Malaysian Applied Biology (2024) 53(6): 1-19
https://doi.org/10.55230/mabjournal.v53i6.R1

Review

Are Locally Sourced Grass or Leaf Meals A Double-Edged Sword in Poultry Broiler Production? A Comprehensive Review

Yee Lyn Ong[1], Eric Lim Teik Chung[1,2]*, Nazri Nayan[1,2], Ngai Paing Tan[3], Faez Firdaus Abdullah Jesse[4], Awis Qurni Sazili[1,2]

1. Institute of Tropical Agriculture and Food Security, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
2. Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
3. Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
4. Department of Veterinary Clinical Studies, Faculty of Veterinary Medicine, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

*Corresponding author: ericlim@upm.edu.my

ABSTRACT

Although antibiotics have considerable positive impacts on poultry production, the use of antibiotics as growth promoters is beginning to diminish as countries continue to prohibit their use, raising concerns about food safety. Consequently, the hunt for antibiotic alternatives is intensified to prevent antimicrobial resistance while not jeopardizing broilers' growth performance. Phytobiotics are of great relevance since, in addition to being derived from plants, they possess valuable pharmacological properties that may benefit the production performances and health status of broilers. Hence, this review will cover the use of grass or leaf meals as a feed additive in broiler diets, as well as the impact on broiler productivity and meat quality. Locally sourced grass or leaf meals could potentially be used as an antibiotic replacement due to bioactive compounds present, however, these very same compounds are deemed to be detrimental if present in high amounts. Therefore, if the appropriate inclusion level is adopted, the addition of grass or leaf meals might successfully be used as an antibiotic alternative while also improving broiler performance and end-product quality.

Key words: Carcass and meat quality, growth performance, nutrient digestibility, phytocompounds

Article History
Accepted: 9 October 2024
First version online: 25 December 2024

Cite This Article:
Ong, Y.L., Chung, E.L.T., Nayan, N., Tan, N.P., Jesse, F.F.A. & Sazili, A.Q. 2024. Are locally sourced grass or leaf meals a double-edged sword in poultry broiler production? A comprehensive review. Malaysian Applied Biology, 53(6): 1-19. https://doi.org/10.55230/mabjournal.v53i6.R1

INTRODUCTION

Globally, the poultry business is one of the fastest-expanding agricultural sectors, and it has grown in importance throughout the world to meet the rising demand for poultry meat and eggs (Wasti *et al*., 2020; Kamaruzaman *et al*., 2022). In 2020, the Food and Agriculture Organization (FAO) reported that global poultry meat production reached 133 million tonnes, comprising 40% of total meat production worldwide. Over the past decade, the consumption of poultry meat has doubled, and projections indicate that this trend will persist, with consumption expected to double again by 2050 (Wasti *et al*., 2020). To fulfill the growing demands for poultry meat, years of commercial intensive selective breeding have allowed the body weight increase of modern strains of broiler chickens to be highly efficient (Zuidhof *et al*., 2014). Besides genetics, the application of novel and innovative technologies at the farm has played a key role in the vast growth of the poultry industry to keep up with the growing market demand for poultry meat (Chowdhury & Morey, 2019). Whilst there is a continuing need to supply the growing demand for chicken meat, sustainable meat production is required to offer safe and high-quality meat for human consumption. However, poultry producers and consumers are challenged with the threat of antibiotic resistance as the animal industry relies on antibiotics to treat diseases (Alghirani *et al*., 2021a).

Antibiotic growth promoter in broiler health and performances

In the poultry sector, besides vaccines, antimicrobials are used as growth promoters, treatment, and prevention of infectious diseases in livestock (Ibrahim *et al*., 2021). Antibiotic growth promoter (AGP) is described as any medicine that is administered at a low, sub-therapeutic dose with the function of destroying or inhibiting bacteria (Hughes & Heritage, 2004). The sub-therapeutic use of antibiotics in animal feeds has been linked to higher rates of antimicrobial resistance (AMR) among pathogens isolated from animals. Evidence suggests that antibiotic-resistance genes can and do transfer from animal to human microbiota (Dibner & Richards, 2005). Consequently, whether it occurs directly through antibiotic residues in meat, potentially leading to side effects; or indirectly through the selection of antibiotic resistance determinants that could transfer to human pathogens or zoonotic bacteria, human health may be compromised. For that reason, several developed countries such as the European Union and the United States have banned the usage of in-feed antibiotics as growth promoters and is to be solely used for treatment (Windisch *et al*., 2008; FAO, 2020; Gheisar & Kim, 2018). Similarly, developing countries such as Malaysia have followed suit and have prohibited the use of antibiotics colistin, erythromycin, enrofloxacin, tetracycline, ceftiofur, tylosin, and fosfomycin in livestock due to high resistance rates to guarantee animal health and consumers' safety (DVS, 2020). With the ban on antibiotics despite their value as a growth promoter, there is increasing pressure on the livestock sector to seek alternatives for antimicrobials to prevent AMR and antibiotic residue in the poultry industry without compromising the performance of the broiler chickens. Common natural feed additives that could be used as an antibiotic alternative are phytogenic groups which include essential oils (Reis *et al*., 2018; Coles *et al*., 2023), enzymes (Rizwanuddin *et al*., 2023), prebiotics and probiotics (Fathima *et al*., 2023), and herbal extracts (Galli *et al*., 2020). These phytogenics possess a plethora of bioactive chemicals or phytocompounds that account for their antioxidant and antimicrobial properties. Therefore, they could potentially be utilized to enhance the diet of broilers to establish a viable and sustainable production cycle.

Grasses and leaves as phytobiotics in poultry

The usage of plants and their extracts have long been used in traditional and alternative medicine to improve livestock production due to their phytogenic and phytobiotic properties (Kuralkar & Kuralkar, 2021). Phytochemicals or phytocompounds are bioactive plant chemicals abundant in fruits, vegetables, grains, and other plant-based foods, believed to possess protective properties for the plant. Phytocompounds are of great interest as they have a wide range of beneficial pharmacological properties such as antimicrobial, anti-inflammatory, antioxidant, anti-allergic, hepatoprotective, anti-thrombotic, anti-viral, and anti-carcinogenic (Thakur *et al*., 2020). Compounds such as flavonoids, tannins, and alkaloids have been discovered to contribute to antimicrobial and physiological activities (Ojo *et al*., 2022). While tannins are known to be an anti-nutritional factor when present in high amounts, this compound has been shown to increase immunological competence, intestinal microbial ecology, and gut heath in broiler chicks when present at a modest dose (Huang *et al*., 2018). Similarly, supplementation of flavonoid-rich diets may contribute to the overall improvement of broiler health and lipid metabolism, on top of increasing immune organ indices and humoral immunity against Newcastle disease and Avian influenza virus (Cao *et al*., 2012; Sugiharto *et al*., 2019). Saponins, on the other hand, have been linked to ruminant intoxication; however, despite the negative effects on ruminants (Chung *et al*., 2018; Muniandy *et al*., 2020), optimal inclusions of saponins in poultry diets have been reported to demonstrate beneficial effects such as improved growth rate, enhanced feed efficiency, lower cholesterol levels, reduced odor in excreta, and overall improvement in bird health (Makkar *et al*., 2007; Chaudhary *et al*., 2018a). Additionally, saponin extracts have been shown to exhibit phytotoxic and antibacterial effects that are particularly efficient against Gram-negative bacteria equivalent to ampicillin, a common antibiotic (Kolawole *et al*., 2007). Although saponins have been noted to affect palatability due to the bitter taste, several studies have shown interesting results that the inclusion of dietary saponins in poultry diets at an appropriate level may prove to be a useful ingredient as a feed additive (Alghirani *et al*., 2021b; Alghirani *et al*., 2023). Furthermore, according to the study by Kanife and Doherty (2012), alkaloids, tannins, saponins, and flavonoids which are the principal physiologically active constituents prevalent in Guinea grass may have antifungal effects and alkaloids present may contribute to antimicrobial actions. Therefore, the use of grass or leaf meals as a feed additive in broiler diets and their effects on the productivity and meat quality of broilers will be covered in this review.

Prisma results

This systematic research was finalized according to the guidelines of "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement" (PRISMA). A systematic literature search was conducted via the electronic database of Scopus where articles were identified using those key words related to production. Keywords included were 'broiler', 'grass meal', 'leaf meal', 'growth performance', 'digestibility', 'carcass quality', and 'meat quality'. Articles were then refined by restricting the publication year to 2013 to 2023, a range of 10 years, and restricted to English-only publications. Only full-text articles with at least one of the growth performance or productivity-related traits included in the articles were selected to ensure the sufficiency of information obtained. A total of 36 full-text articles were assessed for eligibility and 10 were excluded due to not meeting the relevant criteria set, which resulted in a total of 26 articles included in this review. The highest number of papers published in a single year was four in 2018, followed by three in 2014 and 2019. Figure 1 reveals that Africa accounted for the majority of the studies (54%), followed by Asia (19%), Oceania (15%), the Middle East (8%), and only one study from North America (4%). Moreover, the plants researched in the selected papers may also be categorized into three groups: grasses, legumes, and non-legumes. Only one publication (4%) supplemented grass meal to broilers among those studied. Non-legume made up 54% of the publications evaluated, whereas legumes made up 42% (Figure 2). This review will further discuss the application of grass or leaf meals as a feed additive in poultry diets and the effects on growth performance, digestibility, carcass traits, and meat quality.

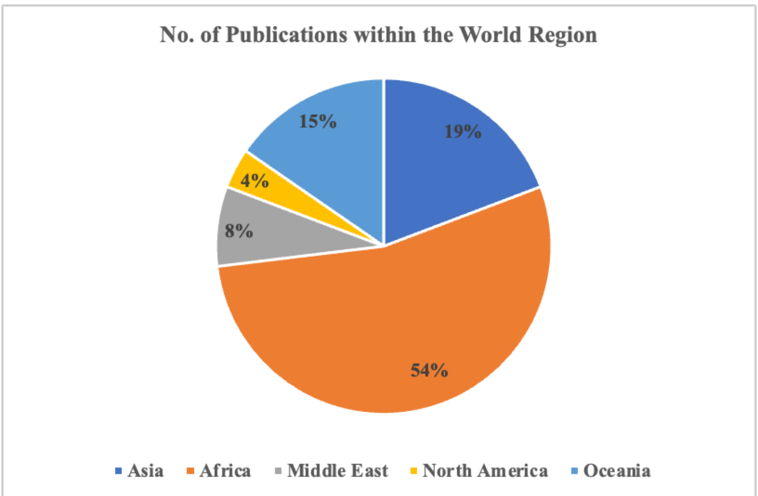

Fig. 1. Number of included publications on grass or leaf meals as a feed additive in broiler diets and their effects on productivity and meat quality based on the world region.

