Chapter 40

Impact of Phytobiotics on Poultry Health and Diseases

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ABSTRACT

This chapter elucidates the implications of different phytobiotics on poultry health and disease management. It delineates the overview of commonly used phytogenic feed additives in poultry nutrition, including garlic, ginger, neem, coneflower, aloe vera, thyme, oregano, cinnamon, turmeric, moringa, peppermint, and coriander. These additives demonstrate substantial improvements in gut health, growth performance, egg production, and lactobacillus count, alongside a reduction in coliform count. Furthermore, the chapter scrutinizes their efficacy as antiparasitic agents against various poultry parasites, such as *Ascaridia galli* and *Eimeria* species, and their antibacterial activity against a myriad of bacterial strains, including *Escherichia coli*, *Clostridium perfringens*, and *Salmonella spp*. Moreover, it elucidates the antiviral properties of these phytogenics against economically important viruses of poultry such as Newcastle disease virus, Infectious bronchitis virus, Avian influenza virus, Chicken infectious anemia virus, and Infectious bursal diseases virus. Lastly, the chapter discusses their antifungal effects against prevalent fungal species and toxins such as Aspergillus spp. and aflatoxins.

KEYWORDS
Phytobiotics, Poultry, Gut health, Viruses, Bacteria, Parasitic diseases, Turmeric, Garlic, Thyme

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INTRODUCTION

The poultry sector is experiencing rapid expansion, especially in developing nations (Bahri et al., 2019). Advancements in manufacturing antibiotics and their efficacy on livestock productivity have led to extensive use of these compounds (Mohammadi Gheisar and Kim, 2017). The antibiotics used as growth promoters in farm animals were prohibited in the year 2005, prompted by apprehensions regarding their remnants in animal products and results in the development of resistance of bacteria. The discontinuation of antibiotic growth promoters has notably augmented the occurrence of infections by pathogens, consequently exerting an adverse impact on the performance of commercial livestock (Mohammadi Gheisar and Kim, 2017). Consequently, phytobiotics are becoming increasingly significant as potential substitutes for antibiotic growth promoters, given their natural composition, widespread availability, non-toxic nature, and absence of residues (Yadav et al., 2016; Alagawany et al., 2019; Abd El-Hack et al., 2020a; Abd El-Hack et al., 2020b). In recent years, there has been a growing interest in phytogenic additives or botanical extract supplements in veterinary practice, serving as a substitute for antibiotics in poultry nutrition (Vidanarachchi et al., 2005). Over the past twenty years lot of research has been done on the different roles of phytobiotics such as anti-inflammatory, antimicrobial, antioxidant, and metabolism-regulating effects (Gupta et al., 2019).

Phytobiotics, alternatively known as phytochemicals or phytogenics, constitute a wide range of bioactive substances derived from plants (Liu, 2004). Phytobiotics consist of bioactive elements or materials from botanical sources, encompassing terpenes, alkaloids, glucosides, and phenolic compounds (Shad et al., 2014). According to the regulation of the European Parliament and of the Council [Regulation (EC) No 1831/2003], a feed additive is defined as "a substance, micro-organism or chemical substance intentionally added to a feed for the purpose of improving feed properties, meeting nutritional requirements of animals, positively influencing genetics and production animal characteristics and welfare and to

increase livestock production". One such additive is phytobiotics [Regulation (EC) No 1831/2003] (Krauze, 2021), and other feed supplements such as vitamins, enzymes, minerals and essential nutrients are supplemented in poultry feed.

Phytobiotics can be categorized based on their purification attributes and origin. The primary divisions of phytobiotic dietary supplements include essential oils, herbs, oleoresins, and spices (Windisch et al., 2008; Huyghebaert et al., 2011; Gheisar et al., 2015). Plants denote temporary blossoming and non-woody flora, including herbs and bushes, utilized as a reservoir of phytogenic feed supplements. Entire botanicals, blossoms, foliage, and roots are harnessed to form phytogenic feed additives (Grashorn, 2010).The incorporation of botanicals within feed has been observed to improve performance of the animal and well-being within the poultry sector (Alghirani et al., 2021). Some of the commonly used phytogenic additives and their active compounds are mentioned in the
Table ***1***.

Table 1: Different types of phytobiotics used in poultry

Plant	Scientific Name	Used Part	Active component	Reference
Garlic	*Allium sativum*	Bulbs in crushed form	Flavonoids, allicin, ajoene, diallyl sulfide, vinyldithiin, phytosterols, mucilages, pectins	(Wenk, 2003; Truchlinski et al., 2006; Yarru et al., 2009; Akyıldız and Denli, 2016; Vinus et al., 2018; Islam and Sheikh, 2021)
Cinnamon	*Cinnamomum zeylanicum* *Cinnamomum cassia*	Cinnamon leaves, bark, and oil	Phenolic and polyphenolic compounds, cinnamaldehyde eugenol	(Al-Kassie, 2009; Akyıldız and Denli, 2016; Chachaj et al., 2019; Islam and Sheikh, 2021; Krauze et al., 2021)
Aloe vera	*Aloe barbadensis*	Gel, powder, leaves, and water extract	Anthraquinones polysaccharides (chiefly icemannan), salicylic acid, vitamins, amino acids, enzymes, and lignin,	(Babak and Nahashon, 2014; Tariq et al., 2014; Taraneh, 2016; Sinha et al., 2017; Ebrahim et al., 2020; Islam and Sheikh, 2021)
Turmeric	*Curcuma longa*	Powder/Rhizome	Turmerones, curcumin	(Babak and Nahashon, 2014; Sinha et al., 2017; Islam and Sheikh, 2021)
Oregano	*Origanum vulgare*	Oil or leaves extracts	Polyphenols, carvacrol and thymol (terpenoids)	(Méndez Zamora et al., 2017; Islam and Sheikh, 2021)
Ginger	*Zingiber officinale*	Oil, powder	Sesquiterpenes and monoterpenes (Gingerol, paradols, shogao)	(Abd El-Hack et al., 2020b; Islam and Sheikh, 2021)
Moringa	*Moringa oleifera*	Extracts, leaves	Carotenoids, ascorbic acid, phenolics, alkaloids, polyphenols, chlorogenic acid, caffeinated, flavonoids,	(Al-Kassie, 2009; Aroche et al., 2018; Islam and Sheikh, 2021)
Neem	*Azadirachta indica*	Plant leaves	Nimbin, Azadirachtin, Salannin	(Islam and Sheikh, 2021)
Coneflower	*Echinacea purpurea*	Root, dried herb leaves, root, alcohol and water extracts	Polyacetylenes, alkylamides polysaccharides, polyphenolic acids, flavonoids	(Vinus et al., 2018; Abd El-Hack et al., 2020a; Islam and Sheikh, 2021; Krauze et al., 2021)
Peppermint	*Mentha piperita*	Powder, leaves	Terpenes, menthol, carvacrol	(Leone et al., 2015; Vinus et al., 2018; Islam and Sheikh, 2021)
Thyme	*Thymus vulgare*	Flowers, leaves	Carvacrol, thymol	(Islam and Sheikh, 2021)
Coriander	*Coriandrum Sativum*	Seeds	Flavonoids, phenolic acid	(Islam and Sheikh, 2021)

