Abd El-Ghany
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REVIEW

The impact of dietary guava (*Psidium guajava* L.) on some livestock production systems

Wafaa A. Abd El-Ghany

Affiliation: Poultry Diseases Department, Faculty of Veterinary Medicine, Cairo University, Giza, 12211, Egypt

Abstract

Due to the growing concerns about antimicrobial resistance and the potential for a ban on antibiotic growth promoters worldwide, there is an increasing demand to find alternatives to antimicrobials in livestock production. One of these alternatives is herbal extracts or phytobiotics that already are used as dietary supplements to improve the general health conditions. Guava (*Psidium guajava* L.) has a long history of nutritional and medicinal properties. All the body parts of guava and the by-products have been applied effectively in livestock systems. The guava plant is a good source of nutrients as it is rich in flavonoids, phenols, tannins, essential oils, lectins, vitamins, fatty acids, etc. All parts of the guava plant including leaves, pulp, and seeds have been used as antioxidant, antimicrobial, antihypertensive, anti-inflammatory, antidiarrheic, anticancer, immuno-stimulant, growth promotor, cough sedative, and hypocholesterolemic. Therefore, this review was planned to focus on the impact of using dietary guava on the different health parameters of some livestock production systems including poultry and rabbits.

Keywords: guava, poultry, rabbits, performance, antioxidant

Introduction

Hazardous usage of antibiotics in the field enables several microorganisms to develop drug resistance (Rossiter *et al*., 2017). In the 21st century, the emergence of antimicrobial bacterial resistance has been notified by the World Health Organization, the United States Center for Disease Control and Prevention, and the European Center for Disease Prevention and Control as one of the most significant threats to public health (World Health Organization (WHO), 2016; Talebi Bezmin Abadi *et al*., 2019). Therefore, the use of herbal medicine represents a promising alternative (Adamczak *et al*., 2019). The ingredients of plant origin (phytopharmaceuticals) can help in the alleviation of drug resistance, which is the most important problem for the pharmaceutical industry and animal production (Abd El-Ghany, 2020a, b, 2022, 2023; Abd El-Ghany and Eraky, 2020; Abd El-Ghany and Babazadeh, 2022).

Guava (*Psidium guajava* L.), family Myrtaceae, is a native tree that has been found in tropical American and South East Asian countries (Ryu *et al*., 2021; Jamieson *et al*., 2023). The different parts of the guava plant have been used in several folk medicinal aspects and also have great applications in the modern era (Nwinyi *et al*., 2008). Nearly all the body parts of guava plant and the by-products have been used effectively and for both the nutritional and medicinal purposes (Takeda *et al*., 2023). Further, guava could be used as an antibiotic alternative in agricultural and poultry sectors in the European Union and in other countries (FAO, 2016).

The rich presence of different minerals and vitamins as well as proteins in guava encourages their utilization as a direct source of nutrients. It is regarded as an inevitable source of numerous bioactive phyto-constituent compounds that enhance and stabilize the different physiological and metabolic functions in the body (Sam Arul Raj *et al*., 2023). Many research have been carried out on the nutritional values and biological activities of guava peel, flesh, and leaves (Gutiérrez *et al*., 2008; Sanda *et al*., 2011). The dried form of guava pomace consists of 94% seeds and 6% skins (Bernardino Nicanor *et al*., 2000; Denny *et al*., 2013). Guava contains fibrous ingredients such as stone cells and seeds, besides, 7.6% protein, 16.0% fat, 61.4% fiber, and 0.93% ash (Prasad and Azeemoddin, 1994; Khalifa, 2014). The chemical analysis of guava showed presence of foliage volatile oils such as -pinene (11.77%), 1,8-cineol (9.22%), globular (5.88%), hexenal (5.03%), epi-bisabolol (10.85%), 1-epi-cubenol (4.56%), and terpineol 4.35% (Ramadan *et al*., 2009). Guava wastes are rich in crude fiber (61%), ether extracts (12%), and a good source of linoleic acid and corrected apparent metabolizable energy (1336 kcal/kg) (Silva *et al*., 2009). The ethanoic extracts of guava leaves are rich in multiple bioactive components such as flavonoids (quercetin and guaijaverin), isoflavonoids, polyphenols, kaempferol, naringenin, rutin, epicatechin, ellagic acid, hyperin, reynoutrin, genistin, avicularin, some acids (corosolic, maslinic, ursolic, and oleanolic) (Nguyen *et al*., 2023), and new substances (psidials L, psidials M, and psipinene) (Chen *et al*., 2023). In addition, the methanolic

