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Review Article

A NATURAL FEED ADDITIVE PHYTOBIOTIC, POMEGRANATE (*PUNICA GRANATUM* L.), AND THE HEALTH STATUS OF POULTRY

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ABSTRACT

The addition of antibiotic growth promotors in poultry diets results in a development of resistant bacterial strains and accumulation of drug residues in the meat and eggs. The new trend in poultry industry is the dietary addition of natural feed additives including phytobiotics. Pomegranate *(Punica granatum* L.*)* is a natural cheap feed source that has been extensively used in the livestock production. In poultry production system, pomegranate by-products such as peel powder or extract, seed oil, or juice showed high nutritional values, several health benefits, and good economic profits. Pomegranate displays a growth promoting effect and an enhancement of carcass traits of broilers, along with an improvement of the egg production traits parameters. Moreover, dietary pomegranate by-products showed a potential antioxidant and antimicrobial effects on the treated birds. Modulation of both humeral and cell mediated immune response, hypo-lipidemia, as well as enhancement of liver functions have been proved following dietary treatment with different pomegranate by-products. Therefore, this review article was designed to present the different effects of dietary pomegranate by-products on the production indices of broilers and layers, the antioxidant, antimicrobial, and immune status, as well as the blood parameters.

Key words: antioxidant, chicken, immunity, performance, *Punica granatum* L.

INTRODUCTION

The emergence of anti-microbial growth promoter's resistance becomes an important threat that affects poultry industry world-wide. Besides, accumulation of drug residues in the livestock edible tissues has an adverse effect on the human's health. Accordingly, the international authorities banned the use of growth promotor's antibiotics since 2006. Nowadays, there is a great demand for searching natural feed additives alternatives. Dietary supplementations of poultry with probiotics, prebiotics, parabiotics, postbiotics, microalgae, and immunoglobulins preparations have been developed to improve the feed utilization efficiency and to maintain the general health conditions (1, 2, 3, 4, 5). The phytobiotics include a large variety of plant-derived products such as essential oils, extracts, herbs, and oleoresin which have positive impacts on the host's productivity and the final product quality (6, 7, 8). Moreover, several types of phytobiotics have been effectively used in poultry industry as growth promoters, antimicrobials, and immuno-modulators (9, 10, 11, 12).

Pomegranate with a scientific Latin name (*Punica granatum* L., family Punicaceae) is commonly called in Latin as ''ponus'' and ''granatus''. It is a native fruit crop that has been widely used as one of the eldest known drug medicines. It has been mentioned in the ancient Egyptian herbs papyrus written in about 1550 BC (13). Moreover, the medicinal properties of pomegranate have been reported in China, Greece, India, Iran, South Africa, and Mediterranean countries such as Turkey, Tunisia,

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Morocco, and Spain (14, 15). Pomegranate has long been considered as a fruit with several health benefits (16). This fruit contains internal membranes which represent about 26-30% of its weight (17). It has been found that the edible parts of the plant involve 78% juice and 22% by-products. The by-products such as seed, husk, peel, etc. have several bioactive polyphenols compounds (18). The pomegranate peel (PP) by-product is rich in numerous high molecular weights polyphenols phytobiotics including phenolic acids (gallic, ellagic, caffeic, citric, tartaric, malic, and ascorbic), flavonoid (flavonols as cathecin, epicatechin, and galloctechin as well as anthocyanins), hydrolyzable tannin (ellagitannins, punicalin, punicalagin, pedunculagin, and gallotannins), and condensed tannins (19). Polyunsaturated fatty acids, vitamins, and minerals are other components of pomegranate (20). The components of pomegranate seed oil are cis-9, trans-11, cis-13 octadecatrienoic (punicic) acid, and one conjugated linolenic acid (21). Therefore, pomegranate displayed numerus nutritional values and health-raising effects which can be used as a cheap alternative feed source in poultry diets (22, 23).

