight, final weight, carcass percentage, meat percentage, fat and skin percentage, bone weight, meat weight, meat bone ratio and nutrient digestibility. Thus, the conclusion was that 4% of betel leaf extract in drinking water positively increased carcass weight and decreased the total number of bacteria.

A study by Gannapao and Patagao, (2020) on a broiler diet supplemented with 4%, 8%, and 12% of *P. betle* showed positive results on body weight, feed consumption, body weight gain, income over feed, soilage, chick and miscellaneous cost. Percentage growth rate, feed conversion ratio, feed conversion efficiency and dressing percentage were not significantly different. Similar results were obtained for liver and pancreas weight, which also did not exceed the toxicity limit indicating no toxic or harmful effects even with a high percentage of inclusion in this study. The betel was also deemed safe to be supplemented in feed.

According to Basit et al. (2020a), the effect of different doses of 2 g/kg, 4 g/kg and 8 g/kg *P. betle* dietary supplements on broilers' growth performance, ileal digestibility and gut morphology were observed. The 2 g/kg and 4 g/kg of betel supplement in feed increased the body weight gain significantly, improved the body weight gain significantly, and improved gut architecture and nutrient digestibility in broiler chickens' starter and grower phase. For the overall growth period, the 4 g/kg betel supplement had the best body weight gain and feed efficiency, among others. The 4 g/kg betel diet supplementation also had significantly longer villi for the duodenum and jejunum and significant improvement in ether extract digestibility and dry matter. However, 8g/kg betel leaf showed significantly least crude protein digestibility. Therefore, the study in 2020a by Basit et al. (2020a) concluded that 4g/kg betel supplement in the feed had improved the microscopic intestinal structure, nutrient digestibility, and the growth performance of broiler chickens that yielded the highest body weight gain.

The study was continued by another study from Basit et al. (2020b) by comparing the 4 g/kg betel leaf supplement with halquinol and tetracycline supplemented broilers to observe the growth performance, gut morphology, ileal digestibility and caecal microbiota composition. The body weight gain of the broiler supplemented with 4 g/kg *P. betle* was significantly enhanced on day 21 and day 42 compared to the negative control. However, the antibiotics only significantly enhanced the body weight gain on day 42 but not on day 21. The feed conversion ratio was significantly reduced in the antibiotics and betel supplemented chickens. A similar trend was observed for the gut morphology, which improved significantly compared to the negative control. Although the study was done with the *Persicaria odorata* leaf meal, maximum villus height in duodenum and jejunum was observed in *P. betle* 4 g/kg dietary supplement. Supplementation of betel significantly improved the dry matter, organic matter, crude protein, ether extract and ash digestibility which was as positive as antibiotics compared to the non-supplemented broilers. Betel and the other supplements also significantly reduced the count of *E. coli*, *Salmonella* and *Staphylococcus aureus*. However, only betel supplements significantly reduced the total anaerobic bacteria and *Clostridium* spp. count compared to non-supplemented broilers. A similar study also observed that only phytobiotic supplements could significantly increase *Lactobacillus* count compared to antibiotics and non-supplemented groups. Basit et al. (2020b) concluded that phytobiotics supplementation in this study, which included *P. betel* resulted in improvements in gut morphology, caecal microbiota dynamics, nutrient digestibility and growth performance in broilers.

THE USE OF *A. GALANGA* AS BROILER DIET SUPPLEMENT

Taxonomy and Distribution

Based on the Integrated Taxonomic Information System (ITIS) in 2023, the taxonomy for the greater Galangal is as follows:

Kingdom: Plantae
- Phylum: Tracheophyta
  - Class: Liliopsida
    - Order: Zingiberales
      - Family: Zingiberaceae
        - Genus: *Alpinia* Roxb.
          - Species: *A. galanga* (L.) Willd

The galangal cultivation is widely distributed in Asian countries exposed to extensive sunlight, like India, Arabia, China, Sri Lanka and Indonesia (Khairullah et al., 2020).