Corresponding Author: Wafaa A. Abd El-Ghany. Email: wafaa.soliman@cu.edu.eg

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leaf extracts have many phyto-elements including catechin, tricin, phlorizin, quinic acid, casuarinin, and guavinoside A (Sherif *et al*., 2023) which have antimicrobial, antioxidant, and anti-inflammatory properties (Gutiérrez-Grijalva *et al*., 2017).

The pharmacological effects denoted that this plant and its extracts are antioxidant (Hawrelak, 2003; Kuber *et al*., 2013; Ruksiriwanich *et al*., 2022; Raj *et al*., 2023), antimicrobial (Almulaiky *et al*., 2018; Chatterjee *et al*., 2022; Pereira *et al*., 2023), immunomodulatory (David *et al*., 2017), anti-inflammatory and antiallergic (Denny *et al*., 2013), antidiabetic (Oh *et al*., 2005; Rai *et al*., 2009; Tella *et al*., 2022), hypoglycemic (Shen *et al*., 2008; Kumar *et al*., 2021), anti-melanogenic (Lee *et al*., 2016), anti-hypertensive (deAssis Braga *et al*., 2022), antihemolytic (Purba and Paengkoum, 2022), growth promotor (Abang *et al*., 2023), and anti-cancer (Ryu *et al*., 2012; Lok *et al*., 2020). The bioactive phyto-compounds that exist in guava could help in the treatment of wounds, ulcers, arthritis, toothache, cholera, and gastroenteritis (Singh *et al*., 2023; Takeda *et al*., 2023). Moreover, a mixture of aromatic substances in guava leaves and phenolic compounds could help in the modulation of blood sugar levels and many other health parameters (Tousif *et al*., 2022).

Therefore, this review was planned to focus on the impact of using dietary guava on the different health parameters of some livestock production systems including poultry and rabbits.

The different effects of feeding on dietary guava on the health conditions of some livestock production systems are presented in Fig. 1.

Review methodology

For this review article, systematic searches of scientific manuscripts that focused on the impact of using dietary guava on the different health parameters of some livestock production systems including poultry and rabbits have been carried out. The author searched many important academic databases such as CAB Abstracts, Google Scholar, and ScienceDirect as well as the recent books. The author searched for terms such as Guava, poultry, rabbits, performance, antioxidant, carcass characteristics, immunity, microbial community, and blood parameters.

Performance parameters

BROILERS

Dietary supplementation of broiler chickens with guava improved the growth performance parameters (Kaileh *et al*., 2007). Feeding of broilers on guava leaf meal up to 4.5% level in diets modified the production performance (Rahman *et al*., 2013). Dietary addition of dried guava leaves (1%) and/or olive oil (1%) induced a significant improvement in body weight (BWt), weight gain (WG), and feed conversion ratio (FCR) without effect on the feed consumption in Cobb broiler chickens (Mahmoud *et al*., 2013). A recent study by Abang *et al*. (2023) showed that dried guava leaf meal (300g and 450g/100kg diet) enhanced growth performance, reduced feed cost/WG, and increased survivability without influencing the organoleptic properties of finisher broiler chickens. Similar results were obtained by Hassan *et al*. (2023) who found that Golden Misri chicks fed on up to 2.5 to 4.5% guava leaf showed better average WG, feed intake (FI), FCR, and specific growth rate when compared with control (Hassan *et al*., 2023). Rahman *et al*. (2013) demonstrated that feeding of broilers with guava leaf meal up to 4.5% of diets did not significantly affect FI, but it reduced the mortality rate. Incorporation of guava leaves extract up to 3.0 ml/kg diet of growing rabbits successfully improved the final BWt, FCR, and carcass percentage, and reduced the diarrhea during the growing period (Morsy *et al*., 2019). Like, rabbits fed diets containing 20% guava showed better WG, FCR, and performance index than control non-treated rabbits (Kamel *et al*., 2016).