Effect of Phytobiotics on the Performance and Productivity of Poultry

Phytobiotics promote poultry growth (Gheisar et al., 2015; Stamilla et al., 2020). Different phytogenic feed additives like thyme, oregano, garlic, neem, coneflower, aloe vera, ginger, cinnamon, turmeric, moringa, peppermint, and coriander can be used in the poultry feed to improve the performance. Thyme, thyme combination with moringa (Wahab et al., 2020), moringa leaf (Akhouri et al., 2013), leaf powder (Swain et al., 2017) and seed combined with phytase (Wahab et al., 2020), garlic (Olobatoke and Mulugeta, 2011) , ginger rhizome powder (Kausar et al., 1999; Tekeli, 2006; Tekeli et al., 2011; Habibi et al., 2014a; Borgohain et al., 2017; Talukder et al., 2017; Shewita and Taha, 2018; Ifelayo et al., 2020; Martha, 2022), the combination of ginger and curry leaf powder (Moorthy et al., 2009), red ginger and ginger root meal (Onimisi et al., 2005; Moorthy et al., 2009; Shewita and Taha, 2018; Ifelayo et al., 2020; Shende et al., 2020), dried neem leaf powder (Ansari et al., 2012), cinnamon (Qaid et al., 2021a), cinnamon bark powder (Qaid et al., 2022) (Jamróz and Kamel, 2002), oregano oil in broilers (Bozkurt et al., 2009; Fotea et al., 2010; Roofchaee et al., 2011; Ghazi et al., 2015; Galal et al., 2016)

(Giannenas et al., 2003; Mohiti-Asli and Ghanaatparast-Rashti, 2015; Mohiti-Asli and Ghanaatparast-Rashti, 2017), oregano oil in quails (Badiri and Saber, 2016), coriander seeds (Cabuk et al., 2003; Hamodi et al., 2010; Rashid et al., 2014) and oil (Ghazanfari et al., 2015) and turmeric rhizome extract (Durrani et al., 2006; Kumari et al., 2007; Abd Al-Jaleel, 2012; Mondal et al., 2015; Arslan et al., 2017; Oluwafemi et al., 2021), supplementation enhance body weight gain (BWG), feed conversion ratio (FCR), European production efficiency factor (Al-Kassie and Witwit, 2010; Toghyani et al., 2010; Veselin et al., 2021) (Bolukbasi and Erhan, 2008; Cayan and Erener, 2015; Asadi et al., 2017; Borgohain et al., 2017; Karim et al., 2017; Shewita and Taha, 2018; Mulugeta et al., 2019; Rastad, 2020; Abd El-Hack et al., 2022), in broilers (Stamilla et al., 2020) and meat-type ducks (Gheisar et al., 2015). However, contradictory results have been found in different studies (Cross et al., 2007; Ocak et al., 2008; Dieumou et al., 2009; Zhang et al., 2009; Onu, 2010; Abdel-Wareth et al., 2012; Shanoon et al., 2012; Habibi et al., 2014b; Mohamed, 2015; Herve et al., 2018).

In a laying bird, phosphorous and calcium are major elements that are involved in the formation of an egg. Phytobiotics tend to enhance shell and egg weight by increasing absorption and accumulation of phosphorus and calcium within the body of layers (Loretts et al., 2024). Thyme (Bolukbasi and Erhan, 2008; Cayan and Erener, 2015; Abd El-Hack et al., 2022), garlic (Olobatoke and Mulugeta, 2011), ginger root oil in Japanese quails (Herve et al., 2019), ginger oil (Nasiroleslami and Torki, 2010) and ginger (Nasiroleslami and Torki, 2010; Akbarian et al., 2011; Zhao et al., 2011) supplementation enhanced egg production, egg sizes, egg weight, egg shell thickness, egg mass and egg yield. However, the haugh unit, egg index, yolk index (Nasiroleslami and Torki, 2010), egg's weight, laying rate (Zhao et al., 2011) remained the same.

Effect of Phytobiotics on Gut Health

Garlic (Peinado et al., 2012; Singh et al., 2017), neem and aloe vera combination (Sujatha et al., 2017), peppermint in quails (Aly et al., 2023), cinnamaldehyde oil (Chowdhury et al., 2018; Qaid et al., 2021b), moringa leaf powder (Moreno-Mendoza et al., 2021), turmeric powder (Namagirilakshmi et al., 2010); Rajput et al. (2013) supplementation improved the gut health in broilers with better intestinal structure such as increased villus height, crypt depth, and decreased goblet cells count and epithelial thickness of intestines (Adibmoradi et al., 2006; Zhang et al., 2022a). However, supplementation of garlic decreased the villus width at the tip including the villi height to crypts depth ratio (Shewita and Taha, 2018), and turmeric powder reduced intestinal crypt depth Rajput et al. (2013) with no changes in crypt length and crypt villi width in another study (Namagirilakshmi et al., 2010).

Garlic (Yang et al., 2009), the mixture of garlic, thyme, and coneflower (Rahimi et al., 2011), aloe vera and neem combination (Sujatha et al., 2017), peppermint in quails (Aly et al., 2023), oregano oil (Zhang et al., 2021), cinnamon oil (Mehdipour and Afsharmanesh, 2018; Yang et al., 2019), moringa leaves (Abu Hafsa et al., 2020), promoting the growth of beneficial bacteria such as Lactobacillus (Elbaz et al., 2021). However, no effect of the combination of formic acid with cinnamaldehyde was seen on the lactobacillus counts (Pathak et al., 2016). The mixture of garlic, thyme, and coneflower (Rahimi et al., 2011), aloe vera and neem combination (Sujatha et al., 2017), peppermint (Mehri et al., 2015; Veselin et al., 2021; Aly et al., 2023), oregano oil (Zhang et al., 2021), cinnamon oil (Saied et al., 2022). combination of cinnamaldehyde and formic acid(Pathak et al., 2016), moringa leaves (Abu Hafsa et al., 2020) (Agashe et al., 2019), inhibited the growth of harmful bacteria such as E. coli, salmonella (Mehri et al., 2015; Pathak et al., 2016; Abu Hafsa et al., 2020; Zhang et al., 2021; Saied et al., 2022; Aly et al., 2023), clostridium (Pathak et al., 2016), staphylococcus (Abu Hafsa et al., 2020). However, no effect of the combination of cinnamaldehyde with formic acid was seen over E. coli in another study (Pathak et al., 2016). Garlic lowers the acidity of digestive contents thereby promoting volatile fatty acid production and ultimately the growth of helpful bacteria (Yang et al., 2009). Oregano oil enhanced trypsin, amylase, chymotrypsin, and lipase activity within the cecum thereby promoting digestion (Zhang et al., 2021). Cinnamaldehyde oil in broilers enhances the activity of intestinal and pancreatic enzymes by triggering secretion from the salivary gland, thereby increasing the activity of digestive enzymes ultimately (Chowdhury et al., 2018). Cinnamaldehyde or its oil improved the ileal digestion of amino acids (such as threonine, histidine, asparagine, serine, lysine, phenylalanine) nutrients and raw fats (Jamroz et al., 2003) and the breakdown of protein via increasing levels of pepsin and hydrochloric acid in the gastrointestinal tract of broilers (Mountzouris et al., 2011). The phytobiotics may improve the uptake and digestibility of nutrients via increased expression of the nutrient transporter genes (Bello et al., 2023).

