The effects of dietary garlic powder on performance, egg yolk and serum cholesterol concentrations in laying quails

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ABSTRACT: This study was conducted to investigate the effects of garlic powder on the performance, egg traits, egg cholesterol and serum parameters of laying Japanese quails. One hundred and twenty 10-weeks-old quails were allocated to four dietary treatments. Quails were caged individually and fed diets supplemented with 0 (control), 1, 2, 4% garlic powder for 12 weeks. There were significant ($P < 0.05$) differences among the diets in feed consumption, feed efficiency and egg production as averaged over 12 weeks. The better values for these parameters were obtained from the 1% garlic powder supplemented group. Garlic powder addition did not significantly affect egg yolk index, egg shell weight and egg shell thickness. However, there were significant differences ($P < 0.05$) in egg albumen index, egg shell index and Haugh unit. There was a significant ($P < 0.05$) reduction in the egg yolk cholesterol concentration when the dietary level of garlic powder was increased from 0 to 4 g/kg. Plasma high density lipoprotein (HDL) cholesterol concentrations increased ($P < 0.05$) with increasing levels of dietary garlic powder. Plasma cholesterol ($P < 0.05$) and triglyceride ($P < 0.05$) concentration decreased with garlic powder supplementation. It was concluded that garlic powder in the diet of laying quails reduced the plasma and egg yolk cholesterol concentration.

Keywords: garlic powder; laying quail; laying performance; egg traits; serum parameters

Garlic (*Allium sativum*) and garlic supplements are consumed in many cultures for their hypolipidemic, antiplatelet and procirculatory effects (Amagase et al., 2001). In addition to these benefits, some garlic preparations have been reported to possess hepatoprotective, immune-enhancing, anticancer and chemopreventive activities. Some preparations appear to be antioxidative, whereas others may stimulate oxidation (Imai et al., 1994). The cardiovascular-protective effects of garlic have also been evaluated extensively in recent years (Yeh and Liu, 2001). In animal experiments, garlic extracts have been shown to lower plasma lipid and cholesterol in rats (Chi, 1982; Mathew et al., 1996), rabbits (Bordia and Verma, 1980) and chickens (Qureshi et al., 1983a,b). Moreover, a number of intervention studies have similarly shown that garlic and garlic preparations significantly reduced plasma lipids, especially total cholesterol and low density lipoprotein (LDL) cholesterol in humans (Jain et al., 1993; Steiner et al., 1996). However, recent studies suggested that not all garlic preparations may be hypocholesterolaemic (Simon et al., 1995; Isaacsohn et al., 1998; McCrindle et al., 1998). Although the reason for these inconsistencies is not readily apparent, it is worth noting that garlic contains a variety of organosulphur compounds. Some of the sulphur compounds such as allicin, ajoene, S-allylcysteine, diallyl disulphide, S-methylcysteine sulphoxide and S-allylcysteine sulphoxide may be responsible for the therapeutic properties of garlic (Chi et al., 1982). Other contributing factors may include the subject recruitment, duration of experiment, dietary control, lifestyle and methods of lipid analyses (Warshafsky et al., 1993; Silagy and Neil, 1994).

Allicin has been proposed as the active compound produced by garlic responsible for health promotion and hypocholesterolaemic benefits (Lawson, 1998). It can reduce the levels of serum cholesterol, triglyceride and LDL (Adler and Holub, 1997). In terms of the mechanism of action, it reduces cholesterol synthesis, inhibits fatty acid synthesis and platelet aggregation and prevents thrombosis. Allicin has also been used for treating and preventing cardiovascular diseases (Tanamai et al., 2004). Although allicin is often emphasised in dehydrated powder, many preparations contained no allicin, possibly reflecting its instability (Yan et al., 1993).