Guava leaf meal extract could improve the digestion and metabolic activities which results in a positive influence on the FI. Additionally, guava leaf meal powder is rich in phenolic compounds, vitamins, carotenoids, alkaloids, and amino acids that increase the appetite. The existence of amino acids including arginine, glycine, and leucine, glutamic acid, aspartic acid (Habib, 1986), besides some fatty acids in guava can increase its nutritive value (Opute, 1978). Additionally, the synergic effect of ether extract and crude fiber of guava may enhance the gastrointestinal transit and consequently improve the WG (Lira *et al*., 2009).

However, the addition of 0.04% or 0.06% of guava leaf extracts to broilers ratio did not show any significant impact on the body weight and weight gain (Rattanaphol and Rattanaphol, 2009). This

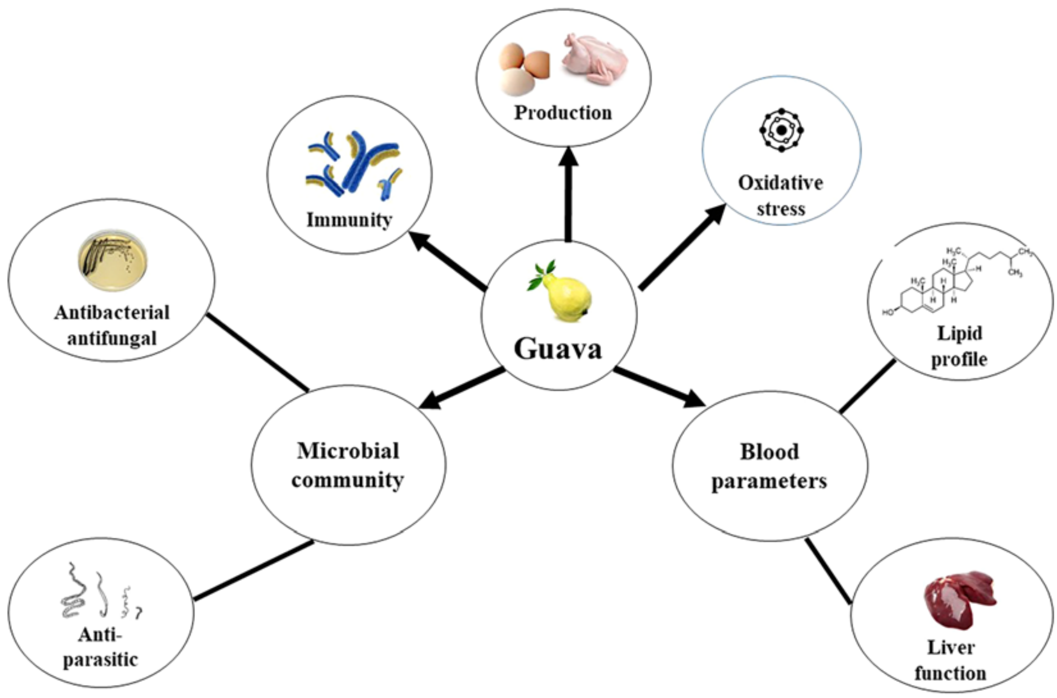

Fig. 1. The different effects of guava on the health conditions.

discrepancy may be related to the presence of different types of guava leaves or the difference in the extraction process and the type of the extract (Porwal *et al*., 2012).

BREEDERS AND LAYERS

The influences of dietary feeding on an aqueous extract of guava leaves (75 mg/kg body weight) on Ross 308 broiler breeder chicken flocks at the end of their first reproduction cycle have been demonstrated (François *et al*., 2021). The results revealed a significant improvement of egg laying rate, external eggs characteristics, incubation performances, and chick viability (François *et al*., 2021). In male rats, the aqueous and methanolic extracts of guava leaves induced positive effects on testicular and epididymal weights, sperm motility, and epididymal concentration (Aruna *et al*., 2013). Feeding on sun dried or processed guava by-products to laying hens helped in keeping the quality of egg number, egg mass, egg weight, and shell (El-Deek *et al*., 2009a). This result may be due to the antioxidant potency of vitamin C (Marquina *et al*., 2008) and the fiber with methoxylated pectin in guava (Uddin *et al*., 2002).

