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Review paper

Effect of garlic on the health and performance of broilers

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Abstract
Antibiotic growth promoters have been extensively used in the poultry feed to improve weight gain, feed efficiency, lessen the number of harmful bacteria, enhance immunity etc. However, they have role in development of the resistance in the pathogenic bacteria and impose negative impact on the consumers due to residues. Medicinal plants are the best replacement option of ABGP. Garlic is the king of the medicinal plants which have growth promoting effect in chicken production. It has antibacterial, antiviral, antifungal and antiprotozoal properties. Moreover, it boosts the immune system, improves the body weight gain, heighten the digestibility of ingredients, decrease the bad cholesterol, and also augment the meat quality parameters. This article describes the detail about the use of garlic in poultry feed which can enhance the productivity and can attain the growth promotion potential without causing adverse effects unlike antibiotic growth promoters.
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Introduction

Feed additives are added in poultry feed to improve nutritive value of ingredients and enhance broiler performance by increasing growth rate and improving feed conversion efficiency. Chemical feed additives e.g. Antibiotic growth promoters (ABGP), have been intensively used in broiler's ration to improve productivity. However, they are notorious for bacterial resistance and their negative impacts on the consumers' health [1]. Thus, use of ABGP has been banned in poultry industry. Now, nutritionists are shifting from chemical growth promoter to phytogenic growth promoters. Thus, it is important to explore the potential of innate feed additives to replace the chemical ones. Herbs could be expected to serve as feed additives due to their suitability and preference, lower cost of production, reduced risk of toxicity, minimum health hazards and environment friendliness [2]. Recent research works on phytogenic feed additives have shown promising results as regards weight gain, feed efficiency, lowered mortality and increased livability in poultry birds [3-7].

Phytogenic substances are supposed to increase performance of birds by stimulating secretion of digestive enzymes, leading to enhanced digestion and absorption [8, 9]. Furthermore, the presence of active ingredients and phenolic compounds can reduce numbers of intestinal pathogens, thus minimizing nutrient loss and improving performance. Both effects may result in better intestinal health and may lead to more protein deposition in body tissues. But, the effects of active ingredients on performance and health of animals are in-consistent, as affected by the number of environmental and agronomical factors leading to differences in amount and activities of active ingredients. In literature, no clear-cut effect of phytogenic compounds on performance parameters in different species of poultry has been reported.

Herbs spices like garlic (*Allium sativum*) have been reported to possess useful pharmacological substances [10]. Freshly crushed garlic contains allicin, alliin, ajoene, diallylsulfide, dithiin, S-allylcysteine. Garlic as natural feed additives in poultry nutrition may be of great benefit and value especially for broiler growers. This is due to their antibacterial, anti-inflammatory, antiseptic, anti-parasitic and immunomodulatory properties of garlic. In Pakistan, farmers are already using this specie in scavenger poultry feed to attain the aforementioned results.

Garlic is used as flavoring agent in different dishes and medicament, antioxidant, antihypertensive, anti-ageing, hypo-lipidaemic, anti-platelet and detoxify the heavy metal [11, 12]. Due to its antimicrobial properties, garlic is the highly studied medicinal plant used as growth promoter in broiler chickens [13, 14]. Therefore, trials have evaluated garlic as an alternative of growth promoters in poultry and revealed its

excellent effects on growth, digestibility and carcass characteristics [15].

The objective of this article is to gather the large amount of research literature into a refined summery so that it can be used as guideline for standard development of garlic use in poultry. For this purpose, antimicrobial and performance enhancing properties of garlic has been discussed in this review.

Antimicrobial properties

Use of garlic and ginger as a medicine and condiment goes back to written history. It is thought that these are originated in traditions of both India and China. Egyptian medical papyrus, Codex Ebers, interpreted in 1937; has more than 800 medical formulations, of which 22 contains garlic.

Recently the first evidence of its antimicrobial properties was established when four men were employed to remove the dead bodies during a plague in Marseilles in 1721 in France. None of them became infected. When research is done to identify the secret then it was known that they use garlic and wine tincture [16]. The precursor alliin, a cysteine sulfoxide, and the corresponding alliinase enzyme are the main components of garlic [17]. Garlic has been used for centuries in many countries to control infectious diseases. It has been used to prevent wound infection and food spoilage in India [18].