Besides, pomegranate and its by-product showed antioxidant, antimicrobial, anti-carcinogenic, anti-inflammatory, and growth promoting effects (24, 25, 26). In poultry, the PP, PP powder (PPP), PP extract (PPE), and pomace of PP have a great influence on the growth performance parameters. The improved production indices of broilers and layers (27, 28) as well as the enhanced immune response (22) of birds fed on pomegranate-derived additives have been described. The biological activities of PP as antibacterial and antioxidant have been investigated (29, 30, 31). Besides, the protective effect of PPP against pulmonary hypertension and mortality of broiler chickens has been demonstrated (32, 33). It is interesting to note that PPE showed an *in-vitro* antiviral potential, as its polyphenols content could prevent the entry of SARS-CoV-2 into the host cells (34).

According to the above mentioned, this review article aimed to describe the different effects of dietary pomegranate by-products on the production indices of broilers and layers, the antioxidant, antimicrobial, and immune status, as well as the blood parameters modifications.

PRODUCTION INDICES

Broilers

The improvement of the feed intake (FI), body weight (BW), BW gain (BWG), feed efficiency, feed conversion ratio (FCR), and carcass and organ parameters have been documented in birds fed on PPP and PPE including broiler chickens (35, 36, 37, 38, 39). Table 1 shows the different effects of PPP on the production indices of poultry (40, 41, 42, 43, 44, 45, 46, 47).

The potential growth-enhancement effect of pomegranate may be owed to the presence of essential oils which inhibit the pathogenic intestinal bacteria, enhance the intestinal flora, improve the nutrients digestion and energy utilization, and promote growth parameters. Moreover, PPP and PPE have different types of alkaloids such as flavonoids, glycosides, and tannins that improve the digestion through decreasing the intestinal motility and thus fluid accumulation (48). It has been reported that PP-containing pro-anthocyanidin could increase the pancreatic and the intestinal digestible enzymes, enhance the nutrient's absorption, and consequently prevent the harmful effect of free radicals on enterocytes (49). Furthermore, PPE is able to prevent the activity of pancreatic lipase and inhibits the intestinal fat absorption excreted in droppings (29). Addition of PPE of 2 mL/L dose in drinking water for broiler chickens increased the blood anti-radical activity and enhanced the intestinal microbial ecology via enhancing the lactic acid bacteria (50). The antioxidant and antimicrobial properties of *Punica granatum* fruit peel have a positive impact on the growth indices of birds (51). Saeed et al. (52) reported that *Punica granatum* L. by-product could modulate both the gut microbiota and immune function of broiler chickens and decrease the odorous gas emissions from droppings. Improvement of the villus length and villus length to villus depth ratio as well as increasing of the intestinal lactic acid bacteria have been found in broiler chickens and laying quails fed on PPE (50). The improvement in the nutrient's availability and intestinal absorption resulted in an enhancement of the bird's performance (44).