Nevertheless, the addition of guava waste to the feed of laying hens did not affect the performance characteristics in the periods from 30 to 39 weeks of age (Guimarães, 2007). The authors did not observe any difference in performance parameters in the periods from 33–36 to 36–39 weeks and throughout the experimental period, from 30 to 39 weeks, when 0, 2, 4, 6, and 8% guava waste was incorporated in the diets of laying chickens.

Carcass characteristics

Medina *et al*. (2006) declared that 0.04% or 0.06% of guava leaves extract induced a significant effect on meat composition. Moreover, El-Deek *et al*. (2009b) reported that broiler chicken's received 8% raw or treated guava by-product revealed significant less abdominal fat than any other dietary levels or the control. In addition, the inclusion of guava waste up 12% in broiler chickens feed could promote the FI, WG, FCR, and carcass yield similar to diets based on corn and soybean meal (Lira *et al*., 2009). The substitution of a portion of alfalfa in rabbits' diets with dried guava waste or dried olive cake (5%) resulted in an improvement of farm economic efficiency and high profit. Nevertheless, their combination in the same diet was not efficient (Wahed *et al*., 2019).

Oxidative stress

The by-product of guava has been applied for broiler as an alternative antioxidant feed additive because its positive influence on the productive performance and the meat quality (Oliveira *et al*., 2018). Guava extract displayed a higher antioxidant activity due to its richness with some antioxidant enzymes such as catalase (CAT) and polyphenol oxidase (Almulaiky *et al*., 2018). Furthermore, the super oxide dismutase (SOD) and glutathione peroxidase (GPx-1) enzymes have been significantly increased following broilers supplementation with dried guava leaves and/or olive oil (Mahmoud *et al*., 2013). Similarly, the highest GPx-1 level was detected in broiler chickens fed on a diet containing 5 mg kg^{-1} guava essential oil (Langerudi *et al*., 2022). Administration of aqueous guava extract for 4 weeks enhanced most of the endogenous antioxidant enzymes including glutathione reductase, SOD, and total antioxidant capacity in streptozotocin induced diabetic animals (Ramadan *et al*., 2009). The antioxidant property of guava extract is usually associated with an increase in the antioxidant defense system and decrease in the lipoid peroxidation and reactive oxygen species (ROS) generation. Moreover, supplementing guava essential oils at 5 mg kg^{-1} feed resulted in the SOD, GPx-1, and glutathione-S-transferase activities; probably, as a result of antioxidant effect and free radical-scavenging abilities (Chen and Yen, 2007).

There is a strong correlation between the phenolic content of guava leaf extract, the antioxidant's potency, and the ability to scavenge ROS free radicals (Chen and Yen, 2007). It has been reported that high concentrations phenols including gallic acid, pyrocatechol, taxifolin, ellagic acid, ferulic acid, and others are responsible for the antioxidant role of guava (Ramadan *et al*., 2009; Haida *et al*., 2011; Farag *et al*., 2020).

Other potential antioxidant flavonoids such as quercetin, hesperetin, kaempferol, rutin, catchin, and apigenin as well as other bioactive substances; kaempfertin, isoquinoline, and corilaginoline alkaloids were identified in guava extracts using high-performance liquid chromatography analysis (Hascik *et al*., 2015; Taha *et al*., 2019). The presence of benzene-1,2-diol,2-O-methyl guanosine, 5-bromo-8-(5-nitrosalicylidene amino) quinoline hydrochloride, guavanoic, protocatechuic, oleanolic, and hydroxyursolic acids (Shen *et al*., 2008), phenols, flavonoids, and pentacyclic triterpenoids (Kumar *et al*., 2021) in guava extracts plays a critical antioxidant and antidiabetic effects. Moreover, 3,4-dihydroxybenzoic acid produced by peroxidase-dependent oxidation of quercetin flavonoids enhanced the antibacterial and antioxidant effectiveness of guava. The flavonoid and polysaccharides constituents of guava leaves exerted protection against the oxidative stress caused by hydrogen peroxide by inhibiting amylase and-glucosidase enzyme activities, the formation of ROS; and consequently, reducing the lipid peroxidation and cell death (Kim *et al*., 2016; Kumar *et al*., 2021). Silver nanoparticles that have been synthesized by utilizing crude polysaccharides of guava showed high 2,2-diphenyl-1 picrylhydrazyl radical and 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) radical cation-scavenging capacity (Wang *et al*., 2017).