Management of Poultry Diseases with Phytobiotics

Parasitic Diseases

Ascaridia galli infestation within birds can be prevented by the use of fresh or water-based extract from garlic (Das and Thakuria, 1974), turmeric alcoholic extract (Alrubaie, 2015) attributed to its allicin constituent (Velkers et al., 2011). Garlic formulations impact worm infestations in poultry (Das and Thakuria, 1974). Garlic use in chickens (Kim et al., 2013; Khan et al., 2019), ginger use in pigeons (Ali et al., 2015), the combination of ginger with garlic (Ali et al., 2019), cinnamaldehyde (Yang et al., 2020), cinnamon powder (Qaid et al., 2021a; Qaid et al., 2022), *Aloe vera* gel (Yim et al., 2011; Hassan et al., 2024), turmeric (Allen et al., 1998), turmeric and salinomycin sodium combination (Abbas et al., 2010), turmeric paste (Favour et al., 2020), oregano oil (Tsinas et al., 2011; Mohiti-Asli and Ghanaatparast-Rashti, 2015), acetone extract of moringa oleifera (Ola-Fadunsin and Ademola, 2013), *moringa oleifera* leaf powder or ethanol extract (Banna H. A, 2016), neem leaves aqueous extract (Qudoos et al., 2020; Onyiche et al., 2021), neem leaf extract in Japanese quail (Ishaq et al., 2022), neem leaf extract in pigeons (Qudoos et al., 2020), *Echinacea purpurea* (Allen, 2003; Ghafouri et al., 2023), peppermint or its powder (Barbour et al., 2015; Hussein, 2021) and thymol in pigeons (Arafa et al., 2020) neutralized and

simultaneously decreased oocyte shedding of *Eimeria* sporozoites in poultry (Table 2).

Table 2: Effect of different phytobiotics on the parasitic infections of the poultry

Phytobiotic	Specie	Dose	Effect	Reference
Garlic	Chickens infected with *Ascaridia galli*	Fresh (2.5mg/bird) or Water-based extract (2.5ml/bird) Every day for 5 days	Garlic showed anti-parasitic effects against *Ascardia galli* infestation in chickens.	(Das and Thakuria, 1974)
Garlic	Broilers infected with *Coccidia*	15g/Kg feed	Garlic showed improved performance and coccidiostatic effect in broilers.	(Ali et al., 2019)
Ginger	Broilers infested with *Coccidia*	5g/Kg feed	Ginger showed improved performance and coccidiostatic effect in broilers.	(Ali et al., 2019)
Ginger	Pigeons natural infection with *Eimeria spp.*	5% ginger extract or 10% ginger extract	10% ginger extract given twice daily for two days prevented the oocyte shedding in (91%) birds, while 5% of the same extract gave less efficiency (70% only).	(Ali et al., 2015)
Cinnamon	Broilers infected with *Eimeria tenella*	6g cinnamon/Kg	Moderately reduced coccidiosis	(Qaid et al., 2021a)
Aloe vera gel	Broilers infection with *Eimeria tenella*	10% gel extract from *Aloe vera* 15ml/liter in drinking water	Prophylactic use *Aloe vera* decreased lesions in the cecum, decreased mortality (12%), and reduced oocysts/gram	(Hassan et al., 2024)
Aloe vera powder	Broilers infected with *Eimeria maxima*	0.5%, 1% and 2% aloe vera powder	Decrease gut lesion scores and reduced fecal oocyst shedding	(Yim et al., 2011)
Turmeric powder	Broilers infected with *Eimeria tenella*	1, 2 and 3% turmeric powder in feed	High levels have coccidiostatic	(Abbas et al., 2010)
Turmeric alcoholic extract	Chicken infested with *Ascaridia galli*	200, 400 and 600 mg/Kg	600 mg/Kg restore intestinal integrity and decrease the length and weight of worms.	(Alrubaie, 2015)
Turmeric paste	Broilers infected with *Eimeria*	0.5g/Kg or 1g/Kg Turmeric paste	Decrease fecal coccidia oocysts at 1g/kg compared to control and 0.5g/kg treated groups	(Favour et al., 2020)
Oregano essential oil	Broilers with coccidiosis	300 and 500 ppm within the diet	Higher dose decrease the detrimental effects and decrease oocyte shedding	(Mohiti-Asli and Ghanaatparast-Rashti, 2015)
Oregano essential oil	Broiler chickens experimental infection with *Eimeria maxima* and *Eimeria acervulina*	300 or 600mg/Kg	Exerts an anticoccidial effect against *Eimeria maxima* and *Eimeria acervulina*	(Tsinas et al., 2011)
Moringa oleifera leaves acetone extracts	Broilers natural infection with mixed species of *Eimeria*	1,2,3,4 and 5g/Kg	Decrease oocyte shedding in dose-dependent manner	(Ola-Fadunsin and Ademola, 2013)
Moringa oleifera ethanolic extract	Boilers infected with *Eimeria spp*.	200 and 400ppm	reduced mortality and improved post-mortem lesions	(Banna H. A, 2016)
Neem aqueous leaf extracts	Broiler chickens were experimentally infected with *Eimeria* oocytes	800 mg/Kg of body weight	Inhibit the oocyte shedding up to 87.44%	(Onyiche et al., 2021)
Neem leaves methanolic extract	Japanese quails infected with *Eimeria tenella*	130 mg/L and 190mg/L	Decrease mortality, oocyte shedding and lesion score and improve intestinal histology	(Ishaq et al., 2022)
Neem leaves an aqueous extract	Pigeons infected with *Eimeria spp*.	2 ml/L drinking water	Reduction of oocysts shedding	(Qudoos et al., 2020)

Purple coneflower Root powder	Broilers infected with coccidia	0.1% and 0.5% in feed	Prophylactic use prevented the decrease in body weight and development of gross lesions	(Allen, 2003)
Purple coneflower	Broilers infected with mixed *Eimeria spp. (Eimeria necatrix Eimeria tenella, Eimeria brunetti and Eimeria maxima)*	2% Extract	Improved the performance and showed anticoccidial effects	(Ghafouri et al., 2023)
Peppermint oil	Broilers infected with *Eimeria tenella, Eimeria acervulina, Eimeria praecox, Eimeria brunetti*, *Eimeria necatrix, Eimeria maxima Eimeria hagani and Eimeria miva*ti	0.69 ml per Kg of BW peppermint oil in drinking water	FCR improved significantly with a decrease seen in oocyst numbers, scores of intestinal lesions and mortality.	(Barbour et al., 2015)
Peppermint powder	Broilers infected with *Eimeria tenella*	5 g/kg (0.5%) peppermint powder or 10 g/kg (1%) peppermint powder	Prevent the decrease in weight gain and improve intestine integrity	(Hussein, 2021)
Thyme	Pigeons infected with *Eimeria labbeana*	40 mg per Kg of BW thymol within feed for a period of about ten days.	BW improved, the impact of clinical signs decreased, and the oocysts count lowered.	(Arafa et al., 2020)