Table 1. The different effects of PPP on the production indices of poultry

Dose of PPP/diet	Species	Findings	Reference
15,000 mg/kg	Broiler chicken	No improvement of BW Decreased ascites-related mortality Decreased lipid oxidation of meat under refrigerated storage	(40)
5%, 10%, and 15%	Laying hens	High egg production No effect on FI, egg weight, egg mass, and FCR	(67)
0.5 and 1.0%	Broiler chicken	Decreased FI Improved FCR	(21)
Up to 2%		Enhance the quality of the breast and thigh muscles	
0.5 and 1.0%	Broiler chicken	Reduced the FI and FCR	(41)
0.01%	Broiler chicken	Improved FI, BWG, and carcass weight percentage	(35)
4.5-7.5%	Japanese laying quail	Increased egg production, egg weight, and egg mass No effect on the growth performance	(68)
0.02%	Broiler chicken	Impaired BWG and FI Improved quality index of breast muscles	(42)
2%	Broiler chicken	Decreased liver, gizzard, and edible giblet proportion Improved thigh muscles palatability	(60)
0.05%	Broiler chicken	Increased BW, BWG, and FCR	(29)
3 g/kg	Broiler chicken	Decreased growth performance parameters	(43)
1%	Japanese laying quail	No effect on egg production, specific gravity, and eggshell thickness	(69)
1% and 1.5%	Japanese quail	Improved carcass quality	(61)
250 and 500 mg/kg	Broiler chicken	No effect on BWG, FCR, and carcass traits	(44)
250, 450, and 650 mg/kg	Heat stressed broiler chicken	Increased BWG and FCR Decreased FI No effect on relative weights of carcass, breast, thigh, abdominal fat, liver, pancreas, gallbladder, heart, gizzard, bursa of Fabricius, and spleen Improved carcass quality during refrigerator storage	(38)
7.5 and 10 g/kg	Broiler chicken	Decreased FI Improved FCR Reduced heart weight and the right-to-total ventricular weight ratio	(33)
2 or 4 g/kg	Broiler chicken	Improved average final BW and daily BWG	(45)
4%	Laying hens	Increased egg production	(27)
6%	Japanese quails	Increased final BW and BWG Decreased total FI	(46)
0.04%	Heat-stressed laying quails	Improved egg quality	(70)
0.25, 0.50, 1.00, and 1.50%	Broiler chicken	Improved BW, BWG, FI, and FCR Increased weights of spleen, thymus glands, and bursa of Fabricious Reduced abdominal fat	(26)
5-10 gm	Broiler chicken	No effect on BW and FCR	(25)
8%	Broiler chicken	Decreased BWG, FI, FCR, and production index	(22)
8%	Broiler chicken	Decreased BWG and FI	(23)
4%	Broiler chicken	Improved gut morphology Improved meat quality	
0%, 5%, and 10%	Laying hens	No significant effect on BW, Haugh unit, egg breaking strength, and yolk color of eggs	(71)
2, 3, and 4 gm/kg	Broiler chicken	Improved BW and BWG No effect on FCR Improved all carcass characteristics, except gizzard and abdominal fat ratio were not affected	(47)

On the other side, PPP or PPE supplementation has no effect on growth parameters in broiler chickens (53, 54). This discrepancy may be attributed to the fact that high doses of polyphenols (polyphenolic hydroxyl groups) in pomegranate by-products can bind to the endogenous proteins (protein carbonyl groups) in the intestinal luminal tract, thus leading to reduction in protein and amino acids digestibility (55). Similarly, Goni et al. (56) demonstrated that polyphenol contents of PP diminished the growth performance in broilers. The previous studies have revealed that tannins in PP adversely affects the physiological functions of the body in terms of improper nitrogen balances, suppressed growth, reduced intestinal absorption of amino acids and sugars, diminished immune response, and improved protein catabolism (57). Tannins also could bind to cholesterol and bile salts, and so, reduce the fat digestibility. Additionally, tannins may interfere with protein and calcium digestibility (58), which consequently induce adverse influences on the growth and other traits. Besides, the high quantity of tannins and crude fiber in PP could decrease the gastrointestinal motility and then reduce the bird's growth performance (22). It has been found that digestive enzymes such as trypsin, lipase, and amylase could bound to tannins and reduce the digestibility of nutrients (59). High levels of dietary PPP (8%) decreased the intestinal crypt depth and the villi/crypts ratio in the intestine of broiler chickens (23).