Morphology

The physical description of galangal is well described by Khairullah et al. (2020). The herb can reach a height of 3.5 cm, with underground rhizomes and minor adventitious roots. The rhizome's exterior appearance is red-brown, while interiorly, it is brown-orange. Further description on the pseudostem show that it is 2.5 to 10cm long, erected above the ground and covered with leaves. Galangal leaves are about 3.8 to 11.5 cm, oblong-lanceoelate, glabrous, distichous and acute. Their flowers are described as a fragrant, compound approximately 3.0 to 4.0 cm long, with green base flower crowns and whitish buds. Next, galangal fruits are red-orange ellipsoidal and capsule-like and measure approximately 1.5 cm in diameter. Several other variations, such as the pink and yellowish-white galangal rhizomes, are noted.

Nutritional and Phytochemical Properties

The summary of nutritional values of *A. galanga* can be found in Table 6. Meanwhile, the phytochemical constituents summary is presented in Table 7 and Table 8.

For galangal, Das et al. (2020) revealed that the biochemical compounds in galangal were mostly the groups of terpenes and phenolic compounds and

Table 6 Nutritional composition of *Alpinia galanga*

	Alpinia galanga powder	*Alpinia galanga* powder
References	Aljobair, (2022)	Arfa and Ghannam, (2022)
Method	Association of Official Analytical Chemists, (2018)	Micro-Kjeldahl method and by difference (total carbohydrate)
Moisture (%)	4.2	5.4
Protein (%)	5.9	2.4
Ash (%)	5.4	3.2
Oil (%)	3.4	-
Carbohydrate (%)	81.1	79.0
Fat (%)	-	1.4
Fibre (%)	-	14.0

Table 7 Phytochemical Constituents of *Alpinia galanga* from Review Articles

***Alpinia galanga* (Galangal)**	
Author	**Findings**
Das et al. (2020)	Biochemical compounds were mostly the groups of terpenes and phenolic compounds and several classes of compounds include flavonoids, terpenoids, saponins, phenolic acids and essential oils. The major bioactive compounds found are galangin, kaempferol, galangal acetate, and 1,8-cineole
Khairullah et al. (2020)	Various compounds that could be discovered in galangal rhizome were mainly essential oils, flavonoids, phenolic acids, saponins and terpenoids. Meanwhile, the main active compounds were mostly galangal acetate, kaempferol and 1-8 cineole
Mandal et al. (2023)	The main compound of galangal rhizome is 1,8-cineole

Table 8 Phytochemical Constituents of *Alpinia galanga* from Research Articles

Author	**Study**	**Result**
Abdel-Azeem and Basyony, (2019)	Analysed the fractions of phenolic compounds and flavonoid compounds of galangal rhizome extract by a high-performance liquid chromatographic (HPLC)	• *Alpinia galanga* rhizome extract contained 13.6% of flavonoids and 35.39% of phenols. • The major phenolic compounds were 1,8-cineole 15.3/34.7 (MG/100G) %, α-terpineol 20.02/4.24 (MG/100G) %, chavicol llylphenol 25.74/30.02 (MG/100G) % and presence of methyl eugenol 8.76/1.68 (MG/100G) %, eugenol 4.35/3.5 (MG/100G) % and β-pinene 1/7.1 (MG/100G) % • The major flavonoid compounds were quercitrin 553.5/23.58 (MG/100G) %, quercetin 679.5/32.6 (MG/100G) %, naringinin 921.5/34.8 (MG/100G) % and presence of kaempferol 239.7/1.01 (MG/100G) %
Elghalid et al. (2021)	Analysed the antioxidant fractions content of galangal powder	• The total phenols were reported at 9.52% • The carotenoids were reported at 0.53% • The total flavonoids were reported at 5.70%
Sani et al. (2019)	Analysed the phytochemical constituents and antioxidant and antibacterial activities of different crude extracts, hexane, ethyl acetate and methanol, from dried *Alpinia galanga* rhizomes.	• Phytochemical screening showed the presence of flavonoids, steroids and terpenoids in hexane extract. • Phytochemical screening showed the presence of the flavonoids, phenols, steroids and terpenoids in ethyl acetate extract. • Phytochemical screening showed the presence of saponins, flavonoids, tannins, phenols, steroids and terpenoids in methanol extracts. • Methanol extracts give the highest number of those phytochemical constituents.
Tirawanchai et. al. (2020)	Analysed the volatile constituents of galangal aqueous and other plant extracts analysed by gas chromatography coupled with a mass spectrometer	• The main volatile constituent of galangal rhizomes was Eucalyptol or 1,8-cineole at 41.41% • Other volatile compounds were β-caryophyllene at 6.81% followed by β-selinene at 5.68% and chavicol acetate at 5.24% and etc.