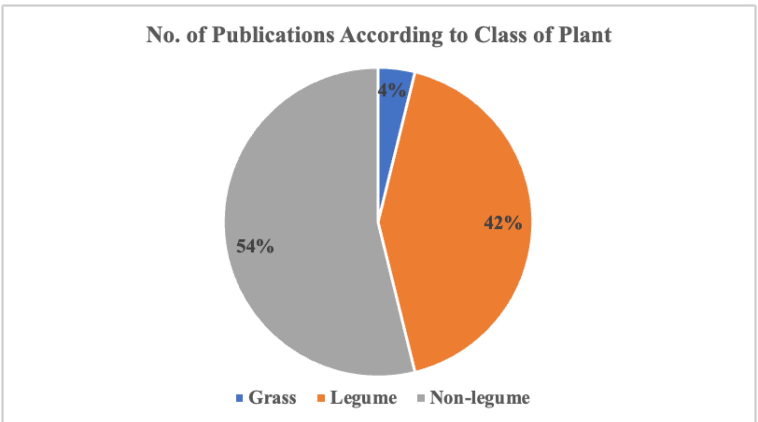

Fig. 2. Number of included publications on grass or leaf meals as a feed additive in broiler diets and their effects on the productivity and meat quality based on classification of plant.

The effects of grasses or leaf meals on the growth performance of broilers

Over the past few decades, phytobiotics have emerged as a prominent alternative to antibiotics in animal feed, owing to their capacity to offer significant advantages in poultry production, such as enhanced growth performance, meat quality, and egg quality (Kikusato, 2021). While the exact mechanism of how these phytobiotics influence growth in poultry has yet to be completely understood, Valenzuela-Grijalva *et al*. (2017) have outlined four key methods by which the addition of phytobiotics may promote growth, which is: 1) increased feed status and feed intake (FI) due to improved flavor and palatability; 2) antimicrobial effects modulating gut fermentation; 3) enhanced nutrient digestion and absorption via modification of gut functions; and 4) anabolic action on target tissues, both direct and indirect, through activation of endocrine and antioxidative defense systems. Supporting that, previous studies by Jang *et al*. (2004) and Czech *et al*. (2009) proposed that these enhancements in poultry development might be linked to the production of digestive enzymes and an increase in antimicrobial activity, resulting in improved gut function. The beneficial effects of these phytogenics are believed to stem from essential bioactive chemical components such as alkaloids, tannins, flavonoids, saponins, and phenolic compounds, which elicit specific physiological responses in animal organisms (Kuralkar & Kuralkar, 2021). These secondary metabolites play vital roles as nutritional additives, growth stimulants, immune enhancers, fertility promoters, and contributors to the reduction of methane and ammonia emissions. In addition, an increase in FI and improvements in (feed conversion ratio) FCR could be linked to the active compounds in herbs or plant extracts as the benefits include stimulation of appetite and enhanced secretion of digestive enzymes, which in turn facilitates the digestion of nutrients and eases absorption (Rahimi *et al*., 2011). Furthermore, several studies have linked an increase in FI to the addition of phytogenics, which may improve the flavor and palatability of the feed (Jamroz *et al*., 2002; Windisch *et al*., 2008). Numerous studies that utilized leaf or grass meals found that they had a good influence on chicken growth performance are discussed below.

Recently, Alghirani *et al*. (2022) conducted a study on the effects of *Brachiaria decumbens* as a novel supplementation on the production performance of Ross308 broilers. It was discovered that supplementing *B. decumbens* at a rate of 25 mg per kg of feed produced broilers with the best growth performance. FI (1.200-1.237 kg) was not substantially different (p>0.05) across treatment groups during the starter phase, but BWG was significantly greater (p<0.05) in the group with 25 mg/kg of *B. decumbens* (0.901 kg) compared to the other treatment groups including the antibiotic-treated group (0.853-0.889 kg), resulting in a lower FCR. These positive effects were credited to steroidal saponins, which are found in high concentrations in *B. decumbens* and have beneficial effects on the digestive tract such as increasing nutrient absorption by increasing villi height, thus elevating nutrient uptake that is not normally absorbed. Furthermore, other phytocompounds present, such as tannins, flavonoids, and alkaloids, possess traits that could enhance growth performance by bolstering immunity, preserving microbial balance, and exerting antimicrobial effects to diminish pathogenic burdens and stabilize intestinal health (Tonda *et al*., 2018; Chaudhary *et al*., 2018b; Redondo *et al*., 2022). However, supplementation of *B. decumbens* at higher levels showed lower feed intake which could be caused by the bitter taste of steroidal saponins and the anti-nutritional effect of both saponins and tannins (Hassan, 2013). Besides, Abang *et al*. (2023) concluded that the final BW and average daily BWG of broiler chickens increased correspondingly with those fed higher levels of dried guava (*Psidium guajava*) leaf meal (DGLM) (p<0.05). Broiler chickens fed with 4.5 g of DGLM recorded an additional +200 g of the final BW and +4.67 g average daily BWG in comparison to the control group. FCR and protein efficiency ratio (PER) followed a similar trend whereby performances improved significantly (p<0.05) as the inclusion level increased. Average daily FI amongst treatment groups did not vary (p>0.05), averaging between 97.42-97.47 g per bird indicating that the inclusion of DGLM was palatable to the chickens. In another prior research by Daing *et al*. (2021), supplementing 10 g and 20 g of guava leaf meal (GLM) per kg of basal diet to broiler chicks significantly (p<0.05) improved BWG and FCR. While the latter study did not discuss physiological changes in broilers with GLM supplementation, Abang *et al*. (2023) credited these beneficial effects in broiler gut health to DGLM's anti-inflammatory and antimicrobial properties as there is an abundance of flavonoids present in DGLM which possess antimicrobial and anti-oxidative properties. As demonstrated by Xue *et al*. (2021), flavonoid-rich extracts from Kudzu-leaf (KLF) treatment were found to demonstrate a significant decrease (p<0.05) in FCR when compared to the control group. Xue *et al*. (2021) ascribed this to the improved proliferation of bacteria and hindered pathogens as gut flavonoid content increased; which in return promoted the substrates available for absorption by gut microbiota, thus improving the feed efficiency. These reports are in line with previous studies which demonstrated that phytocompounds, namely flavonoids, phenolic groups, and alkaloids contribute to the antimicrobial effect which would improve the animals' performance (Taraz *et al*., 2015).

On top of that, studies on *Moringa oleifera* leaf meal (MOLM), which has a wide spectrum of medicinal importance and phytochemical value, demonstrated positive impacts on production performances as it is believed to be an excellent source of antioxidants and anti-inflammatory compounds (Modisaojang-

Mojanaga *et al*., 2019; Hussein & Jassim, 2019; Meel *et al*., 2021). However, the presence of phytate and other anti-nutrients in the leaves may limit nutrient bioavailability and absorption in animal guts. Tannins, which are found in Moringa leaves, have been shown to disrupt the biological utilization of protein and, to a lesser extent, accessible glucose and lipids (Esonu *et al*., 2001). A study by Kakengi *et al*. (2003) linked the decrease in FI to the lower palatability of the MOLM-supplemented diet in broiler chickens (Kakengi *et al*., 2003). Despite that, MOLM-fed chickens still managed to acquire considerably more weight and had a better FCR (p<0.05) than control-fed broilers, suggesting that the improvement might be related to MOLM's nutritional content and Moringa's antibacterial characteristics (Fahey *et al*., 2001). Another experiment comparing the effects of MOLM, a probiotic, and an organic acid as an AGP alternative on the growth performance suggested that the supplementation of MOLM affected the BW similarly to an AGP and organic acid (p>0.05) (Nduku *et al*., 2020). Similar results were found in another experiment, whereby the inclusion of MOLM at ranges of 2.5 g-10 g per kg of feed significantly (p<0.05) improved the final body weight (2641 g-2750 g) and total body weight gain (2492 g-2599 g) of broiler chicks in comparison to the control chickens (2497 g and 2349 g respectively). FI was comparable (p>0.05) amongst all groups resulting in a lower FCR (1.59-1.69) (p<0.05) for MOLM-treated groups compared to the control group (1.82) (Alshukri *et al*., 2018). The increased average daily gain (ADG) of MOLM-fed chickens may be due to the moderating effect of phenolics found in the leaves. Given that the major site of activity in plant extracts such as MOLM is in the gastro-intestinal tract through alterations in gut micro-flora, phenolics found in MOLM may promote enhanced glycolysis and utilization of glucose for energy generation (Mbikay, 2012; Nkukwana, 2012). On top of that, Moringa leaves are high in protein, amino acids, vitamins, and minerals, with antibacterial and therapeutic qualities that may act as a growth promoter (Alshukri *et al*., 2018). Nevertheless, a study by Alidou *et al*. (2016) attributed the lower FI of MOLM-fed chickens to anti-nutritional components that limit nutrient absorption, hence altering production metrics, which Alshukri *et al*. (2018) stated may be related to phytate, an anti-nutritional element.

High levels of tannin-rich leaf meals in broiler diets may hurt productivity and FI (Ncube *et al*., 2012; Martens *et al*., 2013; Ncube *et al*., 2017), whereas lower and appropriate levels of tanniniferous leaf meals in broiler diets might benefit development metrics and gut morphology (Huang *et al*., 2018; Miya *et al*., 2019;). Tanniniferous plants, such as *Acacia*, have been shown to improve animal performance due to their high quantities of natural antioxidants and possibly be employed as a phytobiotic (Jiang *et al*., 2016; Huang *et al*., 2018; Atiba *et al*., 2021). However, it was discovered that the inclusion of *Acacia karroo* leaf meal at 0.5-1.5 g/kg of feed did not affect (p>0.05) the FI, FCR, growth rate, and live weight of both sexes across all treatments during the feeding trial (Kolobe *et al*., 2022). Likewise, another research by Madzimure *et al*. (2018) reported that *Acacia anguistissima* as a protein source had no effect (p>0.05) on FI in broiler chicks across all treatment diets but treatment groups with higher inclusion levels recorded greater total FI value. Conversely, Gudiso *et al*. (2019) found that adding *A. anguistissima* to the broiler diets showed a linear decrease in the average daily FI and ADG. Contradicting results from these studies show that the variations in FI and other productivity indices are influenced by a variety of factors, including palatability, retention time in the GIT, and bioavailability of nutrients (Madzimure *et al*., 2018; Gudiso *et al*., 2019; Kolobe *et al*., 2022). Elevated FI rates suggest that the animal consumes more feed to fill its empty gut as feed moves quickly through the GIT to balance body nutrients (Madzimure *et al*., 2018). Despite the disparities in findings, all three studies on the addition of *Acacia* in broiler diets emphasized the effects of tannins, which are abundant in the plant's leaves and are thought to be the most important component influencing chickens' performance. This is because tannins, which are natural antioxidants, have a high affinity for proteins, with which they connect via hydrogen bonding, hydrophobic association, or covalent bonding, limiting the utilization of proteins that are essential for chicken development (Frutos *et al*., 2004; Garcia *et al*., 2004; Kolobe *et al*., 2022). A previous study by Smith *et al*. (2003) in rats corroborates this statement by reporting that two mechanisms can lead to decreased feed intake: decreased palatability due to astringency (tannin & salivary glycoprotein complexes) and aversive post-ingestive feedback due to nutrient deficiency (tannin-protein complexes), leading to decreased protein availability. Therefore, more studies should be conducted to determine the appropriate levels of *Acacia* in broiler diets to avoid the disruption of protein digestion and absorption as tannins present may cause a retardation in growth despite a higher feed intake.