The mechanism by which garlic or garlic preparations reduce plasma lipids has not been fully investigated. Animal studies, however, have shown that garlic supplementation in the diet depressed the hepatic activities of lipogenic and cholesterogenic enzymes such as malic enzyme, fatty acid synthase, glucose-6 phosphate dehydrogenase (Qureshi et al., 1983a) and 3-hydroxy-3-methyl-glutaryl-CoA (HMG-CoA) reductase (Qureshi et al., 1983a,b; Youn et al., 1996). Qureshi et al. (1983b) reported that significant decreases in hepatic HMG-CoA reductase (79–83%), cholesterol 7α-hydroxylase (43–51%), fatty acid synthetase (17–29%) activities accompanied the feeding of the petroleum ether, methanol and water-soluble fractions of garlic.

Garlic powder is thought to retain the same ingredients as raw garlic, however, the proportions and amounts of various constituents differ significantly (Iberl et al., 1990).

The aim of the study was to investigate if the supplementation of garlic powder to the diet may assist in reducing cholesterol in serum and egg yolk in laying quails.

MATERIAL AND METHODS

Animals, diets and feeding treatments

One hundred and twenty 10-weeks-old laying Japanese quails (*Coturnix coturnix japonica*) were used in this study. Laying quails were caged individually and provided with 16 hours of light daily. The quails were divided into four dietary groups with 30 quails in each. The diets were formulated as isocaloric and isonitrogenous and met or exceeded the nutrient requirements for laying quails (NRC, 1994). The composition of the experimental diets is shown in Table 1. Diets were supplemented with 0 (control), 1, 2 or 4% of garlic powder which was purchased commercially from Arifoglu Spices and Food Limited Inc., Istanbul, Turkey.

Feed and water were provided for *ad libitum* consumption. The experiment was conducted for 12 weeks.

Growth parameters

Laying quails were weighed at the beginning and end of the experiment. Feed consumption was recorded weekly and feed efficiency was calculated during the 12-week experimental period. The value of feed efficiency was calculated as kg feed/kg egg. Eggs were collected daily and egg weights were determined. Egg production was calculated on a hen-day basis. Mortality was recorded as it occurred.

Throughout the experiment, 24 eggs were collected from each group at three-week intervals to determine egg traits. Individual eggs were weighed and their shape index and shell weight were measured. Yolk height and width and albumen height, width and length were determined. The Haugh unit was calculated from the weight and height of the albumen of the egg using the formula suggested by Haugh (1937).

Yolk index was calculated as the ratio of average yolk height to average yolk width following the removal of yolk from the albumen. Egg shape index was calculated for each egg as average width of egg/average length of egg × 100. The albumen index was calculated by dividing the average height of thick albumen by its width.

Egg yolk cholesterol and serum analysis

Fifteen eggs were collected from each group in the middle and at the end of the experiment to determine their cholesterol concentration. Eggs were hard-boiled to separate the yolk. Cooked yolk weights were recorded. Cooked yolk was extracted and subsequently analysed for cholesterol concentration on a per yolk basis. The cholesterol content of the egg yolk was determined using the methods of Biochemical Analysis and Food Analysis (1989).

Table 1. Composition of experimental diets (%)

Ingredient	Garlic powder in diet (%)			
	0	1	2	4
Maize	60.865	59.714	57.963	54.001
Soybean Meal	17.055	13.37	11.331	8.392
Sunflower meal	3.769	4.011	3.782	2.983
Maize gluten	3.156	4.633	4.692	3.796
Full-fat soybean	2.122	4.139	7.104	13.763
Chicken meal	5.000	5.000	5.000	5.000
Bone meal	3.084	3.106	3.106	3.090
Marble powder	4.589	4.433	4.431	4.426
Sodium bicarbonate	0.177	0.203	0.198	0.166
Sodium chloride	0.104	0.084	0.087	0.109
DL-methionine	0.061	0.050	0.054	0.072
Lysine	0.000	0.058	0.053	0.000
Garlic powder	0.000	1.000	2.000	4.000
Vitamin premix*	0.100	0.100	0.100	0.100
Mineral premix**	0.100	0.100	0.100	0.100
Calculated nutrient content				
ME (MJ/kg)	11.71	11.71	11.71	11.71
Crude protein	20.00	20.00	20.00	20.00
Crude fibre	4.00	4.00	4.00	4.00
Crude fat	4.16	4.50	5.00	6.13
Calcium	2.50	2.50	2.50	2.50
Available phosphorus	0.35	0.35	0.35	0.35
Methionine	0.45	0.45	0.45	0.45
Met and Cys	0.76	0.76	0.76	0.76
Lysine	1.00	1.00	1.00	1.00
Sodium	0.15	0.15	0.15	0.15
Sodium chloride	0.25	0.23	0.23	0.24

