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Changes of Cholesterol and Selenium Levels, and Fatty Acid Composition in Broiler Meat Fed with Garlic Powder

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Abstract Effect of garlic on cholesterol and selenium (Se) levels, and fatty acid composition in the broiler chicks (Indian River) fed diet containing 0, 2, 4, 6, and 10% lyophilized garlic powder (GA) for 6 weeks were determined. Supplementation of garlic powder significantly decreased cholesterol level in broiler compared to the control (p<0.05). Se levels were not significantly different (p>0.05) among treatment groups. Percentages of $C_{16:0}$ and $C_{18:1}$ were gradually decreased ($C_{16:0}$; 20.62% of total fatty acid in the control to 17.71% in 10% GA; $C_{18:1}$;34.08% in the control to 30.71% in 10% GA), while that of $C_{18:2}$ was increased from 28.69% in the control to 35.89% of 10% GA diet (p<0.01). These results demonstrate some active components of garlic reduce cholesterol level and affect fatty acid metabolism.

Keywords: garlic, broiler meat, fatty acid, cholesterol, selenium

Introduction

Garlic (*Allium sativum L.*), a flavoring agent, has been reported to lower cholesterol levels, as well as have a beneficial effect on a number of physiological disorders leading to increased cardiovascular risk (1-3). Recent clinical study reported that garlic supplementation significantly reduced total serum cholesterol and triglycerides, while increased high density lipoprotein-cholesterol in patients with coronary artery disease. In addition, several studies have shown that garlic contains active components, which lower blood glucose and lipid levels in humans (4, 5) and animals (4, 6, 7). Garlic also contains many health-enhancing functional components such as Ge, Se, diallyl disulfide, dipropyl disulfide, allicin, and scordinin, among which Se is known to be an essential trace mineral and a component of glutathione peroxidase (GSH-Px, EC.1.11.1.9), which exerts antioxidant effect in the body and protects cellular or subcellular membranes from oxidative damages. Se deficiency results in the inhibition of prostacyclin synthase, an enzyme responsible for prostacyclin formation, due to the elevated levels of lipid hydroperoxides (8), although the relative importance of peroxidases including GSH-Px in destroying lipid hydroperoxides, however, still needs to be clarified. In addition, the greater susceptibility to mastitis as a direct result of Se deficiency in dairy cattle has been documented (9, 10). GSH-Px actvity has been proposed as the best estimate of Se status because the enzyme is a physiologically functional form of Se (11). Several reports have been made that the activity of GSH-Px is directly dependent on the dietary Se intake within a certain range (12, 13). Therefore, in this study, effects of feed containing garlic powder on the levels of cholesterol and Se, and on the composition of fatty acids in broiler chickens were examined.

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Materials and Methods

Experimental animals Three hundred male Indian River broiler chickens (1-day-old) were fed commercial diet until 170 g of body weight was reached, placed randomly into five groups, and fed experimental diet for 6 weeks. The chickens were housed in a battery brooder with wire floors. Initial room temperature was 35±1°C, and lowered by 2°C every week until 24°C was reached. Body weight and amount of feed consumptions were determined every week. The chickens were fed the assigned diet and water *ad libitum*.

Diets Dietary treatments (control, 2% garlic powder, 4% garlic powder, 6% garlic powder, and 10% garlic powder treatments) were prepared by adding ground lyophilized garlic powder to the feed, and were fed to the respective groups for 6 weeks (Table 1 and 2). Energy requirements of the experimental diet were divided into first and latter periods. The energy of feed for first and latter periods was controlled to 3,200 kcal/kg, and the contents of crude protein were 23 and 20%, respectively. Feed containing 0.2% Cr_2O_3 was fed at 3 and 6 weeks after feeding experimental diet to evaluate digestibility. Nutrients and fatty acid composition of feed are shown in Tables 3-5. Se content of garlic was 35.5 μg/100 g dry mass. Feed efficiency was calculated by dividing weight gain by the amount of feed intake.