Studies on copra meal (CM) and cassava leaf meal (CLM) supplementation at 100 g/kg and 200 g/kg to broiler chickens' diets found that there were no effects (p>0.05) on the FI and BWG (Diarra & Anand, 2020; Diarra *et al*., 2023). In addition, the experiment conducted in 2023 found poorer (p<0.05) FCR (1.81-2.13) in the treatment groups during the finisher phase whereas in the 2020 study, the FCR

(1.46-1.40) increased ($p<0.05$) during the starter phase. Bakare *et al*. (2020) which included CLM in broiler diets found similar results whereby FI was not affected ($p>0.05$) by the inclusion of CLM. But, the ADG (0.97 g/kg) and FCR of chickens fed with 300 g/kg CLM decreased ($p<0.05$) in comparison to the control group (1.23 g/kg ADG). While the previous two studies explored the use of enzymes as a technique of boosting high fibrous elements like CM and CLM in broiler diets tract (Diarra, *et al*., 2005; Devi and Diarra, 2017; Diarra *et al*., 2023). According to Bakare *et al*. (2020), CLM is known to contain significant amounts of anti-nutritional substances such as hydrocyanic acid (HCN), tannin, and phytin, which may have interfered with nutrient absorption (Wobeto *et al*., 2007; Oresegun *et al*., 2016). Lipiński *et al*. (2017) have also hypothesized that polyphenols have been shown to suppress digestive enzyme production, increase protein secretion, and decrease protein and amino acid digestibility, resulting in opposite metabolic consequences such as lower body weight and feeding efficiency.

Table 1 summarises the favorable and harmful impacts of including leaf meals in chicken diets on growth parameters. The differing findings might be attributed to the diversity of plant sources utilized, which could have influenced the chickens' acceptance of the meal. Furthermore, variable quantities of phytocompounds and their combination with nutrients in diet may impact broiler bird production indices. Although plant-based phytobiotics may be a viable alternative to antibiotics and growth promoters, further research is needed to discover the optimal dosage for each type of phytobiotic. Furthermore, anti-nutritional factors, harvesting age, continuous supply, storage period, stability, and microbial contamination must be addressed before they can be effectively used in the commercial chicken business.

Table 1. The different effects of various leaf or grass meal supplementation on the growth performance of broilers

Source	Inclusion levels	Growth performance	References
B. decumbens ground leaf powder	25 mg/kg of basal diet without antibiotics	Improved FCR, body weight gain (BWG), and final body weight (BW) throughout both the starter and finisher phases.	Alghirani *et al*. (2022)
Guava (*Psidium guajava*) leaf meal	1.5, 3.0, and 4.5 g of dried guava leaf meal per kg of basal diet	Improved final BW, ADG, FCR, and PER in all treatment groups. No improvements in average daily FI.	Abang *et al*. (2023)
	10 g and 20 g of guava leaf meal per kg of basal diet	Improved BWG and FCR.	Daing *et al*. (2021)
Moringa oleifera leaf meal	1000 g of leaf meal per ton of feed	Lower FI during first 7 days.	Nduku *et al*. (2020)
	0.25, 0.50, 0.75 and 1.0%	Improved final and total BWG, comparable FI, and lower FCR.	Alshukri *et al*. (2018)
Acacia	0.5, 1.0, 1.5 g *A. karroo* leaf meal	No effect on FI, FCR, growth rate, and live weight of male and female broiler chickens.	Kolobe *et al*. (2022)
	50, and 100 g of *A. anguistissima* kg of feed	No effect on FI.	Madzimure *et al*. (2018)
	30, 60, 90, 120, and 150 g/kg DM of *A. anguistissima*	Decrease in ADG and average daily FI.	Gudiso *et al*. (2019)
Copra meal	100 and 200 g of copra meal per kg of feed	No effect on FI and BWG. Decreased FCR during the starter phase.	Diarra and Anand, (2020); Diarra *et al*., (2023)
Cassava leaf meal	100, 200, and 300 g of cassava leaf meal per kg of feed	No effect on FI. Decreased ADG and FCR of chickens fed with 300 g/kg.	Bakare *et al*. (2020)

The effect of grasses or leaf meals on nutrient digestibility of broilers

The digestibility of nutrients with the addition of leaf meals in poultry is still highly debated due to the fiber content and secondary metabolites present which may act as antinutritive compounds. The amount of fiber in the diet is an important component that influences the rate at which the feed travels through the gastrointestinal system, which in turn influences the digestion parameters (Mateos *et al*., 2002). There have been inconsistencies with the data on phytocompounds as tannins, flavonoids, and polyphenols are said to improve digestion (Basit *et al*., 2020b). On one hand, phytocompounds with antioxidant and immunomodulatory qualities are claimed to aid the breakdown and absorption in the gastrointestinal system (Suresh *et al*., 2017) which is believed to improve feed intake and digestibility. This is because they boost nutritional digestion and absorption in the colon by increasing the release of digestive enzymes (Khan *et al*., 2012). Furthermore, the favorable effects of phytobiotics on the structure of the intestine, as well as the decrease of harmful bacteria and inflammation in the gut, help to increase nutrient uptake and absorption, as detailed further in the subsequent sections. However, other studies claimed that digestibility is improved with the inclusion of dietary fiber but phytocompounds such as phytate, tannins, and polyphenols reduce digestibility (Nkukwana *et al*., 2014). Phytate and tannins may bind to proteins in the gastrointestinal tract, limiting protein digestibility and hence, nutritional intake (Selle *et al*., 2010; Moyo *et al*., 2011). Polyphenols were discovered to form complexes or denature enzymes when taken in excess, limiting digestibility (He *et al*., 2007). Having said that, phytocompound-rich herbs have been shown to improve digestion by stimulating saliva secretion, increasing bile acid synthesis in the liver and extraction in the bile, stimulating pancreatic enzyme function, increasing the activity of digestive enzymes in the gastric mucosa, and accelerating digestion (Frankic *et al*., 2009).

Alghirani *et al*. (2022), showed that during both starter and finisher phases of Ross308, there were significant variations (p<0.05) found in the apparent ileal digestibility (AID). CP (59.81%; 62.36%), CF (35.24%; 32.29%), and EE (76.06%; 76.99%) were significantly greater (p<0.05) in the group supplemented with 25 mg of *B. decumbens* per kg of basal diet, whereas DM (63.45%; 62.36%) and ash (41.11%; 31.90%) were lower in comparison to the control group. Grasses and forage plants have been shown to increase feed intake and digestibility by enhancing endogenous secretion production in the small intestine, liver, and pancreas (Cross *et al*., 2007; Akande *et al*., 2010; Martens *et al*., 2012). Yet, Alghirani *et al*. (2022) observed that higher levels of *B. decumbens* supplementation reduced digestibility, which they attributed to anti-nutritional factors such as steroidal saponins and tannins, which could potentially hinder broilers' growth potential by reducing nutrient digestibility (Dei *et al*., 2007; Hidayat *et al*., 2021). Furthermore, high fiber dietary content increases feed volume and, as a result, nutritional density, as well as increases digesta transit rate and lowers feed retention 92 times in chickens, which may reduce intestinal size while lowering nutrient availability for development (Rahman *et al*., 2018). Manyelo *et al*. (2022a) studied the effects of incorporating Amaranth leaf meal into the diets of Ross308 broiler chicks and found that all inclusion amounts had no influence on DM and GE digestibility (p>0.05). Although there was no linear or quadratic effect observed in the digestibility of increasing levels of Amaranth leaf meal, those fed 50 g had higher (p<0.05) CF, CP, and ash digestibility values, while those fed 100 g had higher (p<0.05) EE digestibility. With the above information, it should be emphasized that the inclusion levels did not affect the broilers' performance. In another experiment by Manyelo *et al*. (2022b) which similarly provided Amaranth leaf meal to indigenous Boschveld chickens, found that the digestibility of DM and GE were not affected (p>0.05) but CP, CF, EE, and ash were different (p<0.05) in the group of chickens fed with 50 g of Amaranth leaf meal. Because there are no other studies that are comparable to these, the authors can only speculate that the differences in digestibility are related to the chickens' ability to tolerate the phytocompounds found in the leaves. They also determined that Amaranth leaf meals may be included in the diets of indigenous Boschveld hens at any of the experimental doses since the chickens' nutrient utilization and performance indices were good. Additionally, a linear increase in DM, OM, CP, and EE digestibility was discovered with the increase of *Azolla* leaf meals (ALM) supplementation (Abdelatty *et al*., 2020). The authors attributed the improved nutrient digestibility to the interaction between the supplementation of ALM and intestinal morphology. Similarly, increasing levels of *Ginkgo biloba* leaves (0 to 60 g/kg of diet) that contain bioactive compounds such as flavonoids, bilobalides, and polyphenols improved the apparent digestibility and true digestibility of EE, threonine, valine, leucine, histidine, and methionine linearly (p<0.05) and tended (0.05<p<0.1) to increase the true metabolizable energy (TME), nitrogen corrected TME (TMEn) and arginine (Ren *et al*., 2018).

In another experiment, Sebola *et al*. (2019) studied the apparent digestibility of *Moringa oleifera* mature and tender leaf meals supplemented at 25-100 g/kg of feed to three different strains of chicken (Potchefstroom koekoek (PK), Ovambo (OV) and Black Australop (BA) chickens). Results revealed that adding MOLM at all levels had no negative impact on the nutritional digestibility of PK and OV chickens, and for these two strains, higher inclusion levels of MOLM had better (p<0.05) CP digestibility. However, CP digestibility in BA chickens was reduced. This might be related to the genetic differences in each strain's ability to absorb and digest nutrients in a high-fiber diet. On the contrary, Gakuya *et al*. (2014) found lower (p<0.05) feed intake and DM digestibility in those supplemented with MOLM above 750 g MOLM per kg of diet. While Gukaya *et al*. (2014) did not disclose the strain of broiler chickens used in their experiment, Nkukwana *et al*. (2014) recommended that MOLM be supplemented up to 25 g per kg of feed as there were no apparent (p>0.05) differences in digestibility but it improved growth performance parameters of Cobb500 broiler chickens. Furthermore, supplementing broiler chicks with 4 g/kg *Piper betle* and 8 g/kg *Persicaria odorata* enhanced (p<0.05) digestibility of EE and DM compared to the control group (Basit *et al*., 2020a). The digestibility of CP was found to be higher (p<0.05) in the group fed 8 g/kg *P. odorata*, which is said to be high in flavonoids and polyphenols that improve cellular and mucosal immunity by regulating circulatory and endocrine markers, thus improving broiler health and digestibility (Kamboh *et al*., 2015). In contrast, the group fed with 8 g/kg *P. betle* had the lowest (p<0.05) CP digestibility. High concentrations of tannins could have caused this reduction in the digestion of CP (Sav´on *et al*., 2006).