Bacterial Diseases

Cinnamon oil can inhibit the growth as well as expression of virulence genes of different bacterial pathogens of the including: *Ornithobacterium rhinotracheale adk* gene, *Pasteurella multocida ptfA* gene ,*Staphylococcus aureus sed* gene, *Mycoplasma gallisepticum Mgc2* gene, *Escherichia coli stx1* gene and *Avibacterium paragallinarum HPG-2* gene (Erfan and Marouf, 2019). Garlic (Jimoh et al., 2013), peppermint (Sorour et al., 2021), and coriander seed powder (Taha et al., 2019), diminishes the colony-forming units of the *Clostridium perferinges*. Garlic (Rahimi et al., 2010; Taha et al., 2019) ginger (Dieumou et al., 2009; Elmowalid et al., 2019), thyme (Rahimi et al., 2010), coneflower (Rahimi et al., 2010), peppermint (Veselin et al., 2021), coriander seed powder (Taha et al., 2019), moringa leaf extract (Allam et al., 2016), neem leaf extract (Sarker and Akhter, 2019; Ali et al., 2021), aloe vera gel in guinea fowls (Adzitey et al., 2019), cinnamon extract (Tabatabaei et al., 2015; Radwan et al., 2016) diminished the colony-forming units of the bacteria *E. coli*.

Garlic, ginger (Dieumou et al., 2009; Purwanti et al., 2019), thyme oil (Ahmed et al., 2014), moringa leaf extract (Allam et al., 2016), the combination of ginger and moringa flour in layers (Novalina et al., 2022), neem leaf extract (Sarker and Akhter, 2019; Ali et al., 2021), turmeric alone or in combination with garlic (Purwanti et al., 2019), aloe vera gel in guinea fowl (Adzitey et al., 2019), oregano extract combination with organic acids (Machado et al., 2014) or its essential oil (Xu et al., 2022), cinnamon extract (Radwan et al., 2016) diminished the colony-forming units of the bacteria *Salmonella* (

Garlic (Ahmed et al., 2017), garlic powder (Haq et al., 1999; Pourali et al., 2010; Eid and Iraqi, 2014), turmeric powder or turmeric and thyme powder mixture (Fallah and Mirzaei, 2016), oregano oil (Abdel-Hafez and Mohamed, 2016; Abdulkadhim et al., 2022; Alazzawi and Khammas, 2022), combination of peppermint and eucalyptus oils (Barbour et al., 2010; Awaad et al., 2016) and thyme powder (Fallah and Mirzaei, 2016) show antiviral activities against *Avian influenza virus*. Garlic juice (Al-Shwilly, 2017), garlic powder (Haq et al., 1999; Pourali et al., 2010; Eid and Iraqi, 2014), aloe vera gel (Elaiyaraja et al., 2016), turmeric (Tamam et al., 2010; Shihab, 2017), moringa powder (Mousa et al., 2017; Tolba et al., 2022) and neem leaves (Jawad et al., 2013) improve antibody titer against the *Infectious bronchitis virus* (Table 4). Garlic decreased the signs and symptoms of *Chicken infectious anemia virus* in the affected birds (Abdulkareem et al., 2023). Combination of cinnamaldehyde and glycerol monolaurate and moringa leaf extract (Khan et al., 2022) against the *Infectious bronchitis virus* inhibited the infection (Zhang et al., 2022b).

Table *3*).

Neem leaf extract diminished the colony-forming units of the bacteria *Pasterurella multocida* (Ali et al., 2021). Garlic, ginger reduced the colony-forming units of the bacteria *Shigella* and *Staphylococcci* (Dieumou et al., 2009).

Viral Diseases

Garlic oil, bulb extract from garlic, garlic aqueous extract (Arify et al., 2018; Harazem et al., 2019; Hizam et al., 2019; Doostmohammadian et al., 2020), garlic paste (Hanieh et al., 2010; Chitwan, 2017), garlic juice (Al-Shwilly, 2017), garlic powder (Haq et al., 1999; Pourali et al., 2010; Eid and Iraqi, 2014), cinnamon oil or powder (Abdel-Hameed et al., 2017), aloe vera extract or gel (Ojiezeh and Ophori, 2015; Dziewulska et al., 2018; Islam et al., 2020), turmeric (Tamam et al., 2010; Shihab, 2017; Shah et al., 2021), Turmeric powder or turmeric and thyme powder mixture (Fallah and Mirzaei, 2016),

oregano oil (Abdel-Hafez and Mohamed, 2016; Abdulkadhim et al., 2022; Alazzawi and Khammas, 2022), ginger (Al-Bawi and Rabee, 2020; Untari et al., 2022), moringa leaf extract (Mousa et al., 2017; Tolba et al., 2022), moringa powder (Mousa et al., 2017; Tolba et al., 2022), Moringa leaf meal (Rao et al., 2018), Moringa leaf extract (Khan et al., 2022), Neem leaves (Jawad et al., 2013), Neem aqueous extract supplementation alone or in combination with garlic (Garba et al., 2013), methanolic neem leaf extract (Elbasuni et al., 2023), combination of peppermint and eucalyptus oils (Barbour et al., 2010; Awaad et al., 2016), coneflower (Jouzi et al., 2014) and thyme powder (Fallah and Mirzaei, 2016) supplementation improves the antibody titers against the *Newcastle disease virus*.

Garlic (Ahmed et al., 2017), garlic powder (Haq et al., 1999; Pourali et al., 2010; Eid and Iraqi, 2014), turmeric powder or turmeric and thyme powder mixture (Fallah and Mirzaei, 2016), oregano oil (Abdel-Hafez and Mohamed, 2016; Abdulkadhim et al., 2022; Alazzawi and Khammas, 2022), combination of peppermint and eucalyptus oils (Barbour et al., 2010; Awaad et al., 2016) and thyme powder (Fallah and Mirzaei, 2016) show antiviral activities against *Avian influenza virus*. Garlic juice (Al-Shwilly, 2017), garlic powder (Haq et al., 1999; Pourali et al., 2010; Eid and Iraqi, 2014), aloe vera gel (Elaiyaraja et al., 2016), turmeric (Tamam et al., 2010; Shihab, 2017), moringa powder (Mousa et al., 2017; Tolba et al., 2022) and neem leaves (Jawad et al., 2013) improve antibody titer against the *Infectious bronchitis virus* (Table 4). Garlic decreased the signs and symptoms of *Chicken infectious anemia virus* in the affected birds (Abdulkareem et al., 2023). Combination of cinnamaldehyde and glycerol monolaurate and moringa leaf extract (Khan et al., 2022) against the *Infectious bronchitis virus* inhibited the infection (Zhang et al., 2022b).