Carcass traits

Table 1 reveals the different influences of PPP on the carcass and organs in broilers (60, 61). Previous studies revealed significant improvement of carcass traits following supplementation with PPP (37, 43, 45, 62). An increase in the proportion of muscles resulted in more profitability in the broiler's industry (63). A dietary supplementation of broiler chickens with PPP induced a positive effect on the antioxidant status and consequently the meat quality (62, 64). Szymczyk and Szczurek (65) indicated that increasing the levels of pomegranate seed oil in broiler chickens feed resulted in an increase in the polyunsaturated acids, a decrease in the monounsaturated acids proportions, as well as an increase in the proportion of conjugated linoleic acid of the breast muscles. The improved quality of breast muscles may be attributed to increasing the total phenol and flavonoid contents following dietary inoculation of PPE (37). In the same context, dietary addition of PPE up to 300 mg/kg significantly increased the phenolic content and antioxidant effect in the breast meat of broiler chickens (66).

In contrast, no improvement of the meat quality has been also reported after dietary supplementation with pomegranate by-product (22). Another study of Abdel Baset et al. (39) proved that broiler chickens fed on diets containing PPP showed reduced liver/carcass weight ratio.

Layers

The effects of PPP on the egg production parameters are shown in Table 1 (67, 68, 69, 70, 71). Most studies revealed an improvement in the production parameters of layer hens due to feeding on pomegranate (72). However, no effect of dietary supplementation with pomegranate by-products on the specific gravity and eggshell thickness of laying hens (71) and quails (69) has been reported. Similarly, Sharma et al. (73) did not find any effect of supplying layer hens with a blend of active ingredients from thyme, garlic, and pomegranate on the eggshell breaking strength. Kostogrys et al. (74) observed a dose-dependent increase in FI, egg production, and egg mass of layer hen's supplemented with pomegranate seed oil. This may be related to the antioxidant effect of pomegranate, or the improvement of intestinal enzymatic activity, and the consequent enhancement of digestibility and absorption of specific nutrients required for egg quantity and quality.

ANTIOXIDANT ACTIVITY

A dietary supplementation of broiler chickens with PPP induced different effects on the antioxidant status of poultry (Table 2). Antioxidants in PPP could improve the feed efficiency via reducing the oxidative damage, increasing the gastro-intestinal enzymatic activity, and therefore enhancing nutrient's digestibility and absorption (36). The potential antioxidant character of pomegranate by-products may be due to their rich contents of ellagitannins (75). The polyphenols compounds in pomegranate such as tannins, anthocyanins, ponica, laginine catechin, epicatechin, gallocatechin, gallic, ellagic, caffeic, ellagitannins, and gallotannins could enhance the antioxidant activity in broilers and layers (76, 77, 78). Ahmed et al. (21) demonstrated that dietary inoculation with pomegranate improved the protein and fatty acid profile, but reduced the thiobarbituric acid reactive substances values in breast meat of broilers. Following absorption of polyphenols-associated pomegranate, they bound by erythrocytes, which leads to an increase in the antioxidant blood capacity (79). Additionally, polyphenols and anthocyanins contents of PP could scavenge the hydroxyl and superoxide anion free radicals (43). The level of serum malondialdehyde (MDA) is an indication of lipid peroxidation and oxidative damage caused by reactive oxygen species (ROS). Also, catalase enzyme (CAT) inhibits the lipid peroxidation of hydrogen and peroxide toxicity. The antioxidant enzymes are able to neutralize the free radicals of different types of oxygen. The high concentration of CAT and superoxide dismutase (SOD) could improve the protection of cell membranes against oxidative stress and ROS (62). Pomegranate by-products could inhibit the peroxidation of lipid and induce over-expression of antioxidant genes including CAT and SOD. Dietary pomegranate could decrease the protein and DNA damage and possibly inhibit the ROS production (80), thus protecting the liver against oxidative stress and damage (44).

