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Garlic: An Alternative to Antibiotics in Poultry Production, A Review

Review Article

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ABSTRACT

In last decade, the uncontrolled use of antibiotics as growth promoter for livestock has led to the appearance of antibiotic-resistant pathogens and increased risk of infectious diseases. This situation has triggered intensive research efforts to find safe alternative strategies. Certainly, the plants and vegetables and their derivatives as natural safe substances could be good candidates in this respect. There is huge information on the immunostimulatory properties of herbal plans in human, and may contribute considerably to the improvement of the health and immune response and prevention of certain diseases in animals including poultry. Garlic (*Allium sativum*) is an herbal plant that has traditionally been used for the healing a number of human diseases and has in recent years been revealed to have immunostimulatory, anticardiovascular disease, antitumour, antioxidant and antimicrobial properties. The scientific evidences suggest that allicin and other active components of garlic have also some positive effects for livestock, including hypocholesterolemic, growth promoting, antimicrobial and antioxidant effects.

KEY WORDS broilers, garlic, immunological responses, layer hens, serum lipids.

INTRODUCTION

Antibiotic treatments have been the most successful way to control infection and reduce mortality in humans and animals. However, the increasing use of antibiotics especially as growth promoters for livestock has led in a significant risk of microbial resistance. At present, the World Health Organization is recommending producers to apply alternative ways to antibiotics to prevent and treatment of infectious diseases (Lowenthal *et al*. 1999). On the other hand, while certain infectious diseases have been effectively prohibited by vaccination, it seems that vaccine efficiency has reduced alongside with a raise in virulence of antigens, and some of these are capable of break through vaccination immunity (Lien *et al*. 2007; Wu *et al*. 2008). With the ban of the use of antibiotics as growth promoters in last decade in most countries, attention has focused into finding alternatives ways that do not have the problems associated with antibiotics. Research interest has been focused on herbal plants that are reported to possess various therapeutic properties. This natural and safe source of active substances has been attractive research subjects over the past decades and has led to promising results (Masihi, 2002; Okamura *et al*. 2004; Sampedro *et al*. 2004; Jayaprakasha *et al*. 2006). Phytobiotics, or phytogenic substances, are usually safe natural plant derivatives which as feed additives could improve the health and performance of animals (Windisch *et al*. 2008). Garlic (*Allium sativum*) is commonly used as either a flavoring agent for food or as traditional therapeutic agent for the treatment of different diseases (Essman, 1984; Konjufca *et al*. 1997; Amagase *et al*. 2001; Sallam *et al*. 2004). Animal studies have showed that garlic has hypolip-

idemic, hypotensive, hypoglycemic, hypothrombotic, and hypoatherogenic effects (Bordia *et al*. 1975; Shoetan *et al*. 1984). As said by folk medication, garlic is effective to healing cardiac disease (Essman, 1984). Although there are numerous publications on the hypocholesterolemic effects of garlic in humans (Silagy and Neil, 1994; Warshafsky *et al*. 1993), however, it has suggested that commercially available garlic products may not be hypocholesterolemic (Berthold *et al*. 1998). It could be because of the differences in preparation procedures, the stability of effective components, and the period of the study (Amagase *et al*. 2001).

Compared with human studies, there is relatively limited information on the use of phytonutrients in general, and garlic in particular, in poultry veterinary medicine. The objective of this review was to summarize the recent findings on the impact of garlic and its derivatives as feed additives on performance, immune system as well as lipid metabolism in broiler chickens and layer hens.

Garlic active compounds

The flavonoid and organosulphur components of garlic and garlic derivatives have been shown to have therapeutic and antioxidant effects in both broilers and layer hens (Chowdhury *et al*. 2002; Sallam *et al*. 2004). The therapeutic properties of garlic are mainly attributed to the thiosulfinates, the single most abundant group of sulphur containing compounds (Calvo-Gómeza *et al*. 2004; Lanzotti, 2006). Garlic have at least 33 sulphur-containing substances, several enzymes, 17 amino acids, and trace minerals for example selenium (Newall *et al*. 1996). Allicin (of which allin is the precursor) is the main sulphurcontaining component and usually consists more than two third of the total thiosulfinates (about 4 g/kg fresh mass). Allicin is formed when slicing or crushing the fresh garlic and breaks the intercellular compartments which separate alliin and alliinase (Lawson, 1998; Rybak *et al*. 2004). Allicin is unstable and poorly absorbable (Lawson and Wang, 2001). On the other hand, garlic derivatives which are produced by means of heating or solvent extraction methods are usually contain alliin, however also are free of allinase; therefore, no allicin may be found in the final product.