Table 3: Effect of different phytobiotics on the bacterial infections of poultry

Phytobiotic	Specimen	Pathogen	Dose	Effect	Reference
Garlic	Broilers	*Clostridium perferinges* causing necrotic enteritis	0.5, 1.0, 1.5, 2.0 and 2.5 g/Kg	Bacterial colonies decreased but the effect was most significant at 1 g/Kg	(Jimoh et al., 2013)
Thyme	Broilers	*Escherichia coli*	0.1%	*E. coli* colony forming units decreased in digesta of ileum/cecum	(Rahimi et al., 2010)
Coneflower	Broilers	*Escherichia coli*	0.1%	*E. coli* colony forming units decreased in digesta of ileum/cecum	(Rahimi et al., 2010)
Garlic	Broilers	*Escherichia coli*	0.1%	Decrease the load of *E. coli* in the digesta of ileum/cecum	(Rahimi et al., 2010)
Peppermint powder	Broilers	*Escherichia coli*	0.2%, 0.4%, 0.6%	The levels of *E. coli* decreased at 0.4% or 0.6%	(Veselin et al., 2021)
Peppermint oil	Broilers	*Clostridium perferinges*	15% oil/Water	Reduced the intensity of necrotic enteritis and decreased count of *Clostridium perferinges*	(Sorour et al., 2021)
Thyme oil	Broilers	*Salmonella typhimurium*	2ml/kg in drinking water	Enhanced birds' immunity, thereby decreasing the salmonella infection	(Ahmed et al., 2014)
Coriander seed powder	Broilers	*Escherichia coli* *Clostridium perferinges*	0.1%, 0.2%, 0.4%	Decreased the bacterial counts	(Taha et al., 2019)
Ginger	Broilers	*E. coli; Salmonella; Shigella; Staphylococci*	10 mg per kg per day 20 mg per kg per day 40 mg per kg per day	Colony-forming units of these bacteria decreased	(Dieumou et al., 2009)
Garlic	Broilers	*E. coli; Salmonella; Shigella; Staphylococci*	10 mg per kg per day 20 mg per kg per day 40 mg per kg per day	Colony-forming units of these bacteria decreased	(Dieumou et al., 2009)
Garlic extract	Broiler chicks	*E. coli 078* (Multi-drug resistant)	10-15%	Garlic extract cleared the *E. coli 078* from broilers	(Elmowalid et al., 2019)
Ginger extract	Broilers chicks	*E. coli 078* (Multi-drug resistant)	15 g/kg diet daily for 21 days	Ginger extract cleared the *E. coli 078* from broilers	(Elmowalid et al., 2019)
Moringa leaf extract	Broilers	*E. coli* *Salmonella species*	200 mg/Kgm but in drinking water for 30 days consecutively	Bacterial growth was inhibited	(Allam et al., 2016)
Moringa flour with Ginger flour combination	Layers	*E. coli* *Salmonella species* *Lactic acid bacteria*	0.25% + 0.25% 0.50% + 0.50% 0.75% + 0.75%	A decrease in the number of all the bacteria was observed at 0.75% concentration.	(Novalina et al., 2022)

Neem leaf extract	In-vitro	Multi-drug resistant disease-causing bacteria of birds *Pasteruella multocida, Salmonella pullorum, Salmonella gallinarum, and E. coli*	1ml	Neem leaf extract killed all the pathogenic bacteria of poultry	(Ali et al., 2021)
Neem leaf extract	Broilers	*E. coli; Salmonella typhimurium*	1%, 1.5%, 2%, 2.5%	The growth of *E. coli* and *Salmonella typhimurium* was inhibited by neem leaf extract	(Sarker and Akhter, 2019)
Cinnamon oil	In-vitro	*Staphylococcus aureus; E coli; Pasteruella multocida; Avibacterium paragallinarum*	10 µg/mL	Inhibit the growth of bacteria in laboratory settings	(Erfan and Marouf, 2019)
Cinnamon extract	Broilers	*E. coli*	100 or 200mg/ kg of food	Reduce inflammation in liver	(Tabatabaei et al., 2015)
Cinnamon oil	Broilers	*E. coli; Salmonella* (multi-drug resistant)	2%, 3%	Inhibit the growth of Salmonella and E. coli.	(Radwan et al., 2016)
Oregano extract and organic acids blend	Broiler breeders chicks	*Salmonella Enteritidis*	0.2% (feed) 0.08% (drinking water) 0.2% + 0.08% (feed+ drinking water)	Supplementation in water decreases the disease and eliminate the pathogen but supplementation in feed only reduced the infection but did not eliminate the pathogen	(Machado et al., 2014)
Oregano essential oil	Chicken breeders	*Salmonella pullorum* *Salmonella gallinarum*	200 (preventive dose) and 400 (treatment dose) µL/L oregano essential oil in drinking water	Decrease the infection	(Xu et al., 2022)
Aloe vera gel	Guinea fowls	*E. coli* *Salmonella enterica*	50, 100 and 200 mg/ml	Decreased the bacterial growth, exhibiting antibacterial ability	(Adzitey et al., 2019)
Turmeric Extract	Broiler	*Salmonella pullorum*	2.5%	Broilers became resistant to the salmonella infection.	(Purwanti et al., 2019)
Garlic Extract	Broiler	*Salmonella pullorum*	2%	Broilers became resistant to the salmonella infection.	(Purwanti et al., 2019)
Turmeric and garlic extract mixture	Broiler	*Salmonella pullorum*	2.5%	Broilers became resistant to salmonella infection	(Purwanti et al., 2019)
Turmeric	Broilers	*Listeria sp., Salmonella sp., E. coli, Shigella sp.,* and *Staphylococcus aureus*	0.25%, 0.5%, 1%	Levels of all bacteria were reduced	(Ahmed et al., 2018)
Turmeric extract	Chickens	*Mycoplasma gallisepticum*	0.4 mg/Kg BW extract	The clinical signs of the disease were diminished with decreased pathological changes.	(Handharyani et al., 2020)
Garlic extract	Chickens	*Mycoplasma gallisepticum*	0.4 mg/Kg BW extract	The clinical signs of the disease were diminished with decreased pathological changes.	(Handharyani et al., 2020)
Turmeric and garlic extract in combination with zedoary	Chickens	Mycoplasma gallisepticum	2 mg/Kg BW Nanoparticle and extract combination	Efficient in inhibiting *Mycoplasma gallisepticum*.	(Handharyani et al., 2020)

Turmeric rhizome powder extracts	In-vitro	*Escherichia coli* and *Salmonella enteritis*	75 µl	Inhibition of *E. coli* and *Salmonella enteritidis* (Patil et al., 2019)

Fungal Diseases

Supplementation of, garlic in broilers (Ancsin et al., 2013), oregano oil in Japanese quails (Abdelrazek, 2015), ginger (Rani et al., 2009; H and A, 2015), ginger capsules in pekin ducks (Abu El-Ela et al., 2019), the combination of ginger, garlic, and turmeric (Salako et al., 2022), cinnamon powder in quail (Gadu, 2023), trans cinnamaldehyde in chicken embryos (Yin, 2017; Yin et al., 2017), aloe vera in layers (Seifi et al., 2022) (Mohajer et al., 2021; Sadighara et al., 2021), turmeric extract (Gholami-Ahangaran et al., 2016), turmeric powder (Amminikutty et al., 2023) Abd El-Ghany et al. (2013), ethanolic extract of turmeric (Rangsaz and Ahangaran, 2011), turmeric in ducklings (Ayoub et al., 2011), oregano oil in Japanese quails (Abdelrazek, 2015; Shalaby and El-Tawil, 2016), thyme oil (Manafi et al., 2014; Fawaz et al., 2022) and moringa in layers Suganthi Rajendran et al. (2012); (Saleemi et al., 2023) proved beneficial in broilers intoxicated with T-2 toxin, ochratoxin, B-1 toxin and ameliorated the aflatoxin-caused immune damage (Table 5).