several classes of compounds include flavonoids, terpenoids, saponins, phenolic acids and essential oils. The major bioactive compounds found are galangin, kaempferol, galangal acetate, and 1,8-cineole (Das et al., 2020). In agreement, Khairullah et al. (2020) mentioned various compounds that could be discovered in galangal rhizome were mainly essential oils, flavonoids, phenolic acids, saponins and terpenoids, meanwhile the main active compounds were mostly galangal acetate, kaempferol and 1-8 cineole. Mandal et al. (2023) mentioned that the main compound of galangal rhizome is 1,8-cineole. Similarly, Abdel-Azeem and Basyony, (2019) reported galangal rhizome contained galangin which was a flavonol, a type of flavonoid and galangol oil that could produce cineole, eugenol and pinene. The rhizome extract was also rich in β-Sitostero, l-Diarabinoside, β-sitosterol diglucosyl caprate, galangoflavonoside, and 1-acetoxychavicol acetate (Abdel-Azeem and Basyony, 2019). Abdel-Azeem and Basyony, (2019) reported the study from Li and Xu, (2015) that the total polyphenols from galangal rhizomes was up to 13.43 mg/g at the condition of 60% ethanol concentration, in 1 hour extraction at 30°C and 15:1 solvent to plant ratio. Meanwhile the active component of antioxidant flavonoids in galangal that include (kaemperol, kaempferide, galangin, and alpinin) was 0.21% which made them better antioxidant than other plants (Abdel-Azeem and Basyony, 2019; Elghalid et al., 2021). The content of volatile oils in galangal rhizome extract were 48% methyl cinnamate, 20-30% cineole, α-pinene, β-pinene and camphor, diarylheptanoids, and flavonoids and phenylpropanoids (Abdel-Azeem and Basyony, 2019).

Beneficial Chemical Compounds to Broilers

The beneficial chemical compounds of *Alpinia galanga* to broilers are summarised in Table 9.

In general, total phenols, carotenoids, flavonoids, tannins and saponins present in galangal are renowned antioxidants. Galangal possess the antioxidant

Table 9 Beneficial Chemical Compounds of *Alpinia galanga* to Broilers

Chemical group/ compound	Effect	Reference
2,4-diacetyl phloroglucinol	Antibacterial properties	Elghalid et al. (2021)
Anthocyanin	Antioxidant properties	Abdel-Azeem and Basyony, (2019) Elghalid et al. (2021)
Carboxylic acid	Antibacterial properties	Elghalid et al. (2021)
Essential oil	Managed to decrease the cholesterol biosynthesis and absorption	Elghalid et al. (2021)
Flavonoid	Antioxidant properties, decreased the cholesterol biosynthesis and absorption	Abdel-Azeem and Basyony, 2019; Elghalid et al. (2021)
Glycoside	Antioxidant properties	Abdel-Azeem and Basyony, 2019; Elghalid et al. (2021)
Polyphenol	Antioxidant properties, polyphenolic composite modulated redox homeostasis in chickens, reduced membrane lipid peroxidation that led to lower risk of free radical related disorders and lower serum triglyceride concentration. Managed to effectively inhibit low density lipoprotein oxidation	Abdel-Azeem and Basyony, 2019; Elghalid et al. (2021)
Saponin	Helped to suppress cholesterol uptake via lipase activity inhibition, cholesterol binding and lowering surface tension. Limited fat absorption in the small intestine by binding to triglycerides in the intestinal lumen which inhibit the lipase activity	Abdel-Azeem and Basyony, 2019; Elghalid et al. (2021)
Tannin	Antioxidant properties, helped to suppress cholesterol uptake via lipase activity inhibition, cholesterol binding and lowering surface tension.	Abdel-Azeem and Basyony, 2019; Elghalid et al. (2021)
Thiocarbamate	Antioxidant properties	Abdel-Azeem and Basyony, 2019; Elghalid et al. (2021)
Unsaturated fatty acid	Antioxidant properties	Abdel-Azeem and Basyony, 2019