The oil and steam-distilled derivatives are usually rich in secondary metabolites for example ajoene, but there is no scientific approve on the comparable chemical characteristics of these secondary active compounds in fresh garlic (Newall *et al*. 1995). The another important compound of garlic is inulin and the decreased digesta pH of birds fed garlic could be attributed to higher volatile fatty acids production because of the prebiotic effects of inulin and its hydrolysates which may help to overcome of useful microbes colonization (Grajek *et al*. 2005).

Nuutila *et al*. (2003) reported that garlic husk had higher total phenolics than garlic bulb. It seems that these active pharmacological components act on several intracellular signaling pathways.

Immunomodulatory properties of garlic

It would seem that dietary garlic, at suitable dosages, has a positive effect on functions of the immune system, and could offer a future alternative way in the control of chicken diseases. However the previous reports in on the effects of garlic on chicken immune system responses were not always supportive. For instance, Szigeti *et al*. (1998) found that garlic supplement in broilers augmented antibody production against Newcastle disease virus (NDV), while Jafari *et al*. (2008) observed no beneficial effects on antibody production following 1% or 3% garlic consumption in diet. Hanieh *et al*. (2010) showed that the 3% dietary garlic had less stimulatory effect on immune response, and in some cases the antibody titers were considerably lesser to those at a lower dietary level. They reported that garlic treatment increased lymphocyte proliferation, white blood cells (WBC) count and the relative weights of spleen and thymus of broiler chickens.

The effect of garlic supplement on increases in the size of the spleen, bursa fabricius and thymus of chickens are probably attributed to the more lymphocyte proliferation and the increase in WBC counts (Hanieh *et al*. 2010). Garlic supplementation increased withe blood cells counts in blood stream of the chickens in the study of Hanieh *et al*. (2010). However, Jafari *et al*. (2008) have observed that garlic does not affect leukocyte numbers in broilers. The increased lymphocyte proliferation in company with the potential protection of the cells from oxidative stress suggested to contribute for the increased with blood cells count by garlic supplementation (Hanieh *et al*. 2010). Hanieh *et al*. (2010) also studied the effects of dietary garlic on immune responses in White Leghorn chicken. Garlic at 10 g/kg diet increased anti-NDV, anti-SRBC and anti-*Brucella abortus* (BA) antibody productions, while 30 g/kg diet had less stimulatory effects. They also found an increased splenocyte and thymocyte proliferations in garlic fed chickens.

Macrophage activation is necessary to establish control of infection and progression of certain diseases. Dorhoi *et al*. (2006) also have reported that supplementation garlic extract to a macrophage culture of laying hens at 50 mg/mL tended to increase sheep red blood cell (SRBC) uptake; on the other hand, high dosage of the extract (200 mg/mL) inhibited phagocytosis. Ghazanfari *et al*. (2000) showed that immunostimulatory properties injection of garlic extract or its protein fraction augmented parasite engulfment and destruction in peritoneal macrophages.

Hanieh *et al*. (2012) in an *in vitro* study, showed that garlic extract increased concanavalin A (ConA)-induced splenocytes (4, 8 and 16 mg/mL) and thymocytes (2, 4 and 8 mg/mL) proliferations, and gene expression of IL-2 (8 and 16 mg/mL) and interferon (INF)-g (16 mg/mL). Macrophages also exhibited superior microbicidal activity and reactive oxygen species (ROS) production with garlic extract at 4 and 8 mg/mL. These authors suggested that it is likely that garlic has direct stimulatory effects on immune cell functions. Kyo *et al*. (1999) found that supplementation of garlic extract to a culture increased the production of IL-2, IL-12, INF-γ and tumor necrosis factor (TNF)-α in stimulated splenocytes. Feng *et al*. (1994) showed that diallyl trisulfide, one of the main sulphur compounds of garlic, at lower concentrations of 3-12.5 mg/mL increased the proliferative responses in a culture stimulated with ConA, whereas at higher concentration of 50 mg/mL inhibited T-lymphocyte proliferation in mice.