Oregano (Sadri, 2008) and thyme (Abdel Fatah et al., 2020) decreased the growth of *Candida albicans* (Abdel Fatah et al., 2020).

Table 4: Effect of different phytobiotics on the viral infections of poultry

Phytobiotic	Specimen	Virus	Dose	Effect	Reference
Garlic oil	In-ovo (embryonated chicken egg)	*Newcastle disease (ND) virus*	50 µg/mL	Garlic, along with ND virus inoculation into the egg, showed after incubation that the disease-causing effect of the virus was decreased.	(Hizam et al., 2019)
Garlic bulb extract	ND suspected embryonated chicken eggs	*ND virus*	25, 50, 100 and 200 mg/ml	The garlic extract reduced the egg infective dose at 50%, hemorrhages subcutaneously and the virus count in hemagglutination test.	(Harazem et al., 2019)
Aqueous garlic extract	Embryonated chickens eggs	*ND virus velogenic strain*	10 mg per milliliter 100 mg per milliliter	At 100 milligram per milliliter, extract has more efficient effects against the virus.	(Arify et al., 2018)
Aqueous garlic extract	Embryonated chickens eggs	*ND virus velogenic strain*	0.5, 1, 2, and 4 mg/mL doses	The titers of antibodies against the velogenic strain of ND were more significant in the group treated with garlic extract.	(Doostmohammadian et al., 2020)
Garlic extract	Embryonated chickens eggs	*H9N2* strain of *Avian Influenza virus*	5%, 10%, 15%, 20% and 25%	Garlic extract at the dose rate of 15% exhibited antiviral potentials against H9N2.	(Ahmed et al., 2017)
Garlic paste	Broilers vaccinated against F strain of ND virus	*ND virus*	0.2%, 0.4%, 0.6% and 0.8% in drinking water	The antibody titer increased upon garlic inclusion at the dose rate of 0.4% and 0.6%.	(Chitwan, 2017)
Garlic juice	Broilers are vaccinated against Infectious bursal disease (IBD) and ND virus	*ND virus* *IBD virus*	0.5, 1.0 and 1.50 mL/L	The titer of antibodies against the two viral diseases (IBD and ND) was increased upon garlic juice supplementation at 1 or 1.5 ml/L.	(Al-Shwilly, 2017)
Garlic	White leghorn layers	*Newcastle disease virus*	10 grams per kg 30 grams per kg	At 10 grams per kg, the garlic supplementation produced more antibodies against ND	(Hanieh et al., 2010)
Garlic powder	Broiler chicks are vaccinated against Avian influenza and ND	*ND* *AI*	100, 150 and 200 g/t	Increased titers of antibodies were observed against AI and ND	(Eid and Iraqi, 2014)

Garlic powder	Broilers	*IBD* *ND*	20 g/kg	Antibody titers against both viruses were seen higher in the supplemented group	(Haq et al., 1999)
Garlic powder	Broilers	*ND*	0.2%–1.0%	Antibody titers against ND virus were increased in the supplemented group	(Pourali et al., 2010)
Garlic, turmeric, coriander, nilavembu and fenugreek	Embryonated chicken eggs	*ND virus*	500g grams	The number of titers of the virus was decreased in the herbal mixture treated group	(Priya et al., 2022)
The herbal mixture containing Garlic, onion, apple cider vinegar	Broilers	*Chicken infectious anemia virus*	2.5%, 5%, and 7.5%	The herbal mixture reduced the negative effects of the virus on broilers	(Abdulkareem et al., 2023)
Cinnamon oil	Chickens	*ND virus*	0.1%, 0.3%	Enhanced the immunity of ND virus-challenged birds, thereby exhibiting antiviral potential and increasing the survival rate of chickens	(Abdel-Hameed et al., 2017)
Cinnamon powder	Chickens	*ND virus*	1%, 3%	Enhanced the immunity of ND virus-challenged birds, thereby exhibiting antiviral potential and increasing the survival rate of chickens	(Abdel-Hameed et al., 2017)
Cinnamon, thyme and turmeric	Broilers	*ND virus*	5 grams per liter (infusion)	Immunity to the vaccine for the ND virus has improved	(Sadeghi et al., 2012)
Cinnamaldehyde and glycerol monolaurate	Broiler chicks	*Infectious Bronchitis virus*	1.5 mL/L water	Impeded the infectious bronchitis virus infection	(Zhang et al., 2022b)
Aloe vera gel	Broilers	*ND virus*	5 ml/L, 10ml/L	Enhancement in the titer of antibodies against ND virus.	(Islam et al., 2020)
Aloe vera extract	Broilers	*ND virus*	50 mg, 100 mg, 150 mg	Decrease the intensity of the disease	(Ojiezeh and Ophori, 2015)
Aloe vera extract	Pigeons	*pigeon paramyxovirus type 1*	300 or 500 mg/kg	An improvement in immunity of the pigeons infected with the virus was seen at higher doses	(Dziewulska et al., 2018)
Aloe vera gel extract	White leghorn chicks	*IIBD virus*	3% aloe vera gel in drinking water	An enhancement in non-specific immune response was observed.	(Elaiyaraja et al., 2016)
Aloe vera extract	Broilers	*ND virus*	50 mg, 100 mg and 150 mg	Immunity against the viral disease was not significant.	(Ojiezeh and Eghafona, 2015)
Turmeric	Broilers	*IBD* *ND*	0.2% 0.4% 0.6%	An improvement in titers of antibodies was observed against viral diseases, particularly at 0.4%.	(Shihab, 2017)
Turmeric	Chicks	*ND virus*	0.5% 1%	40% protection was attained against the ND virus upon 0.5% turmeric supplementation Meanwhile, about 65% protection was obtained from 1% turmeric supplementation.	(Tamam et al., 2010)
Turmeric powder	Broilers	*ND* *AI*	5 g/kg	An enhancement in antibody titers was observed.	(Fallah and Mirzaei, 2016)