*each kg of vitamin premix contains: 15 000 000 IU retinol; 5 000 000 IU cholecalciferol; 100 000 IU tocopherol; 5 000 IU phytonadione; 4 000 IU thiamine; 10 000 IU riboflavin; 5 000 IU pantothenic acid; 30 IU cyanocobalamin 50.000 mg L-ascorbic acid; 60 000 mg niacin; 18.000 mg calcium D-pantothenate; 2 000 mg folic acid; 250 mg biotin
**each kg of mineral premix contains: 100 000 mg manganese; 80 000 mg iron; 100 000 mg zinc; 10 000 mg copper; 200 mg cobalt; 1 500 mg iodine 200 mg selenium
*each kg of feed contains 1 g vitamin premix and 1 g mineral premix

Fifteen quails were randomly selected in the middle and at the end of the experiment to determine serum parameters. Blood samples were collected into tubes containing EDTA, which acts as an anticoagulant. Plasma samples were separated by centrifugation at 2 000 rpm for 10 minutes. Plasma

Table 2. Effects of garlic powder on the performance of laying quails

Parameters	Garlic supplementation (%)				
	0	1	2	4	SED
Body weight at the start (g)	369.57	368.82	371.07	370.07	2.872
Body weight at the end (g)	381.47	386.87	391.90	391.10	5.042
Feed consumption (g/day per bird)	44.65^{b}	43.28^{a}	44.44^{b}	44.11^{ab}	0.157
Egg weight (g)	13.55	13.58	13.62	13.50	0.032
Feed efficiency (kg feed/kg eggs)	3.75^{b}	3.52^{a}	3.78^{b}	3.85^{b}	0.027
Egg production (%)	90.23^{b}	92.49^{a}	89.37^{bc}	87.74^{c}	0.390

^{abc}means with different superscripts within the line are significantly different ($P < 0.05$)

SED = standard error of the difference between the means

cholesterol, triglyceride, HDL, LDL, total lipid and glucose concentrations in plasma and plasma fractions were measured using a Shimadzu 1200 spectrophotometer and kits and calibrators from Diasis Diagnostic Systems (Turkey).

Statistical analysis

Data were statistically analysed using the One Way ANOVA procedure of SPSS (Release 11.5) with Duncan's Multiple Range Test to identify significant differences between the means.

RESULTS AND DISCUSSION

Layer performance

The effects of garlic powder on the performance of laying quails are shown in Table 2. The supplementation of garlic powder had no significant effect ($P > 0.05$) on egg weight and body weight. In agreement with the present study, Khan et al. (2008) and Chowdhury et al. (2002) reported that egg weight was not affected by 0, 2, 6 or 8% garlic powder ($P > 0.05$) or by 0, 2, 4, 6, 8 or 10% garlic paste ($P > 0.05$) as averaged over the six-week period respectively. In contrast, Yalcin et al. (2006) found that egg weight increased ($P < 0.01$) when laying hens were fed 5 and 10 g/kg garlic powder supplementation.

Supplementation of diets with garlic powder had significant ($P < 0.05$) effects on feed consumption, feed efficiency and egg production over the 12-week period. While the best values for these parameters were obtained from the 1% garlic powder supplemented group, the 4% garlic powder supplemented group had the poorest values for feed efficiency and egg production. In agreement with the present study, Khan et al. (2007) reported that egg production and feed consumption were affected during the six weeks in which 0, 2, 6 or 8% garlic powder was fed to the laying hens. In contrast, Chowdhury et al. (2002) and Reddy et al. (1991) reported that feed consumption, feed efficiency and egg production were not affected by supplements of 0, 2, 4, 6, 8 or 10% garlic paste ($P > 0.05$) as averaged over the 6-week period or by supplements of 0.02% garlic oil over eight weeks. The reason for this difference might be the duration of the experiment and the fact that different garlic products were used.