Hanieh *et al*. (2010) suggested that the stimulatory effects of garlic on humoral immune response maybe because of the improved immune cell functions that is cytokine production and / or antigen presenting cells phagocytic capacity. Oxidative stress is a potential factor coupled with the immune response itself (Costantini and Møller, 2009). Thus, the antioxidative properties of garlic might have resulted to the improved functioning of the immune cells by protecting them from oxidative stress. Although Allium plants may be valuable to health, the toxicity of these vegetables has been also reported in domestic (Stevens, 1984; Rae, 1999; Van der Kolk, 2000) and laboratory (Munday *et al*. 2003) animals. It is reported that high concentration of garlic extract (200 mg/mL) impairs phagocyte function (Dorhoi *et al*. 2006).

Antimicrobial effect of garlic

Phytobiotics may reduce growth of pathogenic microbes, thus providing a balance of gut microflora. Most of the studies on the use of antibiotic growth promoter alternatives have focused on their antimicrobial activities. The active compound in garlic, allicin, has well known antimicrobial properties (Ankri and Mirelman, 1999; Kim *et al*. 2013) and decrease gut pathogenic populations. Garlic also showed antiviral (Ankri and Mirelman, 1999), antibacterial (Kumar and Berwal, 1998; Ankri and Mirelman, 1999; Sivam, 2001), antifungal and antiparasitic (Ankri and Mirelman, 1999) activities. Hanieh *et al*. (2010) reported that dietary garlic has a stimulatory effect on antibody production against gram-negative bacterial antigen in White Leghorn chickens. Garlic has been recommended for the treatment of parasitoses and other intestinal diseases (Iciek *et al*. 2009). Crude extracts of garlic decreased or eliminated *Hymenolepis*, *Aspiculuris*, *Histomonas* and *Eimeria* parasites in animal models of infection (Ayaz *et al*. 2008; Dkhil *et al*. 2011).

Hypocholesterolemic effects of garlic

One of the well known therapeutic properties of garlic is its hypocholesterolemic effect. This effect has reported in chicken too (Essman, 1984; Warshafsky *et al*. 1993; Silagy and Neil, 1994; Chowdhury *et al*. 2002). Sklan *et al*. (1992) reported lower hepatic cholesterol concentrations in chickens fed 2% garlic 14 d. In the study of Choi *et al*. (2010), increasing the levels of garlic meal and using garlic meal plus α-tocopherol considerably reduced total and low-density lipoprotein cholesterol and increased high-density lipoprotein cholesterol in broiler blood. Konjufca *et al*. (1997) also reported that 3% dietary garlic meal decreased plasma cholesterol and breast and thigh muscle cholesterol in broilers.

In the study of Choi *et al*. (2010), the supplementation with 5% garlic meal or 3% garlic meal plus α-tocopherol significantly decreased total and low density lipoproteins (LDL) levels and increased high density lipoproteins (HDL) levels compared with the control. They explained this finding by the reduction of synthetic enzyme activity. Garlic or garlic plus –tocopherol would be expected to have a much higher antioxidant power or biological effects, among which are reducing the production of free radicals (Chowdhury *et al*. 2002).

In the study of Sharma *et al*. (1979) egg yolk cholesterol was decreased by feeding 1 or 3% garlic meal to laying hens for 3 wk. Yalcin *et al*. (2006), reported that 0.5 and 1% dietary garlic decreased egg yolk cholesterol and serum triglyceride without negative effects on performance and egg traits of laying hens. Garlic paste (3.8%), solvent fractions, or garlic oil equal to this quantity decreased serum cholesterol by 18 and 23% in broilers and 12-wk-old Leghorn pullets (Qureshi *et al*. 1983b). Comparable findings have been reported in laying hens and broiler chicks fed 2, 4, 6, 8, or 10% garlic meal and supplementation with 200 or 400 IU of α-tocopherol (Chowdhury *et al*. 2002; Kim *et al*. 2006). Chowdhury *et al*. (2002) concluded that up to 8% supplemental sun-dried garlic paste decreased serum and yolk cholesterol concentrations and can be used as a hypocholesterolemic agent in practical layer diets. Qureshi *et al*. (1983a) found lower activities of hydroxymethylglutaryl-coenzyme A reductase, cholesterol 7 α-hydroxylase, and fatty acid synthetase when chickens were supplemented with polar fractions of garlic powder (garlic equivalent to 1, 2, 4, 6, and 8% fresh garlic paste) for 3 weeks.