properties due to the presence of polyphenols, anthocyanin, glycosides, and thiocarbamates, which scavenge free radicals that helps to improve the health status of chickens under heat stress conditions (Abdel-Azeem and Basyony, 2019; Elghalid et al., 2021). The antioxidant constituents in galangal were mainly compounds with phenolic hydroxyl groups, dual bonds involving flavonoids, unsaturated fatty acids and tannins (Abdel-Azeem and Basyony, 2019). High antioxidant polyphenolic composites in galangal modulated redox homeostasis in chickens, reduced membrane lipid peroxidation that led to lower risk of free radical related disorders and lower serum triglyceride concentration (Abdel-Azeem and Basyony, 2019; Elghalid et al., 2021). Phenolic components of galangal managed to effectively inhibit low density lipoprotein oxidation (Abdel-Azeem and Basyony, 2019; Elghalid et al., 2021). Besides, the flavonoids and essential oils in galangal managed to decrease the cholesterol biosynthesis and absorption (Elghalid et al., 2021). Other contents of galangal that help to suppress cholesterol uptake were saponins and tannins via lipase activity inhibition, cholesterol binding and lowering surface tension (Elghalid et al., 2021). Saponin in galangal limited fat absorption in the small intestine by binding to triglycerides in the intestinal lumen which inhibit the lipase activity (Abdel-Azeem and Basyony, 2019). Besides, Elghalid et al. (2021) revealed that the galangal has antibacterial properties due to its lipophilic components and antibiotic metabolites like carboxylic acid, 2, 4-diacetyl phloroglucinol, and cell wall degrading enzymes. Elghalid et al. (2021) also added that the components available in galangal rhizomes stimulate the digestive enzymes like glucase, oxidase, catalase and peroxidase which facilitate digestion that eventually increase body weight.

In-vivo Studies on *A. galanga* as Dietary Supplement in Broiler

For *A. galanga*, previous studies had discussed using galangal as a dietary supplement in broiler feed. The *in-vivo* studies on *Alpinia galanga* as dietary supplement in broiler are shown in Table 10.

Abdel-Azeem and Basyony, (2019) studied the different levels of *Alpinia galanga* rhizome extracts on the blood biochemistry, antioxidant biomarkers,

Table 10 *In-vivo* Studies on *Alpinia galanga* as Dietary Supplement in Broiler

Method of Supplementation	Plant form	Result	Reference
Broiler feed supplemented with 250 mg/kg, 500 mg/kg and 750 mg/kg galangal rhizome extracts	Extract	250, 500 and 750 mg/kg supplementation enhanced performance of growth, antioxidant biomarkers, crude protein and ether extract in breast meat and decreased broiler mortality with the best result at 750 mg/kg	Abdel-Azeem and Basyony, (2019)
Broiler feed supplemented with 0.25%, 0.50%, 0.75% and 1.00% of galangal	Powder	Galangal dietary supplement, especially at 0.25%, improves physiological status, performance (increased body weight gain and feed utilization) and blood biochemical parameters, indicating improved antioxidative status.	Elghalid et al. (2021)

lipid peroxidation, productive performance and carcass traits of broilers during heat stress or summer season. The feed trial involved the inclusion of 250mg/kg, 500mg/kg and 750mg/kg galangal rhizome extracts. Results showed significant reduction in the supplemented groups' total plasma cholesterol, triglycerides, low density lipoproteins, and total lipids. In addition, the galangal extract-supplemented group significantly augmented total antioxidant capacity, glutathione S-transferase, superoxide dismutase, catalase, and glutathione peroxidase. The highest dosage of galangal at 750mg/kg showed the least mortality rate, with the best feed conversion ratio and body weight gain. The malondialdehyde amount was also significantly reduced by increasing the galangal dosage levels. Improved percentages of dressing, breast and thigh were significant for supplemented chicks. Increased values of abdominal fat, liver, heart and gizzard weights were observed in all the supplemented groups. The breast meat of supplemented broilers was affected by higher crude protein, moisture and ether extract than the unsupplemented group. Nevertheless, the increase in galangal extract dosages showed the reduction of crude protein in the thigh meat of all the supplemented groups compared with the negative control. These positive results led to the conclusion that the galangal extract supplementation in broiler feed helped to alleviate the adverse effects of heat stress on broiler chickens.