Microbial community

Regarding the antibacterial activity of guava, Pereira *et al*. (2023) demonstrated that the aqueous extract could inhibit the growth of the sensitive and resistant Gram-positive bacterial strains. For instance, guava methanolic extracts inhibited methicillin resistant *Staphylococcus (S) aureus* and *S. epidermidis* (Richard *et al*., 2013; Chakraborty *et al*., 2018), while the aqueous extracts inhibited *Streptococcus* sp. growth (Shafiei *et al*., 2016). Additionally, a methanolic extract of guava leaves revealed antibacterial activity against *Escherichia coli* (*E. coli*) with a minimum inhibitory concentration of 0.79 g/mL with a minimum bactericidal concentration of 51 g/mL (Dhiman *et al*., 2011). Iwu (1993) reported an antibacterial effect of guava leaf extract against *E. coli*, *S. aureus*, and *Streptococcus* sp.

The antimicrobial efficacy of the root (Kidaha *et al*., 2013) and fruit extracts (Iha *et al*., 2008) of guava has been demonstrated. The antimicrobial potential of guava could be owing to presence of high concentrations of guavins A-D and psydiolic acid (Huang *et al*., 2021; Ryu *et al*., 2021), total phenols (Moorthy *et al*., 2013; Pereira *et al*., 2023), as well as flavonoids, especially quercetin, saponins, tannins, phlobatannins, alkaloids anthraquinones, terpenoids, and glycosides (Pandey and Shweta, 2011; Hascik *et al*., 2015; Kumar *et al*., 2021). Moreover, the methanolic (Nair and Chanda, 2007; Rattanachaikunsopon and Phumkhachorn, 2010; Dhiman *et al*., 2011; Ratnakaran *et al*., 2020), ethanolic (Raj *et al*., 2020; Shetty *et al*., 2021), and aqueous (Biswas *et al*., 2013; Fagbohun *et al*., 2013; Patel *et al*., 2019; Millones-Gómez *et al*., 2020) extracts of guava leaves showed a strong antimicrobial efficacy. Additionally, polyphenol compounds as tannin could inhibit and inactivate bacterial growth by reacting with the cell membrane. Tannins extracts from guava leaves prevented the growth of *E. coli*, *Pseudomonas aeruginosa* (*P. aeruginosa*), and *S. aureus* (Mailoa *et al*., 2014). Similarly, lectins in guava were shown to bind to *E. coli* preventing its adhesion to the intestinal wall and thus preventing infection (Okemo *et al*., 2001). Further, the essential oils of guava exhibited strong antimicrobial properties against *P. aeruginosa*, *Streptococcus faecalis*, *S. aureus*, *E. coli*, and *Bacillus subtilis* (Soliman *et al*., 2016). It has been noted that different organic and inorganic antioxidants and anti-inflammatory compounds in guava leaves extract may be the cause of the antimicrobial properties (Naseer *et al*., 2018). Quercetin is regarded as one of the most important flavonoids of guava leaf extract with the highest pharmacological activity (Hirudkar *et al*., 2020). Besides, triterpenoids such as betulinic acid and lupeol showed a strong antibacterial and antifungal activities (Ghosh *et al*., 2010).

Guava leaves solutions were able to inhibit the growth of some fungi such as *Microsporum gypseum* and *Trichophyton mentagrophytes* (Richard *et al*., 2013). The antifungal activity of guava is correlated to its richness with gallic acid, chlorogenic acid, rutin, isoquercitrin, avicularin, quercitrin, kaempferol, morin, and quercetin which inhibit ergosterol "a fungal cell membrane constituent" and glucosamine "a fungal cell growth indicator." Moreover, tannins extracts from guava leaves showed an inhibition of *Aspergillus niger* and *Candida albicans* growth (Mailoa *et al*., 2014).