However there are some reports on the ineffectiveness of dietary garlic or its extract on serum or yolk cholesterol concentration. In a study, this cholesterol reducing effect of garlic was not observed in the yolk and serum of laying

hens fed 3% garlic meal (Birrenkott *et al*. 2000). Birrenkott *et al*. (2000), also found that 3% garlic meal did not change yolk and serum cholesterol concentrations when laying hens were fed diets for 8 month. Egg yolk cholesterol concentrations have been reported to vary depending on the genetic strain of the laying hens (Han and Lee, 1992).

Reddy *et al*. (1991) have reported that 0.02% garlic oil did not have any significant effect on serum cholesterol. Lim *et al*. (2006) also observed that the level of HDL was not changed by 0, 1, 3, or 5% dietary garlic meal in laying hens. The contradictory reports on the effects of garlic on serum and yolk cholesterol could be due to use of different commercial garlic products. It has suggested that some commercial garlic oil, garlic meal, and commercially available garlic extract may not be hypocholesterolemic (Berthold *et al*. 1998).

The different garlic products may be allicin-rich which made from raw garlic or nonallicin-rich which is produced from processed garlic. These products may differ significantly in hypocholesterolemic effects.

Effect of garlic supplementation on broiler performance

There are considerable efforts to introduce garlic as an effective growth promoter for broiler chickens and the most reports have indicated promising outcomes (Javed *et al*. 2009; Aji *et al*. 2011). However the differences in the experimental conditions, birds genetic and health status as well as the type, processing and quality of garlic products have resulted in some controversial recommendations.

Shi *et al*. (1999) fed 0.2, 1 or 2% garlic meal to broilers and found the best performance in birds fed 1% garlic meal. In a comparable report, Javandel *et al*. (2008) supplemented broiler's diets with 0, 0.125, 0.25, 0.5, 1 or 2% garlic meal. The diets containing less than 2% garlic meal improved growth rate and feed conversion ratio (FCR) compared to the control group. However the 2% dietary garlic meal apparently had adverse effects on broiler performance. Jagdish and Pandey (1994) reported a different effective dosage such that a lower FCR was found with 0.25% garlic meal in compare to control group and 0.5% level. However, Qureshi *et al*. (1983b) found no differences in growth performance of broilers up to 5% garlic meal, and in the study of Horton *et al*. (1991) there was no improvement in the performance of broilers fed 0, 0.01, 0.1 or 1% garlic meal.

Reddy *et al*. (1991) and Chowdhury *et al*. (2002) also reported that the sun-dried garlic meal and garlic oil did not affect growth performance. The inconsistency in results may be because of differences in experimental diets and birds, and the quality and quantity of the active components in the garlic product.

Some researchers tried to combine the garlic and other feed additives to achieve more benefits. Choi *et al*. (2010) fed broilers diet treatments containing 0, 1, 3, and 5% garlic meal and 3% garlic powder + 200 IU of α-tocopherol/kg and did not observe any difference in broiler's performance, but the mixture of garlic powder and α-tocopherol supplements increased crude protein, decreased crude fat contents of carcass and also reduced the pH and thiobarbituric acid (TBA) reactive substances values of chicken meat.