Another study by Elghalid et al. (2021) was conducted to observe the effect of including 0.25%, 0.50%, 0.75% and 1.00% of galangal in broiler feed on the productive broiler performance, lipid profile, antioxidant biomarkers, carcass traits, economic efficiency and production index. Supplementing the broilers with galangal at all different levels significantly increased the body weight at 6 weeks of age and weight gain for 6 weeks. The best bodyweight gains were observed in 0.25% and 1.00% galangal supplement levels. The body weight and body weight gain in this study depends on the level of supplements. Feed consumption was significantly lower in supplemented chickens, leading to better feed conversion ratio results, with the best FCR obtained by 0.25% and 1.00% supplement levels. Serum glucose levels, triiodothyronine (T3) and thyroxine (T4) were significantly increased in every supplemented chick group. Galangal inclusion in different levels also significantly decreased the serum concentrations of total lipids, cholesterol, triglycerides, and low-density lipoprotein (LDL). However, the high-density lipoprotein level was unaffected for every treatment group. Moreover, the antioxidant capacity in the galangal supplemented broilers were improved significantly. Increases in glutathione peroxidase activity (GSH-Px) and superoxide dismutase (SOD) were observed in the supplemented groups. As for the carcass characteristics, the carcass percentages of galangal supplemented broilers were enhanced significantly with the best result obtained by the 0.25% supplementation level. All supplement levels showed reduced abdominal fat in the chickens, and non-significantly increased percentages of lymphoid organs, which were the spleen, thymus and bursa. From the economic perspective, the galangal supplementation illustrated that net revenue increased as the dietary galangal supplement nutrient levels increased. The lower level of galangal supplementation at 0.25% was the most excellent in economical efficiency and relative economy efficiency percentage.

POLYHERBAL DIETARY SUPPLEMENTATION OF *A. GALANGA* AND *P. BETLE* IN BROILER

In-vivo study on *Piper betle* and *Alpinia galanga* combination with other plants as dietary supplement in broiler is presented in Table 11.

Oso et al. (2019) mentioned that the approach of various phytogenic feed additives combination could promote synergistic and additive effects of

Table 11 *In-vivo* Study on *Piper betle* and *Alpinia galanga* as Dietary Supplement in Broiler

Method of Supplementation	Plant form	Result	Reference
Drinking water supplemented with 25% of eight combinations of phytobiotics, including *Alpinia galanga* and *Piper betle,* among other plants.	Boiled solution or fermented solution	Fermented solution supplemented group that included galangal and betel plus other plants showed the lowest feed intake and weight gain but lowest feed conversion ratio. Fermented group that included betel without galangal plus other plants had also shown lowest feed conversion ratio	Sari and Hasanah, 2022

several bioactive compounds. The supplementation of *Alpinia galanga* and *Piper betle* had also been mixed previously in a study, even though the study included other medicinal plants in the formulation. Sari and Hasanah, 2022 studied the effect of eight combinations of phytobiotics, including *Alpinia galanga* and *Piper betle,* among other plants. Four groups out of eight treatment groups include *Alpinia galanga* and *Piper betle* in formulating the drinking water supplements. Two of the groups involved the combination of *Alpinia galanga* and *Piper betle* among other plants, either boiled or fermented solution. Meanwhile the two other groups involved only *Piper betle* among other plants, either boiled or fermented. The active ingredient as phytobiotics was set at 1.06%/L drinking water treatment. The fermented solution supplemented group (including galangal and betel with other plants) showed the lowest feed intake and weight gain compared to the rest of the formulations. However, the fermented group (galangal and betel with other plants) and another fermented group (betel only with other plants) had shown very significant lowest feed conversion ratio at 1.23 and 1.17, respectively, compared to the rest of the formulations. All medicinal plants in every group showed significant positive results on the studied parameters: feed intake, body weight gain and feed conversion ratio.