Turmeric powder and Thyme powder	Broilers	*ND* *AI*	2.5 grams per kg of turmeric powder + 2.5 grams per kg of thyme powder	Increase in antibody titers	(Fallah and Mirzaei, 2016)
Thyme powder	Broilers	*ND* *AI*	5 g/kg	An enhancement in antibody titers was observed.	(Fallah and Mirzaei, 2016)
Turmeric	Embryonated chicken egg	*Influenza virus (H9N2)*	0.2 mg/0.2 ml	The mortality of embryos inoculated with the virus was reduced, thereby exhibiting the antiviral properties	(Shah et al., 2021)
Oregano essential oil	Broilers vaccinated with ND vaccine	*ND virus*	50 mL/1000L of drinking water	An efficient immunological response was seen in the vaccinated-treated birds	(Abdulkadhim et al., 2022)
Oregano oil	Broilers	*ND virus*	1 ml/L	Enhanced the immunity of ND virus-challenged broilers to about 90%.	(Alazzawi and Khammas, 2022)
Oregano oil	Broilers	*ND* *AI*	1.5ml/L	An increase in the antibody level against the Avian Influenza and Newcastle disease viruses	(Abdel-Hafez and Mohamed, 2016)
Red ginger powder, ethanolic extract, essential oil	Broilers	*ND virus*	1% (powder in feed, extract, and oil in drinking water)	The high antibody titers against the virus were observed mainly in the ginger powder group	(Untari et al., 2022)
Ginger	Broilers	*ND virus*	2g/kg, 4g/kg and 6g/kg	Ginger supplementation at 4 g/kg or 6 g/kg showed increased Haemagglutination Inhibition antibody titers against the ND virus	(Al-Bawi and Rabee, 2020)
Moringa leaf extract	Broilers	*ND virus*	200 mg/kg	The supplemented group had high Haemagglutination Inhibition titers against ND virus infection	(Tolba et al., 2022)
Moringa powder	Broilers	*IBD* *ND*	1.5%	Titers of antibodies were increased in the supplemented group.	(Mousa et al., 2017)
Moringa leaf meal	Broilers	*ND*	500 and 1000 mg/kg	Titers of antibodies were increased in the supplemented group	(Rao et al., 2018)
Moringa leaf extract	Broilers	*IB* *ND*	60, 90 120 ml/L of drinking water	Titers of antibodies against both diseases were increased in the supplemented group, particularly at the concentration of 120ml/L	(Khan et al., 2022)
Neem leaves	Broilers	*IBD* *ND*	2,4,6 g/kg	Titers of antibodies were raised against both diseases in the supplemented group	(Jawad et al., 2013)
Neem aqueous extract	Broilers	*ND*	5 g	Antibody titers against ND protected the birds	(Garba et al., 2013)
Neem and Garlic Aqueous extract	Broilers	*ND*	2.5 g + 2.5 9	Antibody titers against ND protected the birds.	(Garba et al., 2013)
Methanolic neem leaf extract	Broilers	*ND*	500 and 1000 µg/kg BW in drinking water for 5 days	The neem leaf extract supplementation, particularly at a high dosage of 1000 µg/kg, reduced the number of diseased and dead birds with decreased lesions.	(Elbasuni et al., 2023)
Coneflower	Broilers	*ND*	2%	Increase the antibody titers against Newcastle disease	(Jouzi et al., 2014)

Peppermint and eucalyptus essential oils blend	Broilers	*Velogenic strain of NDV*	0.25 ml/l	A decrease in mortality was seen in the infected and treated groups with a higher antibody titer against the virus	(Awaad et al., 2016)
Peppermint and eucalyptus essential oils blend	Embryonated chicken eggs	*ND* *AI*	0.1 ml/chick embryo	The chicks survived the infection from both viruses to about 100% in the treated groups. However, the AIV is more susceptible to the blend.	(Barbour et al., 2010)
Thyme extract	Broilers	*AI*	0.1%, 0.15% and 0.2%	Supplementation at 0.2% showed higher and specific titers of antibodies against the AI virus	(Talazadeh and Mayahi, 2016)
Thyme essence	Broilers	*AI, IBD, IB, ND*	1 ml, 1.5 ml, 2 ml	No significant change in antibody titers was observed at any dose	(Kalantar et al., 2015)

Table 5: Effect of different phytobiotics on the fungal infections of poultry

Phytobiotic	Study Specimen	Dose	Effect	Reference
Garlic extract and garlic chips	Feed	3% concentration	Inhibition of the growth of Aspergillus parasiticus, Candida albicans, and Aspergillus fumigatus Extract was more effective as compared to the chips.	(Prasad and Sharma, 1981)
Garlic oil	Broilers affected with T2 toxin	0.3 g/Kg, 1.5 g/Kg	Mitigate the adverse effects of T2 toxin in broilers at a lower dose of about 0.3 g/Kg	(Ancsin et al., 2013)
Ginger	White Pekin ducklings affected with aflatoxin	250 mg/Kg Ginger capsules	Amelioration in the adverse effects of aflatoxicosis in ducks when ginger was supplemented in the diet	(Abu El-Ela et al., 2019)
Ginger	Broilers intoxicated with aflatoxin	0.75 g/Kg ration	Returned the physiological, biochemical values to normal, with improved effects on the histopathology of aflatoxin-infected broilers.	(H and A, 2015)
Ginger (Dried and powdered rhizome shade)	Broiler chicks (male) infected with ochratoxin or T2 toxin	0.5%	Plays a protective role against the oxidative stress caused by ochratoxin or T2	(Rani et al., 2009)
Ginger, Garlic, Turmeric	Broilers infected with dietary aflatoxins	2 g/kg	There was an improvement in biochemical parameters, digestibility of nutrients, hematology, and growth performance upon the diet supplementation with ginger, garlic, and turmeric. These parameters were negatively affected by the aflatoxins.	(Salako et al., 2022)
Cinnamaldehyde	Feed	0.4%, 0.8%, 1.0%	*Aspergillus parasiticus* and *Aspergillus flavus* multiplication and growth were inhibited within feedstuff.	(Yin et al., 2015)
Cinnamon powder	Japanese quails (laying) affected with aflatoxins	10 mg/Kg	Cinnamon powder in the diet ameliorated the adverse effects of aflatoxins in quails.	(Gadu, 2023)
Trans cinnamaldehyde	Chickens infected with aflatoxins	0.75%	Hepatoxicity and decreased performance of birds induced by aflatoxins were improved by cinnamaldehyde supplementation.	(Yin, 2017)
Trans cinnamaldehyde	Chicken embryos with aflatoxin-induced toxicity	0.1%	Its supplementation decreased the toxicity in chicken embryos induced by aflatoxins.	(Yin et al., 2017)
Aloe vera	Layers affected with aflatoxins	100 ppm, 300 ppm	Aloe vera supplementation ameliorated the adverse effects of aflatoxins in layers and improved egg weight, shell thickness, and egg production.	(Seifi et al., 2022)
Aloe vera powder	Laying hens fed with aflatoxin B1	100 ppm, 300 ppm	The remnants of B1 aflatoxin within eggs of the layers supplemented with B1-aflatoxin and aloe vera were diminished, indicating a positive role of aloe vera in inhibiting aflatoxin growth.	(Mohajer et al., 2021)
Aloe vera powder	Broilers fed on aflatoxin B1	100 ppm	Diet supplementation with aloe vera reduced the adverse effects of aflatoxins. Lower amounts of toxin residue were found in breast muscle compared to the control group.	(Sadighara et al., 2021)