The effects of garlic powder on the egg traits of laying quails are shown in Table 3. The results show that the inclusion of garlic powder had no significant effect ($P > 0.05$) on egg yolk index, egg shell weight and egg shell thickness. However, there were significant differences ($P < 0.05$) in egg albumen index, egg shell index and Haugh unit. The effect of dietary garlic on egg traits was reported previously by Yalcin et al. (2006). In contrast to the present study, Yalcin et al. (2006) reported that the supplementation of garlic powder had no significant effect ($P > 0.05$) on egg albumen index, egg shell index and egg Haugh unit values when laying hens were fed 5 and 10 g/kg garlic powder for 22 weeks. The reason for these differences might be the low level of garlic powder used.

In the present study, the Haugh unit decreased with an increasing level of garlic powder supple-

Table 3. Effects of garlic powder on egg traits of laying quails

Parameters	Garlic supplementation (%)				
	0	1	2	4	SED
Egg albumen index	9.88[a]	9.85[a]	9.09[b]	8.54[b]	0.105
Egg yolk index	41.98	42.73	41.89	42.24	0.170
Egg shell index	78.45[a]	78.90[a]	78.13[ab]	77.45[b]	0.148
Egg shell weight (g)	1.71	1.75	1.74	1.76	0.012
Egg Haugh unit	85.62[a]	85.65[a]	84.51[a]	82.97[b]	0.356
Egg shell thickness (µm)	0.212	0.212	0.210	0.210	0.001
Egg yolk weight (g)	4.62	4.48	4.45	4.55	0.029
Egg yolk cholesterol (mg/g)	28.90[c]	23.30[b]	20.35[b]	15.49[a]	0.768

[abc]means with different superscripts within the line are significantly different ($P < 0.05$)
SED = Standard error of the difference between the means

mentation. In contrast, Lim et al. (2006) reported that with increasing dietary garlic powder, the Haugh unit linearly increased after two weeks of storage.

Egg yolk weight was not affected by dietary garlic powder in the present study. In experiments by Yalcin et al. (2006) yolk weight did not differ significantly ($P > 0.05$) among dietary treatments. However, Mottaghitalab and Taraz (2002) showed that the inclusion of 0, 5, 10 and 15 g/kg garlic powder significantly ($P < 0.01$) decreased yolk weight. Chowdhury et al. (2002) also reported that yolk weight responded quadratically ($P < 0.05$) in weeks three and four to increasing levels of sun-dried dietary garlic paste.

Egg yolk cholesterol (mg/g)

Egg yolk cholesterol concentrations per gram of yolk decreased linearly ($P < 0.05$) with increasing levels of garlic powder (Table 3). These results indicate that, compared with the control diet, mean egg yolk cholesterol levels dropped by 19.37, 29.58 and 46.40% in the 1, 2 or 4% garlic powder supplemented diets, respectively. Chowdhury et al. (2002) reported that cholesterol concentration per gram of yolk decreased linearly ($P < 0.01$) with increasing levels of sun-dried dietary garlic paste. Dietary garlic paste at 2, 4, 6, 8 or 10% reduced egg yolk cholesterol on average by 5, 9, 14, 20 and 24%, respectively. Khan et al. (2007) also reported that dietary garlic at 2, 6 or 8% reduced egg yolk cholesterol, on average over six weeks, by 5.70, 14.28 and 23.57%, respectively, as compared to the control diet.

The significant ($P < 0.01$) reduction in egg yolk cholesterol confirms results from previous studies (Mottaghitalab and Taraz, 2002; Yalcin et al., 2006; Khan et al., 2008).