In experiment of Olukosi and Dono (2014), the garlic meal in combination with turmeric meal at the rate of 10 g/kg each decreased digesta pH in the crop, proventriculus and ceca, and improved ileal digestible and apparent metabolisable energy but had no effect at the jejunum. The outcome of these changes was improved weight gain and FCR compared to the control group. Adibmoradi *et al*. (2006) reported positive changes in the small intestine morphology of broilers fed garlic meal which resulted in an improved performance. The increased villi heights enhance nutrient absorption because of higher surface area, while deeper crypt can represent increased cell turnover in response to normal cellular sloughing or inflammatory situation. A combination of longer villi and deeper crypt is a sign of a healthy intestinal development in response to the use of the garlic additive. The antioxidant properties of garlic may improve growth and development of birds the digestive tract overall gut function (Halliwell *et al*. 2000).

The enhanced gut function improves nitrogen energy utilization. The lower pH of digesta in birds fed garlic meal may be an indication of the prebiotic effect which was resulted in more volatile fatty acid (VFA) production and supports the proliferation of beneficial microbes (Yang *et al*. 2009). Because the most part of the compounds reach to hind gut fermentation are ingested carbohydrates and protein that escape foregut digestion (Cummings, 1985; Cummings and Macfarlane, 1991), better foregut digestion will improve nutrient utilization for the host and decrease harmful microbes colonization in the gut.

Varmaghany *et al*. (2015) studied the effects of dietary garlic at 0, 0.5, 1.0 or 1.5% dosage on hematological parameters, ascites incidence, and growth performance of an ascites susceptible broiler hybrid under both standard and cold temperature conditions. The final body weight decreased, with increasing dietary garlic in the standard temperature, however the FCR did not affect among all groups under both temperature conditions. They concluded that the 0.5% dietary garlic meal effectively decreased systemic hypertension and prevalence of ascites without any negative effects on broiler chicken performance.

Tables 1 and 2 have summarized the reports on the garlic or garlic products effects on the chicken performance and meat characteristics. Thiobarbituric acid reactive substances (TBARS) - are a sign of lipid peroxidation and can be measured using thiobarbituric acid as a reagent.

Table 1 The summary of reports on the effects of garlic or garlic products on chickens feed intake and weight gain as a percentage of control group