While supplementation of grass and/or leaf meals in chicken diets has been shown to have good effects, there are some contradicting findings, since varied amounts of phytocompounds and their combination with nutrients may have a detrimental influence on broiler chickens' digestibility. Besides, a broiler bird's digestibility may also be influenced by its genetics. Therefore, more research in this area is essential to effectively benefit the broiler sector. Table 2 summarises the effects of different plant meal supplementation and concentrations on the digestibility of poultry.

The effect of grasses or leaf meals on carcass and meat quality of broilers

Because of their antibacterial and antioxidant capabilities, the inclusion of phytobiotics in broiler diets may be beneficial in improving carcass quality while adding value to the products (Adriani *et al*., 2019). Including plant extracts in chicken feed has proven to enhance the eviscerated carcass breast muscle percentage by 1.2% (Puvača *et al*., 2011). Additionally, phytocompounds have been shown to exhibit anabolic effects via two possible modes of action, by altering animal metabolism by acting similarly to β-adrenergic agonist chemicals and/or boosting plasma norepinephrine levels by inhibiting catechol-o-methyltransferase. These two mechanisms alter the animals' metabolism by boosting protein synthesis and lipolysis while lowering lipogenesis, both of which favor muscle tissue growth (Valenzuela-Grijalva *et al*., 2017; Oloruntola *et al*., 2022).

On day 21, Alghirani *et al*. (2022) observed significant differences (p<0.05) in the carcass characteristics of Ross308 broilers supplemented with *B. decumbens* in comparison to the control groups in final live weight, kill-out weight, de-feathered weight, carcass weight, dressing percentage, breast, drumstick, wing, head, neck, shank, GIT, heart, and liver weight. Whereas on day 42, all parameters showed significant differences (p<0.05). Chickens fed with 25 mg/kg of *B. decumbens* had the highest values throughout the experiment, suggesting the best carcass features. These findings were attributed to the favorable effects of saponins and other phytochemicals found in grass, since saponins have been associated with improved nutrient absorption along the gastrointestinal system, leading to superior body weight increase and carcass features. Diarra *et al*. (2022) discovered that chickens given cassava leaf meal had significantly lower (p<0.05) abdominal fat recording (0.9%) than the other groups (1.1-1.5%), likely owing to variations in the sources, namely micronutrients. Similar results were found in the experiment conducted by Faria *et al*. (2011), whereby supplementing Pescoço Pelado broilers with 100 g/kg of cassava leaves resulted in higher (p<0.05) carcass yield, lower back and abdominal fat, as well as better economic efficiency in comparison to other treatments which are rice bran and ground lead tree hay. However, there were no significant (p>0.05) differences in the weight of the neck, wings, drumstick, thighs, and feet of the broiler chickens across all treatments. Similarly, *Lippia javanica* leaf meal inclusion at 5 and 12 g/kg of feed had no effect (p>0.05) on broiler breast weight, thigh weight, carcass weight, or dressing percentage, but significantly increased (p<0.05) abdominal fat weight when compared to those whose diets did not contain *L. javanica* leaf meal. Nonetheless, broilers fed 12 g/kg *L. javanica* leaf meal exhibited the greatest (p<0.05) proventriculus and gizzard weights as well as the longest small intestines (Mpofu *et al*., 2016).

Oloruntola *et al*. (2022) supplemented Arbor Acres broiler chicks with *Mucuna* leaf meal which is rich in alkaloids, flavonoids, saponins, tannins, terpenoids, and other phytocompounds. They reported a higher dressing percentage with increasing levels of *Mucana* leaf meal supplementations (72.30-76.43%) in comparison to the groups supplemented with oxytetracycline (71.08%) and control diet (70.35%) despite not showing significant differences (p=0.45). Additionally, there were no significant (p>0.05) differences in the relative organ weights which indicates that the supplementation did not interfere with the healthy development of the broilers. However, the supplementation of neem leaf meal in broilers at 25 g/kg of feed resulted in a higher average giblet percentage and is cited to be attributed to the bioactive compounds present in the leaf such as isoprenoids and polyphenolics despite not fully understanding the mode of action (Biswas *et al*., 2002; Kumari *et al*., 2014). On the other hand, the addition of Kudzu and alfalfa leaf meal at 60 and 73 g per kg of starter feed over 21 days resulted in lower (p<0.05) carcass weights (822.96-850.90 g) in comparison to the control group (894.10 g). Correspondingly, the whole breast weight and breast percentage yield were also lower (p<0.05) in the treated groups. Generally, the organ weights of chickens on the control diet had a higher liver weight percentage than the chickens fed with Kudzu and alfalfa leaf meals possibly in response to increased fiber content that reduces liver lipid accumulation and plasma lipid content (Gulizia & Downs, 2020). The increase in liver weight could serve the purpose of aiding the absorption of nutrients from the gut as tannins, alkaloids and nitrates in the leaves act as anti-nutritional factors (Kagya-Agyemang *et al*., 2007). The tannins present, according to the investigators, bind to enzymes and restrict the availability of dietary proteins (Donkoh *et al*., 2002).

Table 2. The different effects of various leaf or grass meal supplementation on the nutrient digestibility of broilers

Source	Inclusion levels	Digestibility	References
B. decumbens ground leaf powder	25 mg/kg of basal diet without antibiotics	Improved digestibility of CP, EE, and CF but lowered digestibility of DM and ash.	Alghirani *et al*. (2022)
Amaranth leaf meal	0, 50, 100, 150, and 200 g of Amaranth leaf meal per kg diet	All levels did not affect DM and GE. Ross308 broilers fed with 50 g had higher CF, CP, and ash digestibility. Ross308 broilers fed with 100 g had higher EE digestibility.	Manyelo *et al*. (2022a)
		All levels did not affect DM and GE in indigenous Boschveld chickens. Improved digestibility in CP, CF, EE, and ash in indigenous Boschveld chickens.	Manyelo *et al*. (2022b)
Azolla leaf meals	50 g and 100 g of *Azolla* leaf meals per kg of diet	Linear increase of digestibility in DM, OM, CP, and EE.	Abdelatty *et al*. (2020)
Ginkgo biloba leaf meal	0, 20, 40, 60 g of *Ginkgo biloba* leaves per kg diet	Increasing supplementation of *Ginkgo biloba* leaves increased apparent digestibility and true digestibility of EE, threonine, valine, leucine, histidine, and methionine linearly.	Ren *et al*. (2018)
M. oleifera leaf meal (MOLM)	25, 50, and 100 g of *M. oleifera* leaves per kg diet	Higher inclusion levels had better CP digestibility in Potchefstroom koekoek and Ovambo strain chicken. Reduced CP digestibility in Black Australop chicken.	Sebola *et al*. (2019)
	0, 75, 150, 300 g per MOLM per kg diet	Lower DM digestibility in those supplemented with more than 750 g of MOLM.	Gakuya *et al*. (2014)
	Low (1, 3, 5 g), Medium (3, 9, 15 g), High (5, 15, 25 g) of MOLM per kg diet	No differences in digestibility.	Nkukwana *et al*. (2014)
Piper betle and *Persicaria odorata* leaf meal	4 g *P. betle*, 4 g *P. odorata,* 8 g *P. betle*, 8 g *P. odorata* per kg of basal diet	4 g of *P. betle* and 8 g of *P. odorata* enhanced the digestibility of EE and DM. 8 g of *P. odorata* leaf meal improved CP digestibility. 8 g *P. betle* decreased CP digestibility.	Basit *et al*. (2020a)

The visual appeal of products, particularly the color of meat, significantly influences consumer purchase decisions (Mancini & Hunt, 2005). Additionally, pH value, color, and cumulative drip loss are all critical factors in evaluating meat quality (Janisch *et al*., 2012). According to Abdulla *et al*. (2017), the pH of fresh broiler meat ranged from 6.34 to 6.47. Aside from microbial-related quality loss in meat, oxidation is a primary cause of meat quality decline. Under stressful conditions, excess formation of free radicals beyond what endogenous antioxidant enzymes can control results in the brownish coloration of meat from its natural red hue (Falowo *et al*. 2014). The inclusion of antioxidant-rich feed additives has been proven to promote the preservation of normal meat color (red) in chickens as well as increase meat tenderness (Contini *et al*., 2014). These secondary metabolites are thought to prevent or postpone oxidation via two key pathways: 1) donating electrons to break or terminate the oxidation cycle at the propagation step, preventing the formation of additional lipid and protein radicals; 2) removing free radical (ROS) initiators to quench chain-initiating catalysts (radicals); or limiting the radicals initiators by binding metals such as iron and copper as metal chelators to stabilize them in an inactive or insoluble form (Falawo *et al*., 2014). Furthermore, it was discovered that by directly applying natural antioxidants to meat products, the phytocompounds of these plant-based products could reduce meat spoilage bacteria and decontaminate against *Salmonella* (Mani-López *et al*., 2012; Sant'Ana *et al*., 2014).

The inclusion of MOLM at 1 g/kg of feed was found to improve meat quality of chicken meat, and its effects were comparable to probiotics and organic acid. Despite not showing any significant differences (p>0.05) in pH values among treatments, meat from chickens fed with MOLM had a higher (p<0.05) redness (a*) value (1.43) in comparison to the other treatments (0.73-1.19) which could be attributed to the higher levels of dietary iron in *M. oleifera* (Nduku *et al*., 2020). This may be attributed to *M. oleifera* leaves' high antioxidant activity due to the phytocompounds present such as saponins, glucosinolates, flavonoids, and phenolic acids (Modisaojang-Mojanaga *et al*., 2019). In contrast, Cobb500 chickens that were MOLM-supplemented with low, medium, and high levels had no significant differences (p>0.05) in the meat pH measured at post-mortem. Cumulative drip loss was also significantly decreased (p<0.05) in those fed with high MOLM, and lightness was significantly reduced (p<0.05) while increasing a*, yellowness (b*), chroma, and the hue angle during storage over time (Nkukwana *et al*., 2014). Sebola *et al*. (2019) studied the effects of MOLM on the meat quality of three different chicken strains (PK, OV, BA) and found that there were no 3-way interactions (diet x strain x gender) that affected (p>0.05) a*, b*, pH, and cooking loss but affected (p<0.05) lightness (L*) and shear force. Variations in chicken strains within diets were detected; pH was unaffected (p>0.05), while color, shear force, and cooking loss substantially differed (p<0.05). Because of the high carotene content in MOLM, higher inclusion levels resulted in increased b* of breast meat in the BA strain. Male and female OV strains generated meat with lower shear force (41.29-61.03 N*mm) than the other strains (51.06-86.82 N*mm), which might be attributed to differences in muscle fiber size and genetic diversity across the strains.