Serum parameters (mg/dl)

The effects of garlic powder supplementation on serum parameters of laying quails are shown in Table 4. Garlic powder supplementation did not affect the plasma total lipid and triglyceride concentration significantly ($P > 0.05$). However, compared with the control diet, 1, 2 or 4% garlic powder reduced the total lipid concentration of plasma by 1.60, 14.23 and 16.31%, and plasma triglyceride concentration by 3.77, 6.01 and 8.85%, respectively. Total triglyceride levels were reduced by garlic powder supplementation at the levels of 1% and 2% in laying hens but this was not significant ($P > 0.05$) (Azeke and Ekpo, 2008). In contrast to this study, Yalcin et al. (2006) reported a significant decrease ($P < 0.05$) in serum triglycerides by the supplementation of garlic powder. Youn et al. (1996) also reported that serum triglycerides were lowered significantly ($P < 0.05$) by supplementing garlic powder to the diet.

In this study, 1, 2 or 4% garlic powder reduced the plasma cholesterol concentration on average

Table 4. Effects of garlic powder on serum parameters of laying quails (mg/dl)

Parameters	Garlic supplementation (%)				
	0	1	2	4	SED
Glucose	172.06	149.27	147.64	149.65	8.083
Total lipid	2 364.33	2 326.29	2 027.84	1 978.57	70.124
Plasma cholesterol	171.46^{c}	162.03^{c}	132.07^{b}	87.87^{a}	5.986
Plasma triglyceride	337.57	324.84	317.27	307.67	5.676
HDL	51.86^{c}	105.72^{b}	136.67^{a}	144.44^{a}	6.793
LDL	31.86^{b}	43.27^{a}	37.69^{ab}	40.60^{a}	1.298

^{abc}means with different superscripts within the line are significantly different ($P < 0.05$)
SED = Standard error of the difference between the means

by 5.49, 22.97 and 48.75%, respectively, compared with the control diet. Our results for plasma cholesterol concentration agree with Yalcin et al. (2006), who reported that the levels of serum cholesterol ($P < 0.05$) were significantly reduced by garlic powder supplementation. Similarly, Qureshi et al. (1983b) also reported that the serum cholesterol concentration in White Leghorn pullets was reduced from 20 to 25% by supplementations of garlic paste, solvent extracted garlic paste and commercial garlic oil. The reduction of serum and egg yolk cholesterol observed when garlic paste was fed might be due to the reduction of synthetic enzyme activity (Chowdhury et al., 2002). Qureshi et al. (1983a) reported a dose-dependent inhibition of hepatic HMG-CoA reductase, cholesterol 7α-hydroxylase and fatty acid synthetase when chickens were fed polar fractions of garlic powder equivalent to 1, 2, 4, 6 and 8% of fresh garlic paste. Konjufca et al. (1997) reported that feeding 3% commercial garlic powder reduced the activities of HMG-CoA reductase and cholesterol 7α-hydroxylase by 40%.

The levels of plasma HDL-cholesterol in laying quails fed diets containing 1, 2 or 4% garlic powder were higher than those of the control diet ($P < 0.05$). Interestingly, LDL-cholesterol levels increased in the garlic powder supplemented groups ($P < 0.05$). In contrast with this study, Lim et al. (2006) reported that HDL-cholesterol was not influenced by dietary garlic powder supplementation. Qureshi et al. (1983b) also reported that low density lipoprotein cholesterol decreased by 28–41%, but HDL-cholesterol failed when laying hens were fed a control diet based on maize and soybean meal or an experimental diet containing either 3.8% garlic paste or a solvent extract of garlic paste, the residue or commercial garlic oil for four weeks. Lim et al. (2006) also reported that HDL-cholesterol was not influenced when layers received a diet containing 0, 1, 3 and 5% garlic powder for five weeks.

In conclusion, the results of this study clearly demonstrate that garlic powder has potential benefits as a feed additive in reducing plasma and egg cholesterol in laying quails. Garlic powder up to 4% can be used as a hypocholesterolaemic agent in practical laying quail diets when the low cholesterol egg is desirable in the diet.

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Received: 2009–05–15
Accepted after corrections: 2009–09–30

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