Meat production Broilers fed experimental diet for 6 weeks were killed and deboned to obtain meat. The obtained meat was vacuum-packaged in Ny/Pe film and stored at -15°C.

Measurements of cholesterol, triglycerides, and creatine Plasma total cholesterol concentrations were

Table 1. Compositions of experimental diets given to broilers (starter)

Ingredients (%)	Dietary treatments Garlic (%)				
	0 (control)	2	4	6	10
Corn, yellow	61	58	55	53	48
Corn gluten meal	7.5	7.5	7.5	7.5	7.5
Soybean meal	14	14	14	14	14
Fish meal	11	11	11	11	11
Wheat bran	2.5	2.5	2.5	2.5	2.5
Garlic powder	-	2	4	6	10
Soybean oil	2	3	4	4	5
NaCl	0.3	0.3	0.3	0.3	0.3
Tri-Ca-phosphate	0.7	0.7	0.7	0.7	0.7
Limestone	0.5	0.5	0.5	0.5	0.5
Vit +Min mix[1)]	0.5	0.5	0.5	0.5	0.5

[1)]Contains; Vit A 5,000,000IU; Vit D_3 1,000,000IU; Vit E 2,000IU; Vit K_3 400 mg; Vit B_1 250 mg; Vit B_2 800mg; Vit C 400 mg; Fe 2,000 mg; Cu 20 mg; Vit B_6 2,000 mg; pantothenic acid-Ca 2000 mg; Folic acid 250 mg; Zn 160 mg; Mn 3,600 mg; Co 40 mg; I 80 mg; Niacin 400mg/ 1 kg of pre-mix.

Table 2. Compositions of experimental diets given to broilers (finisher)

Ingredients (%)	Dietary treatments Garlic (%)				
	0 (control)	2	4	6	10
Corn, yellow	62	59	57	55	50
Corn gluten meal	5.5	5.5	5.5	5.5	5.5
Soybean meal	13.5	14.0	13.7	13.5	14.0
Fish meal	8.5	8.5	8.5	8.5	8.5
Wheat bran	5.0	5.0	5.0	5.0	5.0
Garlic powder	-	2.0	4.0	6.0	10.0
Soybean oil	3.0	3.5	3.8	4.0	4.5
NaCl	0.5	0.5	0.5	0.5	0.5
Tri-Ca-phosphate	0.7	0.7	0.7	0.7	0.7
Limestone	0.5	0.5	0.5	0.5	0.5
Vit +Min mix[1)]	0.8	0.8	0.8	0.8	0.8

[1)]Contains; Vit A 5,000,000IU; Vit D 1,000,000IU; Vit E 2,000IU; Vit K_3 400mg; Vit B_1 250 mg; Vit B_2 800mg; Vit C, 400 mg; Fe 2,000 mg; Cu 20 mg ; Vit B_6 2,000 mg; pantothenic acid-C, 2000 mg ; Folic acid 250 mg; Zn, 160 mg; Mn 3,600 mg; Co 40 mg; I 8 0mg; Niacin 400 mg/1kg of pre-mix.

Table 3. Chemical Compositions of experimental diets given to broilers

Chemical Composition (%)	Dietary treatments Garlic (%)				
	0 (control)	2	4	6	10
Initial -3week					
Protein	22.55	22.18	22.41	22.88	22.58
Organic matter	94.25	94.35	94.44	94.16	94.41
Crude fiber	4.46	4.79	4.75	4.71	4.42
Ether extract	5.88	5.95	6.72	5.96	6.19
Ca	1.05	1.08	1.11	1.07	1.01
P	0.82	0.81	0.82	0.79	0.83
4week - 6week					
Protein	20.10	20.33	19.91	20.59	20.63
Organic matter	95.40	95.22	95.43	95.45	95.18
Crude fiber	4.20	4.20	3.75	3.80	4.30
Ether extract	6.37	6.37	6031	6.49	6.61
Ca	0.87	0.85	0.83	0.80	0.80
P	0.58	0.58	0.67	0.62	0.65
Se*	10.42	10.03	13.41	13.96	15.61

*µg/100 g DM (Dry Mass).