Similarly, Ross308 broilers fed feeds containing 0 and 100 g Amaranth leaf meals (ALM) exhibited greater (p>0.05) cooking loss than those fed diets containing 50, 150, and 200 g ALM per kg feed. All inclusion levels had no effects (p>0.05) on the pH value (5.57-6.75) and breast meat a* (-0.99-1.05) or b* (7.33-10.45). But, L* of breast meat from chickens fed with 50 g (51.11) and 100 g (50.16) of ALM recorded significantly lighter (p<0.05) breast meat color than the other treatments (44.56-49.14) which did not differ from each other (p>0.05). In addition, there were no significant differences (p>0.05) in the meat tenderness, juiciness, flavor, and overall acceptability of the meat across all ALM inclusion levels. Broilers fed with 50,100 and 200 g of ALM/kg feed had lower (p<0.05) cooking loss in comparison to the other groups. ALM inclusion into the diet might be responsible for the darker breast meat color due to higher chlorophyll and carotene levels present in the leaves (Manyelo *et al*., 2022a). Another study by Ncube *et al*. (2017) discovered that when *A. angustissima* leaf meal levels increased, L* values declined from 53.66 to 49.23, b* values increased from 12.93 to 19.97, shear force increased from 14.14 N to 14.54 N, and cooking loss increased from 5.95% to 7.64%. On the other hand, Yavaş and Malayoğlu (2018) found that the addition of olive leaf meal (oleuropein) to Ross308 broiler chicks at different levels had no effect (p>0.05) on breast meat brightness (L*), yellowness (b*), and pH after 24 hr, while redness (a*) increased significantly (p<0.05) compared to the control group.

Further investigations on the effects of different plant-based meals incorporated into broiler diets at variable dosages may provide a better knowledge of how phytocompounds alter carcass features and meat quality, and this information may be used to improve end-product value. Table 3 shows the different effects of various leaf or grass meal supplementation on carcass traits and meat quality of poultry.

Table 3. The different effects of various leaf or grass meal supplementation on carcass traits and meat quality of broilers

Source	Inclusion levels	Carcass traits	References
B. decumbens ground leaf powder	25 mg/kg of basal diet without antibiotics	Improved carcass traits across all indicators during the finisher phase.	Alghirani *et al*. (2022)
Cassava leaf meal	100 g/kg (starter) and 200 g/kg (finisher)	Lower abdominal fat percentage.	Diarra *et al*. (2022)
	100 g/kg (starter) and 200 g/kg (finisher)	Lower abdominal fat percentage.	Diarra and Anand (2020)
Lippia javanica leaf meal	5 and 12 g/kg of feed	Significantly increased abdominal fat weight, proventriculus, and gizzard weight. No effect on breast weight, thigh weight, carcass weight, or dressing percentage.	Mpofu *et al*. (2016)
Mucuna leaf meal	5, 10, and 15 g/kg of feed	Higher dressing percentage. No differences in relative organ weight.	Oloruntola *et al*. (2022)
Neem leaf meal	25 g/kg of feed	Higher average giblet percentage.	Kumari *et al*. (2014)
Kudzu leaf meal	60 g/kg of feed	Lower carcass weight, whole breast weight, breast percentage yield. Higher liver weight.	Gulizia and Downs (2020)
Alfafa leaf meal	73 g/kg of feed	Lower carcass weight, whole breast weight, breast percentage yield. Higher liver weight.	Gulizia and Downs (2020)
Source	**Inclusion levels**	**Meat quality**	**References**
Moringa oleifera leaf meal	1 g of MOLM per kg of feed	No effect on pH. Higher a* value.	Nduku *et al*. (2020)
	low (1-5 g/kg of feed, depending on growth stage) medium (3-15 g/kg feed), and high (5-25 g/kg feed)	No effect on pH. Decreased cumulative drip loss in high MOLM. Reduced L*, a*, b*, chroma, and hue.	Nkukwana *et al*. (2014)
	0, 25, 50, 100 g/kg feed	No effects in a*, b*, pH, and cooking loss. Affected L* and shear force.	Sebola *et al*. (2019)
Amaranth leaf meals	50, 100, 150, and 200 g per kg of feed	Had no effects on pH, breast a* and b*, meat tenderness, juiciness, flavour, and overall acceptability. Recorded differences in cooking loss and L*.	Manyelo *et al*. (2022a)
Acacia angustissima leaf meal	0, 50 and 100 g/kg feed	L* declined as supplementation increased. b*, shear force and cooking loss increased linearly along with supplementation.	Ncube *et al*. (2017)
Olive leaf	0, 12.5, 25 and 50 g of olive leaf (oleuropein)	No effect on L*, b*, and pH_{24} Increased a*.	Yavaş & Malayoğlu (2018)

CONCLUSION

According to the information and findings of previous studies, it can be concluded that, with appropriate dosages, grass or leaf meals could potentially be a viable alternative to antibiotics because they have been shown to improve growth performance, carcass characteristics, and meat quality. Nevertheless, additional research is warranted to tackle concerns surrounding optimal dosages, timing of harvest, extraction methodologies, potential antagonistic interactions, and anti-nutritional factors, all aimed at guaranteeing both the safety and efficacy of phytobiotic utilization in broilers. Additional investigation is necessary as well to understand how different phytobiotic sources and their specific phytocompound profiles affect different strains of broilers. Furthermore, for economic reasons, the antibiotic alternative of choice should be one with the lowest feasible cost and equal effects to synthetic antibiotics at a lower cost. Greater knowledge of the interaction and implications of these grass or leaf meals and their phytocompounds on the broiler industry would boost industry confidence in using these phytobiotics as an alternative to AGPs while also improving food safety for consumers.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Higher Education, Malaysia for providing funds for some of the studies conducted in this review. The project was funded by the Fundamental Research Grant Scheme (FRGS), (Grant no: FRGS/1/2020/WAB04/UPM/02/1).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ETHICAL STATEMENT

Not applicable.

REFERENCES

Abang, F.B.P., Echeonwu, I.E. & Amu, M.U. 2023. Effect of graded levels of guava (*Psidium guajava* L.) leaf meal on productive performance and meat organoleptic properties of chicken. Online Journal of Animal and Feed Research, 13(1): 73-78. https://doi.org/10.51227/ojafr.2023.12

Abdelatty, A.M., Mandouh, M.I., Mohamed, S.A., Busato, S., Badr, O.A.M., Bionaz, M., Elolimy, A.A., Moustafa, M.M.A., Farid, O.A.A. & Al-Mokaddem, A.K. 2021. Azolla leaf meal at 5% of the diet improves growth performance, intestinal morphology and P70S6K1 activation, and affects cecal microbiota in broiler chicken. Animal, 15(10): 100362. https://doi.org/10.1016/j.animal.2021.100362

Abdulla, N.R., Zamri, A.N.M., Sabow, A.B., Kareem, K.Y., Nurhazira, S.H., Ling, F.H., Sazili A.Q. & Loh, T.C. 2017. Physicochemical properties of breast muscle in broiler chickens fed probiotics, antibiotics or antibiotic-probiotic mix. Journal of Applied Animal Research, 45(1): 64-70. https://doi.org/10.1080/09712119.2015.1124330

Adriani, L., Latipudin, D., Balia, R.L. & Widjastuti, T. 2019. Improvement of small intestine morphometry in broiler chicken using fermented cow and soymilk as probiotic. International Journal of Poultry Science, 18(6): 255-259. https://doi.org/10.3923/ijps.2019.255.259

Akande, K.E., Doma, U.D., Agu, H.O. & Adamu, H.M. 2010. Major antinutrients found in plant protein sources: Their effect on nutrition. https://doi.org/10.3923/pjn.2010.827.832

Alghirani, M.M., Chung, E.L.T., Jesse, F.F.A., Sazali, A.Q. & Loh, T.C. 2021a. Could phytobiotics replace antibiotics as feed additives to stimulate production performance and health status in poultry? an overview. Journal of Advanced Veterinary Research, 11(4): 254-265.

Alghirani, M.M., Chung, E.L.T., Kassim, N.A., Ong, Y.L., Jesse, F.F.A., Sazali, A.Q. & Loh, T.C. 2022. Effect of *Brachiaria decumbens* as a novel supplementation on the production performance of broiler chickens. Tropical Animal Health Production, 54: 386. https://doi.org/10.1007/s11250-022-03384-4

Alghirani, M.M., Chung, E.L.T., Kassim, N.A., Ong, Y.L., Jesse, F.F.A., Sazili, A.Q. & Loh, T.C. 2023. Blood biochemistry and stress biomarkers of broiler chickens supplemented with different levels of Yucca schidigera saponins reared under tropical conditions. Veterinary Integrative Sciences, 21(1): 001-015.

Alghirani, M.M., Chung, E.L.T., Sabri, D.S.M., Tahir, M.N.J.M., Kassim, N.A., Kamalludin, M.H., Nayan, N., Jesse, F.F.A., Sazali, A.Q. & Loh, T.C. 2021b. Can *Yucca schidigera* be used to enhance the growth performance, nutrient digestibility, gut histomorphology, cecal microflora, carcass characteristic, and meat quality of commercial broilers raised under tropical conditions? Animals,