The variations in the antioxidant capacity of pomegranate depend on the type of its by-product (seed pulp, powder, extract, juice, etc.) and on the processing method (81). For instance, the presence of different amounts of phenolics which acts as hydrogen donors and reducing agents mediates the variation in pomegranate antioxidant activity (82). The results of Benchagra et al. (83) showed that PPP is rich in flavonoids and anthocyanin contents which have free radical scavenging and reducing power, β-carotene bleaching, and hydrogen peroxide scavenging activities. PPP has the ability to inhibit the conjugation and formation of diene and to reduce the α-tocopherol disappearance induced by cupper-sulfate-mediated low-density lipoproteins (LDL) peroxidation. In addition, PPE may modulate the activation of mitogen-activated protein kinase and nuclear factor kappa B in the 12-O-tetradecanoylphorbol13-acetate induced skin carcinogenesis model (84). PPE showed the highest removal activity of 2,2-diphenyl-1-picrylhydrazyl and 2,2′-azinobis [3-ethylbenzothiazoline-6-sulfonic acid] when compared to some other antioxidant fruits (85).

ANTIMICROBIAL ACTIVITY

The various antimicrobial effects of PPP are illustrated in Table 2 (86, 87). Different *in-vitro* reports have shown the antibacterial and the antifungal influences of pomegranate (88, 89). The antibacterial potential of pomegranate against Gram negative and Gram positive bacteria such as *Salmonella* spp., *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), *Clostridium perfringens* (*C. perfringens*), *Listeria monocytogenes (L. monocytogenes)*, *Bacillus cereus*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, and *Helicobacter pylori* has been proven (90, 91, 92, 93, 94, 95, 96). Moreover, the antifungal effect of pomegranate against some fungi such as *Aspergillus niger* has been demonstrated (97, 98). The antimicrobial activity of the phenolic and tannin-rich fractions of the PPP and seed extracts has been demonstrated (93).

The high content of phenolic acid, flavonoid, and hydrolysable tannins in PP is the main reason for its antimicrobial activity (99). The early study of Scalbert (100) showed that tannins inhibited the extracellular microbial enzymes and eliminated the substrates required for microbial multiplication, resulting in distraction of the membrane structure and function. Besides, tannins lowered the harmful gut microbial populations and inhibited their metabolism by preventing the oxidative phosphorylation process (101). The phenolic compounds could adhere to the pathogenic bacteria by the ‘lectin–receptor’ mechanism, inhibit the incorporation of pathogenic microorganism to the mucosa, and decrease the gut pathogenic bacterial count (102). Ferreira et al. (103) reported on the antimicrobial effects of tannin rich plant extract against NH_3 producing *E. coli*, *Klebsiella* spp., and *Pseudomonas* spp. Further, the dissipation of the intestinal pH along with the antimicrobial activity of phenolic tannins may have been responsible for reducing the intestinal *E. coli* and *Salmonella* spp. count (41). The recent study of Tang et al. (104) revealed that the dietary ellagic acid could ameliorate *C. perfringens*-induced subclinical necrotic enteritis in broiler chickens. The authors owed this effect of ellagic acid to the regulation of the jejunal inflammation signaling pathways, reduction of the intestinal oxidative stress, balancing of the cecal microbiota, and inhibition of the intestinal barrier damage (104). Increasing in the intestinal *Lactobacillus* spp. count is usually associated with decreasing in the gut pathogenic bacteria. It seems that that PP could increase the count of the intestinal beneficial *Lactobacillus* spp. by reducing the pathogenic bacteria, and consequently improving the digestion and absorption of broiler chickens (105). In the same line, the *in-vitro* and *in-vivo* anti-parasitic properties of PP have been documented (106, 107, 108, 109, 110, 111, 112).

Phenolics, anthocyanins, hydrolysable tannins, and flavonoids are important anti-parasitic components of PP, flower, seed, and leaf (113).

On the other side, PPE has been widely used as a good food preserver due to its strong antimicrobial effect. A high concentration of PPE could inhibit the growth of bacteria causing spoilage and oxidative rancidity in chicken's products (86). In the same context, chicken meat products contain PPE showed an increase in their shelf life by 2-3 weeks during storage in refrigerator. Dipping of chicken's carcass in pomegranate juice decreased the microbial growth and population under refrigeration condition (114). Juneja et al. (94) demonstrated that PPP could enhance the heat inactivation of *E. coli* in ground chickens. Moreover, the earlier study of Hayrapetyan et al. (115) showed an inhibition of *L. monocytogenes* by PPE in meat paté at different temperatures.