Table 4. Fatty acid compositions of experimental feed given to broilers (starter)

Fatty acids (%)	Dietary treatments Garlic (%)				
	0 (control)	2	4	6	10
C 14:0	1.75^a	3.19^c	2.87^b	2.72^b	3.17^c
C 16:0	17.79^a	17.69^a	16.84^b	15.75^c	15.86^c
C 16:1	2.44^a	2.00^b	1.73^c	1.68^c	1.57^c
C 18:0	3.89	3.64	3.82	3.83	4.02
C 18:1	23.79	22.37	23.18	22.99	23.78
C 18:2	43.40^b	42.75^c	44.35^b	45.49^a	43.51^b
C 18:3	3.85^a	6.40^c	5.72^b	5.19^b	6.20^c
C 20:5	0.99^a	0.79^b	0.65^b	0.93^a	0.55^b
C 22:6	2.09^a	1.18^b	0.84^c	1.42^b	1.33^b
SAF[1)]	23.43^b	24.52^a	23.53^b	22.30^c	23.06^b
MUFA[2)]	26.23^a	24.36^c	24.1^c	25.35^b	25.35^b
PUFA[3)]	50.34^a	51.12^b	51.56^{ab}	51.59^b	51.59^b

[1)]Saturated fatty acid
[2)]Monounsaturated fatty acid
[3)]Polyunsaturated fatty acid.
[a,b,c]Means within the same row with different superscripts are significantly different (p< 0.05).

Table 5. Fatty acid compositions of experimental feed given to broilers (finisher)

Fatty acids (%)	Dietary treatments Garlic (%)				
	0 (control)	2	4	6	10
C 14:0	1.69^a	1.83^a	2.90^b	3.44^b	4.32^c
C 16:0	16.17^b	15.34^c	17.30^a	16.43^b	14.79^c
C 16:1	1.71^a	1.27^b	1.37^b	1.64^a	1.25^b
C 18:0	3.67^b	3.97^a	3.67^b	3.79^b	3.79^b
C 18:1	23.57^b	24.07^a	23.13^c	23.57^b	22.91^a
C 18:2	47.05^a	46.72^a	45.63^b	45.51^a	45.71^b
C 18:3	4.62^b	5.49^a	5.26^a	4.72^b	5.51^a
C 20:5	0.83^a	0.71^b	0.41^c	0.48^c	0.85^a
C 22:6	0.70^b	0.60^b	0.34^c	0.43^c	0.86^a
SAF[1)]	21.53^c	21.14^c	23.87^a	23.66^a	22.91^a
MUFA[2)]	25.28^a	25.35^a	24.50^b	25.20^a	24.16^b
PUFA[3)]	53.20^a	53.51^a	51.63^c	51.14^c	52.93^b

[1)]Saturated fatty acid
[2)]Monounsaturated fatty acid
[3)]Polyunsaturated fatty acid.
[a,b,c]Means within the same row with different superscripts are significantly different (p< 0.05).

determined using the Wako kit (Wako Pure Chemical Ind. Ltd, Osaka, Japan). Plasma triglycerides were analyzed enzymatically using Tri-Es (Harleco, Division of American Hospital Supply Co., Gibson, NJ, USA). Plasma creatine concentrations were determined using the Sigma kit (Sigma-Aldrich Co., St. Louis, MO, USA).

Measurement of selenium Concentration of Se in broiler meat was determined by the procedure described in earlier studies (14) and Inductively Coupled Plasma Spectrometer (Jobin Yvon, JY 38 Plus, France) was used.