Aloe vera dry powder	Ducklings	1% 2-4%	1%: it only relieved the negative impact of aflatoxin on the weight gain in ducklings. 2-4%: it eliminated the adverse effects on weight gain of ducklings induced by aflatoxin	(Hunan, 2011)
Turmeric	Broilers exposed to aflatoxins	5 mg per kg of diet 25 mg per kg of diet	Turmeric ameliorated the negative impact of aflatoxins over liver and kidney roles in broilers	(Gholami-Ahangaran et al., 2016)
Turmeric powder	Aflatoxin B1 exposed Broilers	400 mg/Kg in feed	Adverse effects of aflatoxin were diminished upon turmeric supplementation.	(Amminikutty et al., 2023)
Ethanolic Turmeric extract	Broiler chickens with aflatoxicosis	0.05%	The performance of aflatoxin-affected broilers improved upon turmeric supplementation	(Rangsaz and Ahangaran, 2011)
Turmeric powder	Broilers affected with aflatoxin B1	80 mg/Kg	The adverse effects of aflatoxin B1 were reversed by turmeric powder used in the diet	(Abd El-Ghany et al., 2013)
Turmeric ground roots powder	ducklings	1%	Turmeric protects ducklings against aflatoxicosis	(Ayoub et al., 2011)
Oregano essential oil	Japanese quails (growing) affected with aflatoxins	200 mg/Kg 400 mg/Kg	Especially at the dose rate of about 400 mg/Kg, the oregano essential oil ameliorated the adverse effects in quails caused by aflatoxin B1	(Abdelrazek, 2015)
Oregano	Breeder chickens	0.1% 1 liter of pure oregano dissolved in 1000 liters of water)	The growth of the fungi *Candida albicans* was decreased (95-99.5%) by oregano	(Sadri, 2008)
Oregano oil	Japanese quails affected with aflatoxins	400 mg/ Kg	The immunosuppression caused by aflatoxins in Japanese quails was ameliorated by oregano oil via its antioxidant effect	(Shalaby and El-Tawil, 2016)
Thyme oil	Broilers affected with candidiasis	200 ml/Kg	The symptoms of candidiasis in broilers were reduced upon thyme oil supplementation in the diet	(Abdel Fatah et al., 2020)
Thyme oil	Broiler chickens	200 mg/Kg	The adverse effects of aflatoxin on the weight gain parameters of broilers were ameliorated upon thyme oil supplementation	(Fawaz et al., 2022)
Thyme ethanolic extract	Broilers infected with aflatoxinB1	500 ppm	The adverse effects caused by aflatoxin in feed were alleviated upon thyme inclusion in the diet	(Manafi et al., 2014)
Moringa	White leghorn layers (Male) affected with Aflatoxin B1	1%	The adverse effects of aflatoxin B1 on the hematology and serum enzymes were reduced by adding Moringa to a contaminated diet	(Saleemi et al., 2023)
Moringa leaves	Broilers infected with aflatoxin B1	3 mg/kg	Lessened the aflatoxin-induced adverse effects on the broilers' antioxidative status and biochemical parameters.	(Suganthi Rajendran et al., 2012)

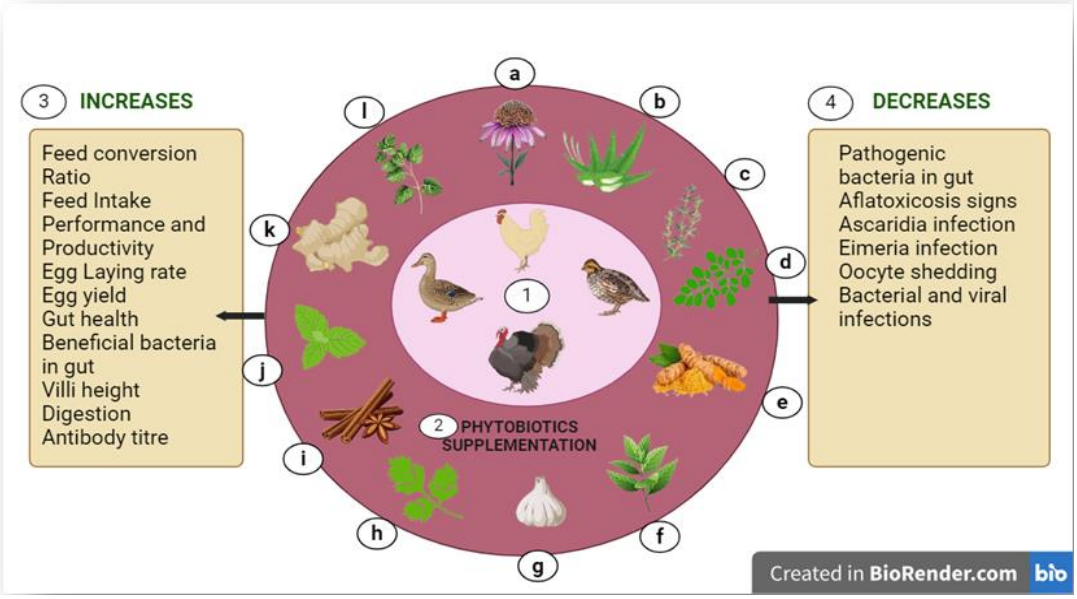

Fig. 1: Schematic diagram showing multiple effects of Phytobiotics used in poultry.
[1,2] In different species of poultry (chickens, ducks, quails, and turkeys), supplementation of various Phytobiotics [(a] coneflower, [b] aloe vera, [c] thyme, [d] moringa, [e] turmeric, [f] neem, [g] garlic, [h] coriander, [I] cinnamon, [j] peppermint, [k] ginger, [l] oregano) [3] increases feed conversion ratio, feed intake, overall performance and productivity, egg laying rate, egg yield, gut health, beneficial gut bacteria, villi height, digestion and antibody titers. [4] While it decreases gut pathogenic bacteria, aflatoxicosis, eimeria, and Ascaridia infections, bacterial and viral diseases, and oocyte shedding.

Conclusion

The beneficial effects of the different phytobiotics are described in the Fig. 1. In a nutshell, phytogenic feed additives usage, as substitutes for the antibiotic performance enhancers within poultry production represents significant progress. As described above, phytobiotics have demonstrated considerable potential in bolstering poultry gut health by increasing villi height and promoting beneficial bacterial populations like Lactobacillus while decreasing pathogenic E. coli and Salmonella. Their different forms and doses have also led to notable increases in growth performance without the residual effects of antibiotics. The bioactive compounds present within the phytobiotics demonstrate various properties such as antiviral, antibacterial, antifungal, and antiparasitic effects (Fig. 1), thereby significant contribution to poultry health maintenance and disease prevention. Future research endeavors should explore synergistic combinations of phytobiotics to modulate the poultry microbiome and further augment overall poultry health.

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