IMMUNO-MODULATION

It has been shown that pomegranate by-products could improve the immune response (36, 37, 38, 52). The immuno-potentiating effect of PPP is listed in Table 2 (116). For example, Saleh (59) found high concentrations of immunoglobulin (Ig) M and Ig G in broilers chickens supplemented by PP. Recently, Elsebai et al. (26) demonstrated an increase in weights of spleen, thymus glands, and bursa of Fabricious of broiler chickens as a result of supplementation with PPP at different dietary levels. On the other side, Rao et al. (44) reported that feeding of broiler chickens on PP significantly enhanced the antibody titers against Newcastle disease virus (NDV) vaccine, while the cell-mediated immune response to phyto-haemagglutinin phosphate was not significantly affected. Pomegranate seeds are a rich source of polyunsaturated fatty acid, especially α-linolenic acid and linoleic acid (117, 118), which are responsible for increasing the weight of immune organs such as spleen and bursa of Fabricius (119).

BLOOD PARAMETERS MODIFICATION

Different concentrations of PPP induced an enhancement in some hematological and biochemical parameters in the treated poultry species. The lowering effect of pomegranate on the lipid metabolism is shown in Table 2 (120). The hypo-cholesterolemic and hypo-lipidemic effects as well as interference with lipid digestion, absorption, and metabolism have been demonstrated following supplementation with pomegranate (120). Pomegranate by-products have numerous key proteins and genes with a cholesterol-lowering effect (121). Supplementation of chicken's diet with pomegranate seed oil induced positive effects on the lipid profile of meat and eggs as well as their cholesterol content (65). Aviram and Fuhrman (122) also reported that PPE reduced the oxidation of LDL. In the same line, the concentration of cholesterol and LDL as well as the lipid peroxidation were decreased in broiler chickens fed on PPP (43). The anti-hyperlipidemic effect of PP was mediated by the down-regulation of peroxisome proliferator activated receptor alpha (33). Moreover, PPE reduced the total cholesterol and LDL through modulating of the activity of HMG-CoA reductase (123). It has been found that Ellagic could improve the cholesterol catabolism via increasing the production of bile acid in the hepatocytes (124). The *in-vitro* study of Zhao et al. (125) demonstrated that polyphenol in pomegranate significantly increased the expression of mRNA in the hepatic cells.

Many pervious reports showed that dietary pomegranate by-products lowered the levels of some liver function enzymes such as aspartate transferase (AST) and alanine transaminase (ALT) in broiler chickens (22, 26, 39) and Japanese quails (68). Similar results were obtained by Sharifian et al. (38) in heat-stressed broiler chickens. The depressant effect of pomegranate on the liver enzymes is related to its phenolic constituent.

Regarding the effect of pomegranate on the other hematological parameters, it has been shown that PPP increased the count of red blood cells (RBCs) count (126). Similarly, PPP at dietary levels of 0.25, 0.50, 1.00, and 1.50% increased the count of RBCs and white blood cells, the hemoglobin concentration, and the packed cell values (26). However, addition of 8% PP to boiler's diet lowered the RBCs count, the hemoglobin concentration, and the packed cell value (22). The recent study of Gultepe et al. (71) revealed that pomegranate juice in 5%, and 10% water solution didn't induce significant effects on the lipid profile, liver enzyme, and most of the hematological parameters. The PPE significantly increased the RBCs count as well as the hemoglobin and hematocrit levels which indicated the increased erythropoiesis process, however, no significant effect on glucose, cholesterol, triglycerides, high density lipoprotein (HDL), and LDL levels had been noticed (127). The oral daily gavage with

Table 2. The different effects of PPP on the antioxidant, antimicrobial, immune status, and lipid metabolism of poultry