FUTURE RECOMMENDATIONS

The administration of these plants as food or drink supplements at the farm level to improve broiler growth performance is still questionable and not convincing due to inadequate scientific evidence to support the practice**.** In response, future researchers are recommended to investigate the ability of polyherbal formulation of *Piper betle* and *Alpinia galanga* to be utilized as growth promoters**.** More *in-vitro* and *in-vivo* studies that cover the impact of these plants on growth performance, haematological parameters, serum biochemistry, immunomodulation, organ toxicity and morphological changes will contribute significantly to advancing the idea of creating useful natural growth promoters**.**

CONCLUSIONS

In conclusion, *Piper betle* and *Alpinia galanga* as two local Asian plants possess the potential to be explored as growth promoters in poultry based on the positive impacts of phytogenic feed additive, beneficial phytochemical properties and previous in-vivo studies. However, more scientific evidence, especially in areas addressed in the recommendations, should be obtained to justify the use of these plants on the farm level.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abd El-Hack, M.E., El-Saadony, M.T., Salem, H.M., El-Tahan, A.M., Soliman, M.M., Youssef, G.B.A., Taha, A.E., Soliman, S.M., Ahmed, A.E., El-kott, A.F., Al Syaad, K.M., Swelum, A.A., 2022. Alternatives to antibiotics for organic poultry production: types, modes of action and impacts on bird's health and production. Poult. Sci. 101(4), 101696.

Abdel-Azeem, A.A., Basyony, M., 2019. Some blood biochemical, antioxidant biomarkers, lipid peroxidation, productive performance and carcass traits of broiler chicks supplemented with alpinia galangal rhizomes extract during heat stress. Egypt. Poult. Sci. J. 39(2), 345–363.

Abdullah, L.C., Pin, K.Y., Tee, L.H., Hadzir, N.H.N., 2019. Sirih: extraction and drying technology of its bioactive components. Universiti Putra Malaysia Press, Malaysia.

Aljobair, M.O., 2022. Chemical composition, antimicrobial properties, and antioxidant activity of galangal rhizome. Food. Sci. Technol. 42, e45622.

Arfa, N.A.M., Ghannam, H.A.E., 2022. Utilization of rhizome (Alpinia galanga L.) in improvement of some quality attributes of some processed meat. Food. Nutr. Sci. 13, 761-779.

Azahar, N.I., Mokhtar, N.M., Arifin, M.A., 2020. Piper betle: a review on its bioactive compounds, pharmacological properties, and extraction process. IOP Conf. Ser. Mater. Sci. Eng. 991, 12044.

Basit, M.A., Arifah, A.K., Loh, T.C., Saleha, A.A., Salleh, A., Kaka, U., Idris, S.B., 2020. Effects of graded dose dietary supplementation of Piper betle leaf meal and Persicaria odorata leaf meal on growth performance, apparent ileal digestibility, and gut morphology in broilers. Saudi. J. Biol. Sci. 27(6), 1503–1513.

Basit, M.A., Kadir, A.A., Loh, T.C., Aziz, S.A., Salleh, A., Zakaria, Z.A., Idris, S.B., 2020. Comparative efficacy of selected phytobiotics with halquinol and tetracycline on gut morphology, ileal digestibility, cecal microbiota composition and growth performance in broiler chickens. Animals. 10(11), 1–18.

Bhagwat, V.G., Balamurugan, E., Rangesh, P., 2021. Cocktail of chelated minerals and phytogenic feed additives in the poultry industry: a review. Vet. World. 14(2), 364–371.

Biswas, P., Anand, U., Saha, S.C., Kant, N., Mishra, T., Masih, H., Bar, A., Pandey, D.K., Jha, N.K., Majumder, M., Das, N., Gadekar, V.S., Shekhawat, M.S., Kumar, M., Radha, Prućków, J., Lastra, J.M.P. de la, Dey, A., 2022. Betelvine (Piper betle L.): a comprehensive insight into its ethnopharmacology, phytochemistry, and pharmacological, biomedical and therapeutic attributes. J. Cell. Mol. Med. 26(11), 3083–3119.

Brown, K., Uwiera, R.R.E., Kalmokoff, M.L., Brooks, S.P.J., Inglis, G.D., 2017. Antimicrobial growth promoter use in livestock: a requirement to understand their modes of action to develop effective alternatives. Int. J. Antimicrob. Agents. 49(1), 12–24.