Authors-year	Breed	Sex	Length of trial	Garlic products	Dosage	Feed intake Change (%)	Weight gain change (%)
Abdullah *et al.* (2010)	Lohmman	F	42	Dried garlic powder	0.25	3.40 ↓	5.58 ↑
Abdullah *et al.* (2010)	Lohmman	F	42	Dried garlic powder	0.5	1.42 ↑	2.67 ↓
Abdullah *et al.* (2010)	Lohmman	F	42	Dried garlic powder	1	4.08 ↑	3.85 ↓
Ao *et al.* (2011)	Arbor Acres	M	35	Fermented garlic powder	0.1	1.03 ↑	2.03 ↑
Ao *et al.* (2011)	Arbor Acres	M	35	Fermented garlic powder	0.2	2.37 ↑	0.19 ↑
Ao *et al.* (2011)	Arbor Acres	M	35	Fermented garlic powder	0.4	2.05 ↑	1.52 ↑
Choi *et al.* (2010)	Arbor Acres	M	35	Garlic powder	1	0.08 ↑	0.59 ↑
Choi *et al.* (2010)	Arbor Acres	M	35	Garlic powder	3	0.12 ↑	0.75 ↑
Choi *et al.* (2010)	Arbor Acres	M	35	Garlic powder	5	0.11 ↑	0.74 ↑
Cross *et al.* (2002)	Ross 308	F	42	Garlic powder	1	0.82 ↑	-
Dehkordi *et al.* (2010)	Ross 308	M	50	Garlic powder	2	2.32 ↑	-
Hanieh *et al.* (2010)	White Leghorn	M	63	Powder	1	2.20 ↑	-
Hanieh *et al.* (2010)	White Leghorn	M	63	Powder	3	4.40 ↑	-
Jimoh *et al.* (2013)	-		49	Garlic meal	0.05	1.54 ↑	-
Jimoh *et al.* (2013)	-		49	Garlic meal	0.1	9.63 ↑	-
Jimoh *et al.* (2013)	-		49	Garlic meal	0.15	14.79 ↑	-
Jimoh *et al.* (2013)	-		49	Garlic meal	0.2	3.70 ↑	-
Jimoh *et al.* (2013)	-		49	Garlic meal	0.25	5.09 ↓	-
Kirkpinar *et al.* (2014)	Hubbard	Mix	42	Garlic essential oil	0.03	2.55 ↓	3.82 ↓
Kumar *et al.* (2010)	Cobb 400		42	G-PRO naturo	250 ppm	4.77 ↑	-
Olukosi and Dono (2014)	Ross 308	M	21	Garlic meal	1	3.82 ↑	0.09 ↑
Petrolli *et al.* (2012)	Ross 308	M	40	Garlic extract	75 ppm	3.91 ↑	0.77 ↓
Petrolli *et al.* (2012)	Ross 308	M	40	Garlic extract	150 ppm	7.27 ↑	3.38 ↑
Pourali (2010)	Ross 308	M	42	Garlic powder	0.2	15.86 ↑	-
Pourali (2010)	Ross 308	M	42	Garlic powder	0.4	8.47 ↑	-
Pourali (2010)	Ross 308	M	42	Garlic powder	0.6	0.85 ↓	-
Pourali (2010)	Ross 308	M	42	Garlic powder	0.8	4.05 ↓	-
Pourali (2010)	Ross 308	M	42	Garlic powder	1	14.70 ↑	-
Raeesi *et al.* (2010)	Ross 308	Mix	42	Garlic powder	0.5	2.97 ↓	-
Raeesi *et al.* (2010)	Ross 308	Mix	42	Garlic powder	1	3.45 ↑	-
Raeesi *et al.* (2010)	Ross 308	Mix	42	Garlic powder	3	1.35 ↑	-
Rahimi *et al.* (2011)	Ross 308	M	42	Aqueous extract	0.1	0.73 ↑	0.042 ↑
Shams Shargh *et al.* (2012)	Ross 308	M	42	Garlic extract	1000 ppm	2.05 ↓	3.65 ↓
Toghyani *et al.* (2011)	Ross 308	M	42	Garlic powder	0.2	2.69 ↑	-
Toghyani *et al.* (2011)	Ross 308	M	42	Garlic powder	0.4	0.41 ↑	-
Puvača *et al.* (2015)	Hubbard	Mix	42	Garlic powder	0.5	14.21 ↑	-
Puvača *et al.* (2015)	Hubbard	Mix	42	Garlic powder	1	12.52 ↑	-
Zekić *et al.* (2014)	Hubbard	Mix	42	Garlic powder	2	3.57 ↑	-
Sarica *et al.* (2005)	Ross 308	M	42	Garlic powder	0.1	-	4.51 ↓
Varmaghany (2015)	Arian 386	M	42	Garlic bulbs	5 g	7.35 ↑	-
Varmaghany (2015)	Arian 386	M	42	Garlic bulbs	10 g	4.47 ↑	-
Varmaghany (2015)	Arian 386	M	42	Garlic bulbs	15 g	6.42 ↓	-

M: male and F: female.

Table 2 The summary of reports on the effect of garlic and garlic products on the chicken meat characteristics