Dose of PPP/diet	Species	Findings	Reference
0.01%	Broiler chickens	Reduced *Bacillus cereus* and *S. aureus* in the retail meat products	(86)
0.05%	Broiler chickens	Decreased serum total cholesterol and LDL	(120)
0.5 and 1.0%	Broiler chickens	Increased weights of the spleen and bursa of Fabricius Increased serum concentration of IgA and IgG Increased intestinal *Bacillus* spp. Reduced *E. coli* and *Salmonella* spp.	(41)
20 g/kg	Broiler chickens	Enhanced immune function Proliferation of intestinal beneficial bacteria Reduced pathogenic bacteria	(36)
0.02%	Broiler chickens	High serum SOD and glutathione peroxidation No effect on glutamic oxaloacetic transaminase and glutamic pyruvic transaminase enzymes Reduced lipid peroxidation of breast meat Enhanced humoral immune response	(42)
100 mg/kg	Heat-stressed broiler chickens	No significant increase in antibody titer to NDV vaccine Reduced cholesterol level	(116)
250 and 500 mg/kg	Broiler chickens	Increased glutathione peroxidation and SOD in liver Reduced lipid peroxidation	(44)
250, 450, and 650 mg/kg	Heat-stressed broiler chickens	Decreased MDA in the breast muscle Increased water holding capacity of breast meat during storage Increased IgG and anti-sheep RBCs titers Reduced cholesterol and LDL Increased HDL	(38)
7.5 and 10 g/kg	Broiler chickens	Upregulation of hepatic CAT and SOD Reduced MD, triglycerides, cholesterol, and abdominal fat deposition Increased nitric oxide	(33)
4%	Laying hens	Reduced MDA Enhanced antioxidative enzymes and total antioxidant blood capacity	(27)
5-10 gm	Broiler chickens	No effect on glutathione peroxidase, SOD, and CAT Decreased MDA in breast meat Reduced cecal *C. perfringens* count	(25)
4% and 8%	Broiler chickens	Increased total antioxidant capacity, SOD, and glutathione peroxidase Decreased MDA and LDL in meat Increased IgG, IgM, and total immunoglobulins	(22)
3% and 9%	Quails	Improved antioxidant activity and greater expression of hepatic growth hormone receptors gene Increased immune cells count	(46)
4 g/kg	Broiler chickens	Increased IgM	(39)
4%	Broiler chickens	Decreased peroxidase value in meat High intestinal *Lactobacillus* count Low intestinal coliform populations	(23)
5% and 10%	Layer hens	Decreased IgG	(71)
400 ppm	Broiler chickens	Decreases intestinal lesions Decrease *Eimeria* oocysts count	(87)

0.8 mL/kg pomegranate seed oil in rats resulted in a significant elevation of creatinine, urea, LDL, triglyceride, and glucose levels in serum and increasing of urine markers and MDA in tissue homogenates, but a significant reduction in total thiol content and serum HDL (128). The study of Attia et al. (129) revealed that administration of pomegranate juice (3 mL/kg/day) and peel water extract (200 mg/kg/day) resulted in a significant reduction in serum glucose, triglycerides, total cholesterol, LDL, urea, uric acid, and creatinine, however, HDL was elevated in diabetic and hypercholesterolemic rats. Besides, a significant increase in white blood cells and RBCs were detected in hypercholesterolemic rats treated with a pomegranate juice (129).

CONCLUSION

Pomegranate is a widely known plant that shows promising effects as a natural feed additive in poultry production system. The plant and its by-products showed positive influences on the production of poultry. More in-depth research work on the effects of pomegranate by-products on poultry health and immunity must be carried out.

CONFLICT OF INTEREST

The author declares that they have no potential conflict of interest with respect to the authorship and/or publication of this article.

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AUTHORS' CONTRIBUTIONS

WAA has collected and drafted the manuscript, formatted it, and approved the final manuscript.

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