Čabarkapa, I., Puvača, N., Popović, S., Čolović, D., Kostadinović, L., Tatham, E.K., Lević, J., 2020. Aromatic plants and their extracts pharmacokinetics and in vitro/in vivo mechanisms of action. In: Florou-Paneri, P., Christaki, E., Giannenas, I. (Eds.) Feed additives. Academic Press, London, pp. 75-88.

Carsono, N., Tumilaar, S.G., Kurnia, D., Latipudin, D., Satari, M.H., 2022. A review of bioactive compounds and antioxidant activity properties of piper species. Molecules. 27(19), 1–22.

Christaki, E., Giannenas, I., Bonos, E., Florou-Paneri, P., 2020. Innovative uses of aromatic plants as natural supplements in nutrition. In: Florou-Paneri, P., Christaki, E., Giannenas, I. (Eds.), Feed additives. Academic Press, London, pp. 19-34.

Das, S., Ray, A., Nasim, N., Nayak, S., Mohanty, S., 2019. Effect of different extraction techniques on total phenolic and flavonoid contents, and antioxidant activity of betelvine and quantification of its phenolic constituents by validated hptlc method. 3 Biotech. 9(1), 37.

Das, G., Patra, J.K., Gonçalves, S., Romano, A., Gutiérrez-Grijalva, E.P., Heredia, J.B., Talukdar, A.D., Shome, S., Shin, H.S., 2020. Galangal, the multipotent super spices: a comprehensive review. Trends. Food. Sci. Technol. 101, 50-62.

Department of Statistics Malaysia. 2023. Annual Economic Statistics 2022 – Agriculture. Department of Statistics Malaysia, Malaysia.

Elghalid, O.A., El-Tahawy, W.S., Abdel Salam, H., Elnaggar, A.S., 2021. Effect of dietary inclusion of galangal (Alpinia galanga) on growth performance and some physiological parameters of broiler chicks. Egypt. Poult. Sci. J. 41(4), 723-737.

Franz, C.M., Baser, K.H.C., Hahn-Ramssl, I., 2020. Herbs and aromatic plants as feed additives: aspects of composition, safety, and registration rules. In: Florou-Paneri, P., Christaki, E., Giannenas, I. (Eds.), Feed additives. Academic Press, London, pp. 35-56.

Gannapao, J.S., Patagao, T.G., 2020. Growth performance of broilers fed with piper betle L. Leaves as Soilage. Int. J. Ecol. Conserv. 32(1), 102-109.

Huyghebaert, G., Ducatelle, R., Immerseel, F.V., 2011. An update on alternatives to antimicrobial growth promoters for broilers. Vet. J. 187(2), 182-188.

Kamil, M.A.I.M., Abu-Bakar, L., Reduan, M.F.H., Kamaruzaman, I.N.A., Mahamud, S.N.A., Azmi, A.F.M., Rahman, M.S.A., Nordin, M.L., Shaari, R., Shean, S.C.S., 2023. The use of medicinal plants in avian colibacillosis management: A review. Vet. Integr. Sci. 21(2), 507-522.

Karak, S., Das, S., Biswas, M., Choudhury, A., Dutta, M., Chaudhury, K., De, B., 2019. Phytochemical composition, β-glucuronidase inhibition, and antioxidant properties of two fractions of Piper betle leaf aqueous extract. J. Food Biochem. 43(12), 1–12.

Khairullah, A.R., Solikhah, T.I., Ansori, A.N.M., Fadholly, A., Ramandinianto, S.C., Ansharieta, R., Widodo, A., Riwu, K.H.P., Putri, N., Proboningrat, A., Kusala, M.K.J., Rendragraha, B.W., Putra, A.R.S., Anshori, A., 2020. A review of an important medicinal plant: alpinia galanga (l.) willd. Syst. Rev. Pharm. 11(10), 387–395.

Kuralkar, P., Kuralkar, S.V., 2021. Role of herbal products in animal production – an updated review. J. Ethnopharmacol. 278, 114246.

Lodang, E.M.F., Dewi, G.A.M.K., Nuriyasa, I.M., 2020. The effect of giving betel leaf extract (piper betel l.) on the production and quality of broiler carcasses. Int. J. Life Sci. 4(1), 19-25.