Authors-year	breed	Sex	Garlic products	Dosage (%)	pH	Cooking loss, (%)	Juiciness, (%)	Shear force, (kg/cm)	Colour coordinates			WHC, (%)	TBARS, mg of MDA/kg-
									L*	a*	b*		
Abdullah *et al.* (2010)	Lohmman	F	Dried garlic powder	0.25	2.30 ↓	3.80 ↑	0.30 ↓	0.30 ↓	2.86 ↑	13.72 ↑	1.06 ↓	1.06 ↓	-
Abdullah *et al.* (2010)	Lohmman	F	Dried garlic powder	0.5	0.33 ↑	2.53 ↑	6.57 ↓	6.57 ↓	0.69 ↓	19.03 ↑	5.35 ↑	5.35 ↑	-
Abdullah *et al.* (2010)	Lohmman	F	Dried garlic powder	1	0.66 ↓	2.53 ↑	8.96 ↓	8.96 ↓	1.35 ↑	9.73 ↓	6.94 ↑	6.94 ↑	-
Ao *et al.* (2011)	Arbor Acres	M	Fermented garlic powder	0.1	0.34 ↓	2.68 ↓	-	-	0.51 ↑	2.93 ↑	4.99 ↑	2.36 ↑	10.42 ↓
Ao *et al.* (2011)	Arbor Acres	M	Fermented garlic powder	0.2	1.54 ↓	2.77 ↓	-	-	4.83 ↑	3.94 ↑	4.55 ↑	3.63 ↑	25.00 ↓
Ao *et al.* (2011)	Arbor Acres	M	Fermented garlic powder	0.4	1.20 ↓	2.73 ↓	-	-	0.27 ↑	9.53 ↑	4.05 ↓	3.09 ↑	33.33 ↓
Choi *et al.* (2010)	Arbor Acres	M	Garlic powder	1	0.66 ↓	-	-	2.43 ↑	1.58 ↓	6.81 ↑	1.18 ↑	1.06 ↑	6.52 ↓
Choi *et al.* (2010)	Arbor Acres	M	Garlic powder	3	2.32 ↓	-	-	6.74 ↓	2.82 ↓	7.75 ↑	5.59 ↑	2.28 ↑	15.22 ↓
Choi *et al.* (2010)	Arbor Acres	M	Garlic powder	5	3.81 ↓	-	-	1.35 ↓	3.12 ↓	8.13 ↑	7.65 ↑	3.57 ↑	28.26 ↓
Kirkpinar *et al.* (2014)	Hubbard	Mix	Garlic essential oil	0.03	0.68 ↓	-	27.21 ↑	-	0.99 ↓	4.41 ↑	0.70 ↓	-	17.24 ↓
Kim *et al.* (2009)	Arbor Acre	M	Garlic dried	2	0.51 ↓	1.36 ↓	3.90 ↑	9.43 ↓	-	-	-	3.58 ↑	6.12 ↓
Kim *et al.* (2009)	Arbor Acre	M	Garlic dried	4	2.69 ↓	1.50 ↑	4.36 ↑	20.86 ↓	-	-	-	1.71 ↑	6.12 ↓

M: male and F: female.
L*: lightness; a*: yellowness; b*: redness; WHC: water-holding capacity and TBARS: thiobarbituric acid reactive substances.

As reactive oxygen species (ROS) have very short half-lives, they are complex to determine directly. As an alternative, TBARS are measured as an oxidative stress indicator (Pryor, 1991).

Laying hen performance

In the study of Yalcin *et al*. (2006), the diets containing 0.5 or 1% garlic meal increased egg weight without adverse effects on performance and egg traits of laying hens. However, in another study, Yalcin *et al*. (2007) found that body weight, feed intake, and feed conversion ratio were not influenced by the dietary garlic. These authors suggested that the strong odor of garlic does not act as a deterrent of feeding. Reddy *et al*. (1991) observed that egg production; egg mass, body weight, feed consumption, and feed efficiency were not affected during the 8 weeks that 0.02% garlic oil was fed to the Babcock B-300 strain.

Chowdhury *et al*. (2002) evaluated the effect of dietary garlic on overall performance in different layer hen strains. Thirty-six, 28-wk-old, Hisex Brown, Isa Brown, Lohmann, Starcross, Babcock, and Starcross-579 strains were fed diets containing 0, 2, 4, 6, 8 or 10% sun-dried garlic meal for 6 weeks. They found no differences among diets or strains in egg weight, egg mass, feed consumption, feed efficiency, and body weight gain over 6 weeks. Yolk weight, however, responded quadratically with increasing levels of dietary garlic. Organoleptic effects of garlic also have evaluated. Birrenkott *et al*. (2000), found no differences in color and flavor in eggs from hens consuming up to 3% dietary garlic powder.

CONCLUSION

Herbal plants have considerable promise in health promoting effects in poultry, and because of the these substances are considered as potential alternatives to antibiotics, there is no time delay for discovering and testing their therapeutic properties. In general the majority of the data generated from evaluation of garlic and garlic derivatives in poultry, have confirmed improvement in performance, cholesterol reduction in blood and products and also antimicrobial properties. Therefore, garlic show promising potential for applications in organic and conventional poultry production. However, there are data gaps which need to be filled. Due to the complexity of the active compounds of garlic, a concentration is needed in order to find the best usage recommendation in different category of poultry.

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