11: 2276. https://doi.org/10.3390/ani11082276
Alidou, C., Salifou, A., Djossou, J., Mazou, M., Tchebo, F.P. & Soumanou, M.M. 2016. Roasting effect on anti-nutritional factors of the *Moringa oleifera* leaves. International Journal of Advance Research, 4: 78-85.
Alshukri, A.Y., Ali, N.A., Abbas, R.J., Alkassar, A.M. & Jameel, Y.J. 2018. Effect of dietary supplementation with differing levels of Moringa oleifera leaf meal on the productivity and carcass characteristics of broiler chickens. International Journal of Poultry Science, 17: 536-542. https://doi.org/10.3923/ijps.2018.536.542
Atiba, E.M., Laban, R.K., Zewei, S., Qingzhang, Z., Aschalew, N.D. 2021. Implications of tannin containing plants for productivity and health in small ruminant animals: A review. Agricultural Reviews, 42(2): 156165. https://doi.org/10.18805/ag.R-173
Bajagai, Y.S., Petranyi, F., J. Yu, S., Lobo, E., Batacan Jr, R., Kayal, A., Horyanto, D. Ren, X., Whitton, M.M. & Stanley, D. 2022. Phytogenic supplement containing menthol, carvacrol and carvone ameliorates gut microbiota and production performance of commercial layers. Scientific Reports, 12(1): 11033. https://doi.org/10.1038/s41598-022-14925-0
Bakare, A.G., Cawaki, P., Ledua, I., Kour, G., Jimenez, V., Sharma, A. & Tamani, E. 2020. Acceptability, growth performance and nutritional status of chickens fed cassava leaf meal (CLM)-based diets. Tropical Animal Health and Production, 52: 2481-2489. https://doi.org/10.1007/s11250-020-02274-x
Basit, M.A., Kadir, A.A., Loh, T.C., Abdul Aziz, S., Salleh, A., Zakaria, Z.A. & Banke Idris, S. 2020b. 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): 2150. https://doi.org/10.3390/ani10112150
Biswas, K., Chattopadhyay, I., Banerjee, R.K. & Bandyopadhyay, U. 2002. Biological activities and medicinal properties of neem (Azadirachta indica). Current Science, 82(11): 1336-1345.
Cao, F., Zhang, X., Yu, W., Zhao, L. & Wang, T. 2012. Effect of feeding fermented *Ginkgo biloba* leaves on growth performance, meat quality, and lipid metabolism in broilers. Poultry Science, 91(5): 1210-1221. https://doi.org/10.3382/ps.2011-01886
Chaudhary, S., Rokade, J., Aderao, G., Singh, A., Gopi, M., Mishra, A. & Raje, K. 2018a. Saponin in poultry and monogastric animals: a review. International Journal of Current Microbiology and Applied Sciences, vol(issue): 3218-3225. https://doi.org/10.20546/ijcmas.2018.707.375
Chaudhary, S.K., Bhar, R., Mandal, A.B., Rokade, J.J., Jadhav, S.E., Kannan, A. & Gopi, M. 2018b. Effect of dietary soapnut (*Sapindus mukorossi*) shell powder on selected stress indices, lipid profile and litter quality in broiler breeders. Animal Nutrition and Feed Technology, 18(3): 311-320. https://doi.org/10.5958/0974-181X.2018.00029.X
Chowdhury, E. & Morey, A. 2019. Intelligent packaging for poultry industry. Journal of Applied Poultry Research, 28(4): 791-800. https://doi.org/10.3382/japr/pfz098
Chung, E.L.T., Predith, M., Nobilly, F., Samsudin, A.A., Jesse, F.F.A. & Loh, T.C. 2018. Can treatment of *Brachiaria decumbens* (signal grass) improve its utilization in the diet in small ruminants? -a review. Tropical Animal Health and Production, 50(8): 1727-1732. https://doi.org/10.1007/s11250-018-1641-4
Coles, M., Graham, B., Latorre, J., Petrone-Garcia, V., Hernandez-Velasco, X., Castellanos-Huerta, I., Sun, X., Hargis, B., El-Ashram, S., Shehata, A. & Tellez-Isaias, G., 2023. Essential oils as an alternative to antibiotics to reduce the incidence and severity of necrotic enteritis in broiler chickens: A short review. Food and Nutrition Sciences, 14: 233-257. https://doi.org/10.4236/fns.2023.143016
Contini, C., Alvarez, R., O'Sullivana, M., Dowling, D.P., Gargan, S.O. & Monahan, F.J. 2014. Effect of an active packaging with citrus extract on lipid oxidation and sensory quality of cooked turkey meat. Meat Science, 96: 1171-1176. https://doi.org/10.1016/j.meatsci.2013.11.007
Cross, D.E., Mcdevitt, R.M., Hillman, K. & Acamovic, T. 2007. The effect of herbs and their associated essential oils on performance, dietary digestibility and gut microflora in chickens from 7 to 28 days of age. British Poultry Science, 48(4): 496-506. https://doi.org/10.1080/00071660701463221
Czech, A., Kowalczuk, E. & Grela, E.R. 2009. The effect of a herbal extract used in pig fattening on the animals' performance and blood components. Annales UMCS, Zootechnica, 27(2): 25-33. https://doi.org/10.2478/v10083-009-0009-7
Daing, M.I., Pathak, A.K., Sharma, R.K. & Zargar, M.A. 2021. Growth performance, nutrient utilization, blood indices and immunity of broiler chicks fed diets with graded level of condensed tannins containing *Psidium guajava* leaf meal. Animal Nutrition and Feed Technology, 21(2): 327-340. https://doi.org/10.5958/0974-181X.2021.00027.5
Dei, H.K., Rose, S.P. & Mackenzie, A.M. 2007. Shea nut (*Vitellaria paradoxa*) meal as a feed

ingredient for poultry. World's Poultry Science Journal, 63(4): 611-624. https://doi.org/10.1017/S0043933907001651

Department of Veterinary Service [DVS]. 2020. Surveillance program antimicrobial resistance and data analysis 2018 - 2019. Disease Control Division and Veterinary Biosecurity.

Devi, A. & Diarra, S.S. 2017. Influence of dietary protein source and utilisation of copra meal in finishing broiler chicken. Indian Journal of Animal Nutrition, 34(2): 193-200. https://doi.org/10.5958/2231-6744.2017.00033.0

Diarra, S. S. & Anand, S. 2020. Impact of commercial feed dilution with copra meal or cassava leaf meal and enzyme supplementation on broiler performance. Poultry Science, 99(11): 5867-5873. https://doi.org/10.1016/j.psj.2020.08.028

Diarra, S.S., Anand, S., Lemuelu, T., Areta, F., Mathew, E., Lehi, E., Hoponoa, S., Kava, F., Mafi, J. & Taliauli, F., 2023. Commercial feed diluted with different fibre sources and enzyme product for broilers: Growth performance, carcass and gut health. Brazilian Journal of Poultry Science, 25: 1-8. https://doi.org/10.1590/1806-9061-2021-1546

Diarra, S.S., Sandakabatu, D., Perera, D., Tabuaciri, P. & Mohammed, U. 2015. Growth performance and carcass yield of broiler chickens fed commercial finisher and cassava copra meal-based diets. Journal of Applied Animal Research, 43(3): 352-356. https://doi.org/10.1080/09712119.2014.978774

Dibner, J. & Richards, J. 2005. Antibiotic growth promoters in agriculture: history and mode of action. Poultry Science, 84(1): 634-643. https://doi.org/10.1093/ps/84.4.634

Donkoh, A., Atuahene, C.C., Anang, D.M., Badu-Botah, E.K. & Boakye, K.T. 2002. Response of broiler chickens to the dietary inclusion of *Chromolaena odorata* leaf meal. Journal of Animal and Feed Sciences, 11(2): 309-320. https://doi.org/10.22358/jafs/67815/2002

Esonu, B.O., Emenalom, O.O. & Udedibie, A.B.I. 2001. Performance and blood chemistry of weaner pigs fed raw mucuna bean (velvet bean) meal. Tropical Animal Production Investigations, 4: 49-54.

Fahey, J.W., Zakmann, A.T. & Talalay, P. 2001. The chemical diversity and distribution of glucosinolates and isothiocyanaes among plants. Corrigendum Phytochemistry, 59: 200-237. https://doi.org/10.1016/S0031-9422(01)00419-8

Falowo, A.B., Fayemi, P.O. & Muchenje, V. 2014. Natural antioxidants against lipid-protein deterioration in meat and meat products: A review. Food Research International, 64: 171-181. https://doi.org/10.1016/j.foodres.2014.06.022

FAO, 2020. gateway to poultry production and products. From Food and Agriculture Organization. URL https://www.fao.org/poultry-production-products/production/en/ (accessed 04.30.22)

Faria, P.B., Vieira, J.O., Silva, J.N., Rodrigues, A.Q., Souza, X.R., Santos, F.R. & Pereira, A.A. 2011. Performance and carcass characteristics of free-range broiler chickens fed diets containing alternative feedstuffs. Brazilian Journal of Poultry Science, 13(3): 211-216. https://doi.org/10.1590/S1516-635X2011000300009

Fathima, S., Shanmugasundaram, R., Sifri, M. & Selvaraj, R. 2023. Yeasts and yeast-based products in poultry nutrition. Journal of Applied Poultry Research, 32(2): 100345. https://doi.org/10.1016/j.japr.2023.100345

Frankic, T., Voljg, M., Salobir, J. & Rezar, V. 2009. Use of herbs and spices and their extracts in animal nutrition. Acta Agriculturae Slovenica, 92(2): 95-102. https://doi.org/10.14720/aas.2009.94.2.14834

Frutos, P., Hervás, G., Giráldez, F.J. & Mantecón, A.R. 2004. Review: Tannins and ruminant nutrition. Spanish Journal of Agricultural Research, 2(2): 191-202. https://doi.org/10.5424/sjar/2004022-73

Gakuya, D.W., Mbugua, P.N., Kavoi, B. & Kiama, S.G. 2014. Effect of supplementation of Moringa oleifera leaf meal in broiler chicken feed. https://doi.org/10.3923/ijps.2014.208.213

Galli, G.M., Gerbet, R.R., Griss, L.G., Fortuoso, B.F., Petrolli, T.G., Boiago, M.M., Souza, C.F., Baldissera, M.D., Mesadri, J., Wagner, R., da Rosa, G., Mendes, R.E. Gris, A. & Da Silva, A.S. 2020. Combination of herbal components (curcumin, carvacrol, thymol, cinnamaldehyde) in broiler chicken feed: Impacts on response parameters, performance, fatty acid profiles, meat quality and control of coccidia and bacteria. Microbial Pathogenesis, 139: 1-11. https://doi.org/10.1016/j.micpath.2019.103916

Garcia, R.G., Mendes, A.A., Sartori, J.R., Paz, I.C.L.A., Takahashi, S.E., Pelícia, K., Komiyama, C.M. & Quinteiro, R.R. 2004. Digestibility of feeds containing sorghum, with and without tannin, for broiler chickens submitted to three room temperatures. Brazilian Journal of Poultry Science, 6(1): 55-60. https://doi.org/10.1590/S1516-635X2004000100007

Gudiso, X., Hlatini, V., Chimonyo, M. & Mafongoya, P. 2019. Response of broiler (*Gallus gallus domesticus*) performance and carcass traits to increasing levels of *Acacia angustissima* leaf meal as a partial replacement of standard protein sources. Journal of Applied Poultry Research, 28(1): 13-22. https://doi.org/10.3382/japr/pfx068

Gulizia, J.P. & Downs, K.M. 2020. Comparison of dietary Kudzu leaf meal (*Pueraria Montana* var. *lobata*) and Alfalfa meal supplementation effect on broiler (*Gallus gallus domesticus*) performance, carcass characteristics, and organ parameters. Animals, 10(1): 147. https://doi.org/10.3390/ani10010147

Hassan, S.M. 2013. Effects of guar meal, guar gum and saponin rich guar meal extract on productive performance of starter broiler chicks. African Journal of Agricultural Research, 8(21): 2464-2469.

He, Q., Lv, Y. & Yao, K. 2007. Effects of tea polyphenols on the activities of α-amylase, pepsin, trypsin and lipase. Food Chemistry, 101(3): 1178-1182. https://doi.org/10.1016/j.foodchem.2006.03.020

Hidayat, C., Irawan, A., Jayanegara, A., Sholikin, M.M., Prihambodo, T.R., Yanza, Y.R., Wina, E., Sadarman, S., Krisnan, R. & Isbandi, I. 2021. Effect of dietary tannins on the performance, lymphoid organ weight, and amino acid ileal digestibility of broiler chickens: A meta-analysis. Veterinary World, 14(6): 1405. https://doi.org/10.14202/vetworld.2021.1405-1411

Huang, Q., Liu, X., Zhao, G., Hu, T. & Wang, Y. 2018. Potential and challenges of tannins as an alternative to in-feed antibiotics for farm animal production. Animal Nutrition, 4: 137-150. https://doi.org/10.1016/j.aninu.2017.09.004

Hughes, P. & Heritage, J. 2004. Antibiotic growth-promoters in food animals. FAO Animal Production and Health Paper. p. 160.