Mandal, D., Sarkar, T., Chakraborty, R., 2023. Critical review on nutritional, bioactive, and medicinal potential of spices and herbs and their application in food fortification and nanotechnology. Appl. Biochem. Biotechnol. 195(2), 1319-1513.

Mehdi, Y., Létourneau-Montminy, M.P., Gaucher, M.L., Chorfi, Y., Suresh, G., Rouissi, T., Brar, S.K., Côté, C., Ramirez, A.A., Godbout, S., 2018. Use of antibiotics in broiler production: global impacts and alternatives. Anim. Nutr. 4(2), 170–178.

Nayaka, N., Sasadara, M.M.V., Sanjaya, D.A., Yuda, P., Dewi, N., Cahyaningsih, E., Hartati, R., 2021. Piper betle (L): recent review of antibacterial and antifungal properties, safety profiles, and commercial applications. Molecules. 26(8), 2321.

Nguyen, L.T.T., Nguyen, T.T., Nguyen, H.N., Bui, Q.T.P., 2020. Simultaneous determination of active compounds in Piper betle Linn. leaf extract and effect of extracting solvents on bioactivity. Eng. Rep. 2(10), 2–9.

Oso, A.O., Suganthi, R.U., Reddy, G.B.M., Malik, P.K., Thirumalaisamy, G., Awachat, V. B., Selvaraju, S., Arangasamy, A., Bhatta, R., 2019. Effect of dietary supplementation with phytogenic blend on growth performance, apparent ileal digestibility of nutrients, intestinal morphology, and cecal microflora of broiler chickens. Poult. Sci. 98(10), 4755–4766.

Rafiq, K., Tofazzal Hossain, M., Ahmed, R., Hasan, M.M., Islam, R., Hossen, M.I., Shaha, S.N., Islam, M.R., 2022. Role of different growth enhancers as alternative to in-feed antibiotics in poultry industry. Front. Vet. Sci. 8, 1–9.

Sani, S.A., Faik, A.M., Abdulla, R., Kunasekaran, S., 2019. Phytochemical, antioxidant and antibacterial activities of two kinds of sabah zingberaceae. J. Phys. Conf. Ser. 1358, 12012.

Sari, T.V., Hasanah, U., 2022. The effectiveness of fermented and boiled solution of various medicinal plants in drinking as phytobiotics on broiler performance. IOP Conf. Ser. Earth. Environ. Sci. 977, 12142.

Shah, S.K., Garg, G., Jhade, D., Patel, N., 2016. Piper betle: phytochemical, pharmacological and nutritional value in health management. Int. J. Pharm. Sci. Rev. Res. 38(2), 181-189.

Skoufos, I., Bonos, E., Anastasiou, I., Tsinas, A., Tzora, A., 2020. Chapter 18 - effects of phytobiotics in healthy or disease challenged animals. In: Florou-Paneri, P., Christaki, E., Giannenas, I. (Eds.), Feed additives. Academic Press, London, pp. 311-337.

Stevanović, Z.D., Bošnjak-Neumüller, J., Pajić-Lijaković, I., Raj, J., Vasiljević, M., 2018. Essential oils as feed additives—future perspectives. Molecules. 23(7), 1717.

Tabashsum, Z., Biswas, D., 2019. Chapter 17 - acceptable alternative growth promoters for organic farm animal production. In: Biswas, D., Micallef, S.A. (Eds.), Safety and practice for organic food. Academic Press, London, pp. 345-363.

Tirawanchai, N., Kengkoom, K., Isarangkul, D., Burana-osot, J., Kanjanapruthipong, T., Chantip, S., Phattanawasin, P., Sotanaphun, U., Ampawong, S., 2020. A combination extract of kaffir lime, galangal, and lemongrass maintains blood lipid profiles, hepatocytes, and liver mitochondria in rats with nonalcoholic steatohepatitis. Biomed. Pharmacother. 124, 109843.

Toldrá, F., Reig, M., 2016. Growth Promoters: Characteristics and Determination. In: Encyclopedia of Food and Health. Academic Press. 266–269.

Toldrá, F., Reig, M., 2016. Growth promoters: Characteristics and determination.

Vijayanchali, S.S., 2018. Nutrient composition, phytonutrient constituents and antioxidant activity of the dried betel leaves (Piper Betle). Int. J. Res. Dev.Vol. 5(5), 24-28.

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