The efficacy of crude extracts of guava (0.04% and 0.06%) was similar to vaccination and coccidiostat in *Eimeria tenella*-challenged broiler chickens (Rattanaphol and Rattanaphol, 2009). Similarly, supplementation with guava essential oils at 5 mg kg^{-1} of feed may help in the prevention of coccidiosis in broiler chickens (Langerudi *et al*., 2022). Moreover, Lee *et al*. (2013) declared that the essential oils of guava significantly reduced the count of *Toxoplasma gondii* tachyzoites in comparison with clindamycin.

Both β-caryophyllene and α-pinene essential oils in guava extract probably play a key role in the anticoccidial properties of guava. These oils change integrity and permeability of parasite's membrane and; and consequently, lead to membrane damage, intracellular content leakage, and cell death (Moo *et al*., 2020; Allenspach and Steuer, 2021).

Immunity

Dietary guava could increase the levels of immunoglobulins and immune variables in and chickens (Aroche *et al*., 2018) and fish (Giri *et al*., 2015; Abdel-Tawwab and Hamed, 2020). Supplementation of broiler chickens with dietary guava leaves led to enhancing immunity through increasing the levels of the total protein, globulin, and leukocyte count (Medina *et al*., 2006; Mahmoud *et al*., 2013). Ali and Shamsuzzaman (1996) demonstrated that flavonoids in guava leaves may inhibit the growth of immuno-suppressive bacteria such as *S. aureus*. Therefore, the positive impact of guava leaves supplementation on the immune response of broiler chickens may be owing to the presence of flavonoids, which have anti-microbial activity (Pandey and Shweta, 2011). In addition, guava leaves extracts may act on the intestinal mucosal cells, help in the upregulation of interleukin-7 synthesis, and consequently the development of B and T cells (Comber and Bamezai, 2012).

Blood parameters

LIPID PROFILE

Inoculation of broiler chicks' diets with 1% dried guava leaves significantly decreased the level of lipids metabolites except for low density lipoprotein (Mahmoud *et al*., 2013). Besides, feeding of broilers on guava extract decreased the triglycerides, cholesterol, and low density lipoprotein, but increased the high density lipoprotein concentrations (Crespo and Esteve-Garcia, 2002). Rabbit's diets contagion guava leaves ethanol extracts significantly reduced the triglycerides and low-density lipoprotein serum levels, and alleviated the high-density lipoprotein levels (Olaniyan, 2017).

A high blood level of cholesterol (hypercholesterolemia) could be mediated by the effects of many bioactive compounds with antioxidant properties in guava leaves extracts (Jiménez-Escrig *et al*., 2001). Flavonoids such as quercetin, kaempferol, guaijaverin, avicularin, myricetin, hyperin, and apigenin in these extracts showed glucosidase and amylase inhibitory activities (Wang *et al*., 2010). Triglycerides are secreted from the liver into the blood by triglyceride-rich lipoproteins. So, the pronounced effect of guava extract on the lipid profile may be related to impaired hepatic lipogenesis which lead to decreasing in the blood plasma concentrations of triglycerides (Bölükbaş and Erhan, 2007).

LIVER FUNCTIONS

The hepato-protective effects of guava leaf extract have been reported (Roy *et al*., 2006). Increasing the levels of alanine transaminase and aspartate aminotransferase is an indication of fatty liver, which could be restricted by the supplementation with guava leaf extract (Yoshitomi *et al*., 2012). The bioactive compounds guaijaverin and avicularin constituents of guava leaves are potential inhibitors of dipeptidyl-peptidase IV and glucose transporter 4-mediated glucose uptake which are responsible for increasing the blood glucose levels (Eidenberger *et al*., 2013). It has been shown that treatment of rats with type 2 diabetes mellitus with guava leaf extract containing high flavonoid levels enhanced the resistance to insulin and also restricted the increase in glucose as well as lipid levels (Zhu *et al*., 2020).

Conclusion

Guava components have characteristic medicinal profiles that endorse multiple applications in human and veterinary medicine. Guava contains numerous diverse metabolites which play roles as performance promotors, antioxidants, antimicrobials, immune stimulators, and blood parameters modifiers in animal production systems. Despite guava plant parts have multiple beneficial properties, they need further development for wider applicability. Moreover, the identification and development of new natural products can be the key research area in the future studies.

CONFLICT OF INTEREST

The author declares that there are no competing interests.

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