Antibacterial affects

Historically it is believed that Louis Pasteur first scientist who demonstrate the antimicrobial effects of garlic 'juices' in 1858, however, no reference is available. Recently it is proved that garlic is effective against many acid-fast, gram-positive and gram-negative bacteria. These include *Escherichia coli* (E. Coli), Salmonella [19], Clostridium [20], *Staphylococcus aureus*, *Pseudomonas*, *Proteus* [21], *Klebsiella* [22], *Micrococcus*, *Bacillus subtulis* [23] and Helicobacter [24]. So, garlic can be used to treat Colibacillosis, Salmonellosis and Cholera in poultry. Garlic exerts a differential inhibition between beneficial intestinal microflora and potentially harmful enterobacteria [25]. For the same garlic dose inhibition zone observed in E. coli was more than 10 times than that seen in *Lactobacillus casei* [26]. The exact mechanism of this differential inhibition is not known, but one of the possible reasons may be the change in chemical composition of membranes of different bacteria and their absorptivity to allicin [27]. An inhibitory synergism of antimicrobial properties of garlic was observed when it was used in combination with vancomycin [28].

Antiviral effects

Mostly the commercially available antibiotics are not affective against viruses. That is the reason these cannot be used to control the viral diseases of poultry. Very less research is done on antiviral properties of garlic compared to antibacterial. Allicin and allicin-derived substances are active against viruses and no activity has been indicated with alliin or S-allyl cysteine. It has been proved that garlic shows in vitro activity against influenza A and B viruses, rhinovirus, HIV, herpes simplex virus 1 and 2, cytomegalovirus, viral pneumonia and rotavirus [29-33].

Anti-protozoal Affects

Use of garlic in poultry feed exhibits antiprotozoal effects in poultry but the exact mechanism of action remains to be explored. Several studies have shown that it is effective against a host of protozoa including *Opalina ranarum*, *Entamoeba histolytica*, *Balantidium entozoon*, *O. dimidicita*, *Trypanosomes*, *Leishmania*, and Leptomonas [34]. Diallyl trisulfide a component of garlic is commercially available in many countries like China in commercial preparation named Dasuansu and has been prescribed for treatment of diseases caused by *Trichomonas vaginalis* and *Entamoeba histolytica* [35]. Allicin, ajoene and organosulfides are the main components of garlic which have antiprotozoals properties. Thiol content of microbial cells are not quite enough, to counterbalance the thiol oxidation by allicin and allicin-derived products that why these are more affected than animal cells [34].

Antifungal effects

Alike other antimicrobial properties antifungal activity of garlic has also been proven to be thanksgiving. The first ever report of antifungal activity of garlic in epidermophyte cultures was

reporterd by Schmidt and Marquardt [36]. Studies suggest that garlic can prevent the growth of Aspergillus, Torulopsis, Trichophyton, Cryptococcus, Candida, Trichosporon and Rhodotorula [37-39]. Garlic has oxygen scavenging molecules which decrease the oxygen uptake [40], reduce the growth of the organism, stops the synthesis of protein, lipids, and nucleic acids [41] and denature the membranes [42]. A sample of pure allicin was shown to be antifungal. Solvent extraction of allicin from garlic decreased the antifungal activity [43]. Activity has also been observed with diallyl trisulfide against cryptococcal meningitis [44], and ajoene, against Aspergillus [45], Candida [46].

Broiler Growth Performance

Many scientists investigated the effects of long term feeding of garlic and its' preparations on the performance of broilers. Most of these studies reported a statistically significant improvement in cumulative feed conversion ratio. Garlic increases growth and improves feed conversion ratio [47] by increasing height of villus of small intestine, activation of absorption process. To support these ideas a study has proven that dietary fermented garlic supplementation in broiler ration can increase the intestinal villus height, villus area, cell area, cell mitosis in the intestine and results in better feed efficiency [48].

Serum cholesterol

Garlic, being the king of medicinal plants, imposes beneficial effects on body metabolites. Several clinical studies have supported this idea [49-52]. Allicin may reduce the levels of serum cholesterol, triglyceride and LDL [53]. Diets comprising garlic powder has ability to lower down serum and egg cholesterol level in hens [54]. An investigation has reported that supplementation of garlic powder at the levels of 0, 2, 6 and 8% does not affect the egg weight, egg mass, feed consumption and feed efficiency in the laying hens [55]. However, lowering effect on the serum and egg yolk cholesterol concentrations was observed with dietary garlic [56]. Garlic paste, solvent-extracted fractions or garlic oil reduced the concentration of serum cholesterol by 23% and 18% in twelve week-old Leghorn pullets and broilers, respectively, when diets were fed for 4 week [57]. Decrease in hepatic cholesterol concentration in chickens was observed when 2% garlic was fed for 14 day [58]. Similar effects of garlic were found in rats fed diets containing either cholesterol or triglyceride [59].