Fatty acid analysis Fatty acid composition was determined by the method of Lepage and Roy (15) using acetyl chloride as the methylation reagent.

Statistical analysis Differences among dietary treatments were analyzed statistically using the analysis of variance technique and Duncan's New Multiple Range Test was used for the comparison of treatment means (16).

Results and Discussion

The initial average weight of the broilers was 170±2.0 g, and values of weight gain and feed efficiency over the entire feeding period are shown in Table 6. No significant differences in weight gain and no significant effects of garlic-added feed on weight gain and feed efficiency were observed during the entire experimental period.

Changes in cholesterol and triglyceride levels in blood plasma Effects of experimental feed containing GA on the levels of cholesterol and triglyceride in broiler plasma after 6 weeks are shown in Table 7. Contents of total plasma cholesterol decreased significantly with the addition of GA in feed, with 10% GA treatment resulting in the lowest level of total cholesterol and no significant difference were observed among 2, 4, and 6% GA treatments (p>0.05). No significant differences were observed as well in the levels of triglycerides among the treatment groups (p>0.05). According to Chang and Johnson (17), contents of total lipids in serum, triglyceride and free fatty acid in livers decreased in garlic powder-fed rats. They suggested that the main functional components of garlic were allyl propyl disulfide and diallyl disulfide. Chi *et al.* (18) also reported that the plasma cholesterol, triglyceride, and VLDL-cholesterol levels decreased, whereas HDL-cholesterol level increased, with garlic supplementation in the rats fed cholesterol and lard diets. They observed that the excretion of neutral sterol was increased by feeding of the garlic.

Compared to the control, the level of creatine were increased with the addition of 6% GA in feed (p<0.01) (Table 7). Creatine, an energy storage molecule in the muscle, is used as an index of kidney function; increase in the concentration of creatine in the blood plasma to 20~40 mg/L, could be an indication of damaged kidney. These results show that GA the in feed at the level supplemented did not cause kidney damage.

Changes in nutrient contents of broiler meat Table 8 shows the changes in nutrient contents of the broiler meat after feeding of GA-containing feed for 6 weeks. Content of total cholesterol in 100 g meat after feeding of 10% GA was significantly decreased compared to the control (p< 0.05). However, no significant differences were observed among 2, 4, and 6% GA treatment groups (p>0.05). Changes in the moisture content after feeding of 10% GA feed were significantly higher than those of other treatments (p< 0.01). However, 2 and 6% GA feed treatments resulted in lower moisture content than the control. Content of ether extract was increased by increasing GA content in the feed up to 6%; only 10% GA treatment showed lower content of ether extract than the control. These results suggest that

Table 6. Effect of garlic on weight change and feed efficiency of broiler during 6 weeks feeding of garlic diet

Item	Dietary treatments				
	Garlic (%)				
	0 (control)	2	4	6	10
Weight gain (g)					
Initial-1 wk feeding	246.8±3.8^{A}	240.8±4.0^{AB}	246.5±5.1^{A}	247.7±5.2^{A}	236.5±4.9^{B}
1 wk-2 wk feeding	297.3±8.3^{a}	334.8±10.1^{b}	325.8±9.5^{ab}	313.8±9.2^{ab}	312.8±9.4^{ab}
2 wk-3 wk feeding	389.7±11.2	383.0±12.3	395.0±15.1	372.0±13.5	375.0±16.2
3 wk-4 wk feeding	849.0±28.0	849.7±26.5	828.2±25.1	830.0±29.1	853.8±28.5
4 wk-5 wk feeding	523.8±19.9	560.0±26.5	508.8±29.3	484.7±27.7	502.5±22.8
5 wk-6 wk feeding	381.2±21.6	404.8±19.6	375.7±24.5	366.0±17.9	432.3±25.0
Feed efficiency					
Initial-1 wk feeding	0.92±0.01^{a}	0.95±0.08^{a}	0.87±0.06^{b}	0.88±0.04^{b}	0.90±0.92
1 wk-2 wk feeding	2.20±0.08^{A}	1.96±0.09^{B}	2.01±0.06^{AB}	2.11±0.04^{AB}	2.05±0.05^{AB}
2 wk-3 wk feeding	2.21±0.06	2.32±0.08	2.11±0.04	2.25±0.07	2.23±0.06
3 wk-4 wk feeding	1.15±0.02	1.24±0.05	1.19±0.03	1.18±0.06	1.15±0.04
4 wk-5 wk feeding	2.28±0.14	2.19±0.12	2.34±0.13	2.43±0.18	2.48±0.20
5 wk-6 wk feeding	3.56±0.19	3.46±0.21	3.61±0.24	3.68±0.22	3.59±0.18