Hussein, H.H. & Jassim, J.M. 2019. The influence of Moringa oleifera leaf meal and their aqueous and ethanolic leaf extracts on growth performance and blood parameters of broiler chickens. Plant Archives, 19(2): 1848. https://doi.org/10.37077/25200860.2019.275

Ibrahim, S., Wei Hoong, L., Lai Siong, Y., Mustapha, Z., C.W.Zalati, C.W.S., Aklilu, E., Mohamad, M., Kamaruzzaman, N.F. 2021. Prevalence of antimicrobial resistance (AMR) *Salmonella* spp. and *Escherichia coli* isolated from broilers in the east coast of Peninsular Malaysia. Antibiotics, 10(5): 579. https://doi.org/10.3390/antibiotics10050579

Jamroz, D., Orda, J., Kamel, C., Wilickiewicz, A., Wertelecki, T. & Skorupińska, J. 2002. The influence of phytogenic extracts on performance, nutrient digestibility, carcass characteristics, and gut microbial status in broiler chickens. Journal of Animal and Feed Sciences, 12(3): 583-296. https://doi.org/10.22358/jafs/67752/2003

Jamroz, D., Wertelecki, T., Houszka, M. & Kamel, C. 2006. Influence of diet type on the inclusion of plant origin active substances on morphological and histochemical characteristics of the stomach and jejunum walls in chicken. Journal of Animal Physiology and Animal Nutrition, 90(5□6): 255-268. https://doi.org/10.1111/j.1439-0396.2005.00603.x

Jang, I.S., Ko, Y.H., Yang, H.Y., Ha, J.S., Kim, J.Y., Kang, S.Y., Yoo, D. H., Nam, D.S., Kim, D.H. & Lee, C.Y., 2004. Influence of essential oil components on growth performance and the functional activity of the pancreas and small intestine in broiler chickens. Asian-Australasian Journal of Animal Sciences, 17(3): 394-400. https://doi.org/10.5713/ajas.2004.394

Jiang, J. & Xiong, Y. 2016. Natural antioxidants as food and feed additives to promote health benefits and quality of meat products: Review. Meat Science, 120: 107-117. https://doi.org/10.1016/j.meatsci.2016.04.005

Kagya-Agyemang, J.K., Takyi-Boampong, G., Adjei, M. & Karikari-Bonsu, F.R. 2007. A note on the effect of *Gliricidia sepium* leaf meal on the growth performance and carcass characteristics of broiler chickens. Journal of Animal and Feed Sciences, 16: 104-108. https://doi.org/10.22358/jafs/66731/2007

Kakengi, A.M.V., Shem, M.N., Sarwatt, S.V. & Fujihara, T. 2003. Can Moringa oleifera be used as a protein supplement to ruminants? Asian-Australasian Journal of Animal Sciences. 18(1): 42-47. https://doi.org/10.5713/ajas.2005.42

Kamaruzaman, N., Fauzi, M. & Yusop, S. 2022. Characterization and toxicity evaluation of broiler skin elastin for potential functional biomaterial in tissue engineering. Polymers, 14(5): 963. https://doi.org/10.3390/polym14050963

Kamboh, A.A., Arain, M.A., Mughal, M.J., Zaman, A., Arain, Z.M. & Soomro, A.H. 2015. Flavonoids: Health promoting phytochemicals for animal production-a review. Journal of Animal Health Production, 11: 369-373.

Kanife, U. & Doherty, F. 2012. Phytochemical composition and antifungal properties of leaf, stem, and florets of *Panicum maximum* Jacq, (Poaceae). International Journal of Biology, 4(2): 64-69. https://doi.org/10.5539/ijb.v4n2P64

Khan, R.U., Naz, S., Nikousefat, Z., Tufarelli, V., Javdani, M., Qureshi, M.S. & Laudadio, V. 2012. Potential applications of ginger (*Zingiber officinale*) in poultry diets. World Poultry Science Journal, 68: 245-252. https://doi.org/10.1017/S004393391200030X

Kikusato, M. 2021. Phytobiotics to improve health and production of broiler chickens: functions beyond the antioxidant activity. Animal Bioscience, 34(3): 345. https://doi.org/10.5713/ab.20.0842

Kolawole, A., Fafunso, M. & Dairo, J. 2007. Phytotoxic and antimicrobial activities of saponin extracts from lemon grass. International Journal of Biomedical and Health Sciences, 3(1): 53-58.

Kolobe, S.D., Manyelo, T.G., Ngambi, J.W., Nemauluma, M.F.D. & Malematja, E. 2022. Effect of *Acacia karoo* leaf meal inclusion levels on performance and gut morphology of broiler chickens. Advances in Animal and Veterinary Sciences, 10(11): 2347-2355. https://doi.org/10.17582/journal.aavs/2022/10.11.2347.2355

Kumari, P., Kumar, K. & Kumar, S. 2014. Effect of dietary supplement of sugar beet, neem leaf, linseed and coriander on growth performance and carcass trait of Vanaraja chicken, Veterinary World, 7(9): 639-643. https://doi.org/10.14202/vetworld.2014.639-643

Kuralkar, P. & Kuralkar, S.V. 2021. Role of herbal products in animal production-an updated review. Journal of Ethnopharmacology, 278: 114246. https://doi.org/10.1016/j.jep.2021.114246

Lipiński, K., Mazur, M., Antoszkiewicz, Z. & Purwin, C. 2017. Polyphenols in monogastric nutrition-a review. Annals of Animal Science, 17(1): 41-58. https://doi.org/10.1515/aoas-2016-0042

Low, S. 2015. Signal grass (*Brachiaria decumbens*) toxicity in grazing ruminants. Agriculture, 5(4): 971-990. https://doi.org/10.3390/agriculture5040971

Madzimure, J., Motsi, R., Bakare, A.G. & Zimondi, M. 2018. Growth performance, economic benefits and sensory characteristics of meat from broilers finished on *Acacia anguistissima* leaf meal-based diets. Tropical Animal Health and Production, 50: 1485-1491. https://doi.org/10.1007/s11250-018-1585-8

Makkar, H., Francis, G. & Becker, K. 2007. Bioactivity of phytochemicals in some lesser-known plants and their effects and potential applications in livestock and aquaculture production systems. Animal, 1(9): 1371-1391. https://doi.org/10.1017/S1751731107000298

Mancini, R.A. & Hunt, M.C. 2005. Current research in meat colour. Meat Science, 71: 100-121. https://doi.org/10.1016/j.meatsci.2005.03.003

Mani-López, E., Garcia, H.S. & López-Malo, A. 2012. Organic acids as antimicrobials to control Salmonella in meat and poultry products. Food Research International, 45(2): 713-721. https://doi.org/10.1016/j.foodres.2011.04.043

Manyelo, T.G., Sebola, N.A., Ng'ambi, J.W. & Mabelebele, M. 2022b. Influences of amaranth leaf meal on performance, blood profiles, and gut morphology in Boschveld chickens. Advances in Animal and Veterinary Sciences, 10(12): 2464-2475. https://doi.org/10.17582/journal.aavs/2022/10.12.2464.2475

Manyelo, T.G., Sebola, N.A., Ng'ambi, J.W., Weeks, W. & Mabelebele, M. 2022a. The influence of different amaranth leaf meal inclusion levels on performance, blood profiles, and gut organ characteristics of Ross 308 broiler chickens. Frontiers in Veterinary Science, 9: 869149. https://doi.org/10.3389/fvets.2022.869149

Martens, S.D., Tiemann, T.T., Bindelle, J., Peters, M. & Lascano, C.E. 2012. Alternative plant protein sources for pigs and chickens in the tropics-nutritional value and constraints: A review. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 113(2): 101-123.

Mateos, G.G., Lázaro, R. & Gracia, M.I. 2002. The feasibility of using nutritional modifications to replace drugs in poultry feeds. Journal of Applied Poultry Research, 11(4): 437-452. https://doi.org/10.1093/japr/11.4.437

Mbikay, M. 2012. Therapeutic potential of Moringa oleifera leaves in chronic hyperglycaemia and dyslipidemia: A review. Frontiers in Pharmacology, 3: 1-12. https://doi.org/10.3389/fphar.2012.00024

McSweeney, C.S., Collins, E.M.C., Blackall, L.L. & Seawright, A.A. 2008. A review of anti-nutritive factors limiting potential use of *Acacia angustissima* as a ruminant feed. Animal Feed Science and Technology, 147(1-3): 158-171. https://doi.org/10.1016/j.anifeedsci.2007.09.015

Meel, M.S., Sharma, T., Joshi, M., Gurjar, M.L., Sharma, S.K. & Kumari, M. 2021. Effect of feeding Moringa oleifera leaf meal with multienzyme on performance, carcass characteristics and economics of production of broiler chicks. Asian Journal of Dairy and Food Research. 40(1): 118- 122. https://doi.org/10.18805/ajdfr.DR-1612

Meel, M.S., Sharma, T., Joshi, M., Gurjar, M.L., Sharma, S.K. & Kumari, M. 2021. Effect of feeding *Moringa oleifera* leaf meal with multienzyme on performance, carcass characteristics and economics of production of broiler chicks. Asian Journal of Dairy and Food Research, 40(1): 118- 122. https://doi.org/10.18805/ajdfr.DR-1612

Miya, A., Sithole, A.N., Mthethwa, N., Khanyile, M. & Chimonyo, M. 2019. Response in carcass yield, organ weights and gut morphology of broiler chickens to incremental levels of Vachellia tortilis leaf meal. Canadian Journal of Animal Science, 100(2): 1-31. https://doi.org/10.1139/cjas-2019-0041

Modisaojang-Mojanaga, M.M., Ogbuewu, I.P., Oguttu, J.W. & Mbajiorgu, C.A. 2019. Moringa leaf meal improves haemato-biochemical and production indices in broiler chickens: A review. Comparative Clinical Pathology, 28: 621-632. https://doi.org/10.1007/s00580-019-02900-7

Mohammadi Gheisar, M. & Kim, I.H. 2018. Phytobiotics in poultry and swine nutrition-a review. Italian Journal of Animal Science, 17(1): 92-99. https://doi.org/10.1080/1828051X.2017.1350120

Moyo, B., Masika, P.J., Hugo, A. & Muchenje, V. 2011. Nutritional characterization of moringa (*Moringa oleifera* Lam.) leaves. African Journal of Biotechnology, 10(60): 12925-12933. https://doi.org/10.5897/AJB10.1599

Mpofu, D. A., Marume, U., Mlambo, V. & Hugo, A. 2016. The effects of *Lippia javanica* dietary inclusion on growth performance, carcass characteristics and fatty acid profiles of broiler chickens. Animal Nutrition, 2(3): 160-167. https://doi.org/10.1016/j.aninu.2016.05.003

Muniandy, K.V., Chung, E.L.T., Jaapar, M.S., Hamdan, M.H.M., Salleh, A. & Jesse, F.F.A. 2020. Filling the gap of *Brachiaria decumbens* (signal grass) research on clinico-pathology and haemato-biochemistry in small ruminants: A review. Toxicon, 174: 26-31. https://doi.org/10.1016/j.toxicon.2019.12.158

Ncube, S., Halimani, T.E., Mwale, M. & Saidi P.T. 2017. Effect of Acacia angustissima leaf meal on the physiology of broiler intestines. The Journal of Agricultural Science, 9: 53. https://doi.org/10.5539/jas.v9n2p53

Ncube, S., Hamudikuwanda, H. & Saidi, P.T. 2012. The potential of *Acacia angustissima* leaf meal as a supplementary feed source in broiler finisher diets. International Journal of Poultry Science, 11: 55-60. https://doi.org/10.3923/ijps.2012.55.60

Nduku, X.P., Mabusela, S.P. & Nkukwana, T.T. 2022. Growth and meat quality of broiler chickens fed Moringa oleifera leaf meal, a probiotic and an organic acid. South African Journal of Animal Science, 50(5): 710-718. https://doi.org/10.4314/sajas.v50i5.8

Nkukwana, T.T. 2012. The Effect of *Moringa oleifera* Leaf Meal on Growth Performance, Gut Integrity, Bone Strength, Quality and Oxidative Stability Of Meat From Broiler Chickens (PhD Dissertation). University of Fort Hare, Alice, South Africa.