The mechanism which involved in decreasing the cholesterol, triglyceride and LDL is that it reduces the activities of hepatic lipogenic and cholesterogenic enzymes such as fatty acid synthase, malic enzyme, 3-hydroxy-3-methyl-glutaryl-CoA (HMG CoA) reductase and glucose-6 phosphate dehydrogenase [60]. Garlic also increased the excretion of cholesterol, as demonstrated by enhanced excretion of acidic and neutral steroids after garlic feeding [61]. LDL isolated from human, given aged garlic extract [62] and aqueous garlic extract [63] was found to be decisively more resistant to oxidation. Suppressed LDL oxidation may be one of the controlling mechanisms for the benefits of garlic in atherosclerosis [64]. Allicin was identified initially as the active compound responsible for depressing the atherosclerotic effect. However, in vitro studies revealed that organosulfur compounds especially, diallyl-di-sulfide, present in garlic oil and water-soluble S-allyl cysteine, present in aged garlic extract are also potent inhibitors of cholesterol synthesis [65].

Hematology

Garlic supplementation in poultry imposes positive effects on hematological parameters of poultry birds. Hematological analysis reported by Kung-chi et al. [66] demonstrated that intake of garlic oil significantly increased white blood cell and reduced red blood cell counts, hemoglobin, hematocrit and mean corpuscular hemoglobin values in rats. Addition of garlic in diet of fish increase the red blood cells and mean corpuscular volume when it was used at the concentration of 20, 30 40g/Kg [67]. The scientists reported that hematocrit values reached a significant increase in fish fed on 20 g garlic but no significant differences in mean corpuscular hemoglobin concentration was noted.

It is also possible that the end product of garlic metabolism in the body stimulates the kidney directly to cause formation and secretion of

erythropoetin. Now, scientists are trying to determine the effect of garlic on erythropoetin level. Another experiment concluded that garlic supplementation increases the white blood cells, lymphocytes and immunoglobulin G in broilers [68]. In contrast, it has been reported that garlic does not affect leukocyte numbers in broilers [69]. With regards to WBC counts, it was reported that dietary addition of garlic increased lymphocyte concentration in peripheral blood of pigs. The enhanced lymphocyte proliferation by garlic treatment along with the possible protection of the cells from oxidative stress seemed to contribute for the increased WBC count [70-75].

Immune System

Although garlic kills viruses, bacteria and other microorganisms directly, it also excites the body's natural defenses against these antigens. Garlic's amazing and famous power against diseases is due to a combination of both these properties. Aged garlic extracts have an immunomodulatory effect and lessens the age-related deterioration of the immune response. Garlic supplementation in chickens increase the relative weights of the spleen, bursa of Fabricius and thymus [68, 73].

In vitro garlic extracts excites the rat and human lymphocytes. A protein fraction (F4), isolated from aged garlic extract, boost the cytotoxicity of human peripheral blood lymphocytes against natural killer-sensitive and resistant cell lines and induced lymphocyte infiltration and cytokine release [74, 75]. Diallyltrisulfide and protein fraction, the components of garlic has been shown to enhance activation of T lymphocytes [76, 77] and also progresses the ratio of helper to suppressor T cell in AIDS. It also enhances antibody production against *Salmonella enteritidis, Pasteurella multocida and Leptospira Pomona* bacteria [78], which indicate that it increase the activity of B lymphocytes. Alliums at low levels in the diet improved the humoral immune response against *Brucella abortus* (non-replicating T-cell independent antigen) in chickens [68].