Nkukwana, T.T., Muchenje, V., Pieterse, E., Masika, P.J., Mabusela, T.P., Hoffman, L.C. & Dzama, K. 2014. Effect of *Moringa oleifera* leaf meal on growth performance, apparent digestibility, digestive organ size and carcass yield in broiler chickens. Livestock Science, 161: 139-146. https://doi.org/10.1016/j.livsci.2014.01.001

Ojo, O., Ojo, A., Barnabas, M., Iyobhebhe, M., Elebiyo, T., Evbuomwan, I.O, Michael, T. Ajiboye, B.O., Oyinloye, B.E. & Oloyede, O. 2022. Phytochemical properties and pharmacological activities of the genus *Pennisetum*: A review. Scientific African, 16: e01132. https://doi.org/10.1016/j.sciaf.2022.e01132

Oloruntola, O.D., Ayodele, S.O., Omoniyi, I.S., Adeyeye, S.A. & Adegbeye, M.J. 2022. The effect of dietary supplementation of mucuna leaf meal on the growth performance, blood parameters, and carcass quality of broiler. Acta Scientiarum Animal Sciences, 44: 55362. https://doi.org/10.4025/actascianimsci.v44i1.55362

Oresegun, A., Fagbenro, O.A., Ilona, P. & Bernard, E. 2016. Nutritional and anti-nutritional composition of cassava leaf protein concentrate from six cassava varieties for use in aqua feed. Cogent Food and Agriculture, 2: 1147323. https://doi.org/10.1080/23311932.2016.1147323

Puvača, N. & Stanaćev, V. 2011. Selenium in poultry nutrition and its effect on meat quality. World's Poultry Science Journal, 67(3): 479-484. https://doi.org/10.1017/S0043933911000523

Rahimi, S., Zadeh, Z., Karimi Torshizi, M., Omidbaigi, R. & Rokni, H. 2011. Effect of the three herbal extracts on growth performance, immune system, blood factors and intestinal selected bacterial population in broiler chickens. Journal of Agriculture Science and Technology, 13(4): 527-539.

Rahman, M.M. & Yang, D.K. 2018. Effects of Ananas comosus leaf powder on broiler performance, haematology, biochemistry, and gut microbial population. Revista Brasileira de Zootecnia, 47: 1-6. https://doi.org/10.1590/rbz4720170064

Reda, F.M., El-Saadony, M.T., Elnesr, S.S., Alagawany, M. & Tufarelli, V. 2020. Effect of dietary supplementation of biological curcumin nanoparticles on growth and carcass traits, antioxidant status, immunity and caecal microbiota of Japanese quails. Animals, 10(5): 754. https://doi.org/10.3390/ani10050754

Redondo, E.A., Redondo, L.M., Bruzzone, O.A., Diaz-Carrasco, J.M., Cabral, C., Garces, V.M., Lineiro, M.M. & Fernandez-Miyakawa, M.E. 2022. Effects of a blend of chestnut and quebracho tannins on gut health and performance of broiler chickens. PLoS ONE, 17(1): E0254679. https://doi.

org/10.1371/journal.pone.0254679
Reis, J.H., Gebert, R.R., Barreta, M., Baldissera, M.D., Dos Santos, I.D., Wagner, R., Campigotto, G., Jaguezski, A.M., Gris, A., de Lima, J.L.F., Mendes, R.E., Fracasso, M., Boiago, M.M., Stefani, L.M., dos Santos, D.S., Robazza, W.S. & Da Silva, A.S. 2018. Effects of phytogenic feed additive based on thymol, carvacrol and cinnamic aldehyde on body weight, blood parameters and environmental bacteria in broilers chickens. Microbial Pathogenesis, 125: 168-176. https://doi.org/10.1016/j.micpath.2018.09.015
Reis, J.H., Gebert, R.R., Barreta, M., Boiago, M.M., Souza, C.F., Baldissera, M.D., Santos, I.D., Wagner, R., Laporta, L.V., Stefani, L.M. & Da Silva, A.S. 2019. Addition of grape pomace flour in the diet on laying hens in heat stress: impacts on health and performance as well as the fatty acid profile and total antioxidant capacity in the egg. Journal of Thermal Biology, 80: 141-149. https://doi.org/10.1016/j.jtherbio.2019.01.003
Ren, X.J., Yang, Z.B., Ding, X. & Yang, C.W. 2018. Effects of *Ginkgo biloba* leaves (*Ginkgo biloba*) and *Ginkgo biloba* extract on nutrient and energy utilization of broilers. Poultry Science, 97(4): 1342-1351. https://doi.org/10.3382/ps/pex445
Rizwanuddin, S., Kumar, V., Naik, B., Singh, P., Mishra, S., Rustagi, S. & Kumar, V. 2023. Microbial phytase: their sources, production, and role in the enhancement of nutritional aspects of food and feed additives. Journal of Agriculture and Food Research, 100559. https://doi.org/10.1016/j.jafr.2023.100559
Sant'Ana, A.S., Franco, B.D.G.M. & Schaffner, D.W. 2014. Risk of infection with *Salmonella* and *Listeria monocytogenes* due to consumption of ready-to-eat leafy vegetables in Brazil. Food Control, 42: 1-8. https://doi.org/10.1016/j.foodcont.2014.01.028
Savón, L., Scull, I. & Martinez, M. 2006. Integral foliage meal for poultry feeding. I chemical composition, physical properties and phytochemical screening. Revista Cubana de Ciencia Avícola, 41: 359-369.
Sebola, N.A., Mlambo, V. & Mokoboki, H.K. 2019. Chemical characterisation of *Moringa oleifera* (MO) leaves and the apparent digestibility of MO leaf meal-based diets offered to three chicken strains. Agroforestry Systems, 93: 149-160. https://doi.org/10.1007/s10457-017-0074-9
Selle, P.H., Cadogan, D.J., Li, X. & Bryden, W.L. 2010. Implications of sorghum in broiler chicken nutrition. Animal Feed Science and Technology, 156(3-4): 57-74. https://doi.org/10.1016/j.anifeedsci.2010.01.004
Sugiharto, S., Yudiarti, T., Isroli, I., Widiastuti, E., Wahyuni, H. & Sartono, T. 2019. Recent advances in the incorporation of leaf meals in broiler diets. Livestock Research for Rural Development, 31(7).
Suresh, G., Das, R.K., Kaur Brar, S., Rouissi, T., Avalos Ramirez, A., Chorfi, Y. & Godbout, S. 2017. Alternatives to antibiotics in poultry feed: Molecular perspectives. Critical Reviews in Microbiology, 44(3): 318-335. https://doi.org/10.1080/1040841X.2017.1373062
Taraz, Z., Shargh, M., Samadi, F., Ebrahimi, P. & Zerehdaran, S. 2015. Effect of chicory plant (*Cichorium intybus* L.) extract on performance and blood parameters in broilers exposed to heat stress with emphasis on antibacterial properties. Poultry Science Journal, 3(2): 151-158.
Thakur, M., Singh, K. & Khedkar, R. 2020. Phytochemicals: extraction process, safety assessment, toxicological evaluations, and regulatory issues. Academic Press. https://doi.org/10.1016/B978-0-12-818593-3.00011-7
Tonda, R.M., Rubach, J.K., Lumpkins, B.S., Mathis, G.F. & Poss, M.J. 2018. Effects of tannic acid extract on performance and intestinal health of broiler chickens following coccidiosis vaccination and/or a mixed-species Eimeria challenge. Poultry Science, 97(9): 3031-3042. https://doi.org/10.3382/ps/pey158
Valenzuela-Grijalva, N.V., Pinelli-Saavedra, A., Muhlia-Almazan, A., Domínguez-Díaz, D. & González-Ríos, H. 2017. Dietary inclusion effects of phytochemicals as growth promoters in animal production. Journal of Animal Science and Technology, 59(1): 1-17. https://doi.org/10.1186/s40781-017-0133-9
Wasti, S., Sah, N. & Mishra, B. 2020. Impact of heat stress on poultry health and performances, and potential mitigation strategies. Animals, 10(8): 1266. https://doi.org/10.3390/ani10081266
Windisch, W., Schedle, K., Plitzner, C. & Kroismayr, A. 2008. Use of phytogenic products as feed additives for swine and poultry. Journal of Animal Science, 86: 140-148. https://doi.org/10.2527/jas.2007-0459
Wobeto, C., Corrêa, A.D., De Abreu, C.M.P., Dos Santos, C.D. & Pereira, H.V. 2007. Anti-nutrients in the cassava (*Manihot esculenta* crantz) leaf powder at three ages of the plant. Ciência E Tecnologia De Alimentos, 27(1): 108-112. https://doi.org/10.1590/S0101-20612007000100019
Xue, F., Wan, G., Xiao, Y., Chen, C., Qu, M. & Xu, L. 2021. Growth performances, gastrointestinal epithelium and bacteria responses of yellow-feathered chickens to kudzu-leaf flavonoids supplement.

AMB Express, 11(1): 125. https://doi.org/10.1186/s13568-021-01288-4

Yavaş, İ. & Malayoğlu, H.B. 2019. Effects of olive leaf (oleuropein) supplementation on quality of breast meat in broilers. Journal of Agricultural Sciences, 25(4): 467-473. https://doi.org/10.15832/ankutbd.426521

Zuidhof, M., Schneider, B., Carney, V., Korver, D. & Robinson, F. 2014. Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005. Poultry Science, 93(12): 2970-2982. https://doi.org/10.3382/ps.2014-04291