Garlic extracts have been found to suppress pro-inflammatory cytokines like IL-2 and elevate inter lukin (IL) -10 and IL-12 in monocytes [79]. Garlic preparations encouraged the macrophage infiltration and cytokine release. Garlic components boost the immune stimulation by mitogenic activation (e.g. allicin). Scientists have reported that addition of garlic extract to a macrophage culture of laying hens at 50 µg/mL tended to enhance Sheep red blood cells uptake; on the other hand, high concentration of the extract (200 µg/mL) inhibited phagocytosis [80]. Experiments in humans and mice revealed that addition of aged garlic extract to a culture enhances the phagocytosis of peritoneal cells and increases the production of interleukin (IL)-2, IL-12, interferon-y and tumor necrosis factor-a from spleenocytes [73], and the addition of different garlic extracts enhances the engulfment ability of phagocytes [81], as well as the secretory metabolism of macrophages [77, 82, 83].

Aged Garlic Extract excites the proliferation of spleen cells, release of cytokines and phagocytosis (the ability of immune cells to engulf foreign agents) of peritoneal macrophages. Immune enhancing effects of commercial garlic preparations was studied and it was found that aged garlic extract was the most effective for improving immune factors, specifically macrophage and T-lymphocyte activity [84].

Hanieh et al. [68] reported supplementing chickens with garlic exerted enhancing effect on the humoral immune responses against Newcastle disease virus and sheep RBC (non-replicating T cell-dependent antigens). It has been studied that supplementing broilers with a liquid product including garlic, feed acidifier and microbial cell extract increase antibody production against Newcastle disease vaccine [78] and infectious bursal disease vaccine [85, 86]. These inconsistencies in the results may be due to preparation method of the garlic. However, there might be possibility that immunomodulatory property could be antigen- dependent [87, 88]. Aged Ginger has antibacterial properties and kills cold viruses so, indirectly stimulate the immune system. Nidaullah et al. [89] concluded that aqueous extract of garlic bulb and ginger (*Zingiber officinale*) rhizome plays a very important role as immunstimulant against Coccidiosis, Newcastle disease, Infectious bronchitis and infectious bursal disease.

Carcass Characteristics

One of the new insights in poultry industry is to improve the quality of meat with nutrition modelling. Alteration in the quality of intact muscle is possible by nutrition. Direct addition of antioxidants or feed additives to improve the quality of meat are too effective because these compounds are not deposited in the muscles where these are required and this can be done by adding them in the feed [90].

To prevent the oxidative deterioration of meat by free radicals, antioxidants have been extensively used as feed additives. Synthetic antioxidants are extensively used for industrial processing in order to prolong the storage stability of meat. Antioxidants like butylated hydroxyanisole and butylated hydroxytoluene have been widely rejected by the consumers due to their supposed carcinogenic potential as demonstrated by toxicologists [91]. Rejection to synthetic food additives by the consumer has been increasing in advanced countries. That's why scientists are searching for the natural additives which have the greatest potential of anti-oxidation.

Garlic supplementation has an antioxidant effect that is why lowers the thiobarbituric acid-reactive substance value and might protect lipid oxidation [68]. Garlic has many kinds of antioxidant compounds such as flavonoid and sulfur containing compounds [92]. Besides, Leonarduzzi et al. [93] reported that LDL particles may have significant amount of cholesterol oxidation products. Therefore, the decrease in LDL cholesterol could also mirror the antioxidant effects of garlic supplementation. The anti-oxidative impact of garlic in meat becomes more authoritative in less developed nations, considering storage problems and increasing use of alternative feed resources without due consideration for meat quality [94]. By using garlic as feed additive in broiler ration we can get the bioactive components in meat that directly cannot be consumed by human.

Research findings indicated that pH plays a significant role in the extent of microbial spoilage [95]. Glycogen concentration in muscle is the main factor on which pH relies. If birds are exposed to stress before slaughtering then glycogen is depleted in the muscles [96]. Meat having higher pH, holds more water during storage and will produce more juice after meat preparation. If more juice is produced from the meat then it will give juicier, more succulent and tender eating experience. The pH values of chicken sausage can be increased by the treatment of garlic [97]. The pH of meat of finishing pigs can also be increased by garlic treatment [98].

Conclusion

Garlic is king of medicinal plants and it has wondrous effects in poultry. The garlic supplementation of poultry feed has shown better performance of birds, ultimately enhancing the production potential. Additionally, garlic reduces the number of pathogenic bacteria like Campylobacter, *E. coli* and Salmonella, clostridium, etc. It has beneficial effects on consumer's immunity. So, it can be effectively used to replace the antibiotic growth promoter in poultry feed. Although, there is huge pile of research literature in this area, but still there is a need to establish standards of garlic use in poultry feed. To fulfill this purpose more research is needed in this economics friendly supplement.

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