^{A,B}Means within the same row with different superscripts are significantly different (p< 0.05).
^{a,b}Means within the same row with different superscripts are significantly different (p< 0.01).

Table 7. Effect of garlic on content of cholesterol, triglyceride, and creatine of broiler plasma in 6 weeks feeding of garlic diet

Item	Dietary treatments				
	Garlic (%)				
	0 (control)	2	4	6	10
Total cholesterol (mg/dl)	159.23±4.22^{A}	145.45±5.41^{B}	145.30±4.64^{B}	138.26±5.26^{BC}	132.90±3.80^{C}
Triacylglycerol (mg/dl)	83.55±4.22	82.68±4.22	80.28±4.22	80.43±4.22	81.04±4.22
Creatine (g/dl)	0.71±0.13^{ab}	0.68±0.09^{a}	0.74±0.07^{abc}	0.87±0.11^{cd}	0.97±0.10^{d}

^{A,,B,C}Means within the same row with different superscripts are significantly different (p< 0.05).
^{a,b,c,d}Means within the same row with different superscripts are significantly different (p< 0.01).

Table 8. Compositions of broiler meat produced from garlic added diets feeding for 6 weeks

Components	Dietary treatments				
	Garlic (%)				
	0 (control)	2	4	6	10
Total cholesterol					
mg/100g meat-wet basis	87.4±4.7^{A}	83.9±2.8^{AB}	84.2±3.1^{AB}	83.5±2.2^{AB}	80.4±4.1^{B}
Moisture, %	69.9±0.2^{b}	65.2±0.1^{a}	67.3±0.1^{ab}	66.7±0.3^{a}	72.8±0.1^{c}
Ether extract, %					
- dry basis	34.0±0.4^{a}	42.7±0.3^{b}	40.8±1.5^{b}	42.7±1.2^{b}	32.2±1.8^{a}
Selenium, μg/100g					
- dry basis	26.11±1.4	32.78±2.1	29.16±1.8	29.39±0.9	39.02±2.4

[A, B]Means within the same row with different superscripts are significantly different (p< 0.05).
[a,b,c]Means within the same row with different superscripts are significantly different (p< 0.01).

the active components of garlic were effective in reducing fat-soluble components of the broiler muscle after feeding of 10% GA feed for 6 weeks. No significant differences were observed in the Se content of the broiler meat among the treatment groups (p>0.05). These results indicate GA-added feed was effective in reducing the cholesterol content of the broiler meat probably due to the reduction of fatty acid synthesis by garlic, thereby resulting in the reduction of triacylglycerol and fat accumulation in the liver are reduced (17). However, no significant effect of GA-added feed on the Se content was observed.

Changes in fatty acid composition of broiler meat Fatty acid compositions of all treatment groups changed significantly after 6 weeks of garlic feeding (Table 9). The fatty acid composition of broiler meat after feeding control diets were not similar to those of each experimental diets (Table 4, 5) which suggests that the changes in fatty acid composition of meat after 6 weeks feeding were not completely due to fatty acid in the feed. Contents of palmitic acid and oleic acid decreased significantly (p< 0.01), while those of linoleic acid and linolenic acid increased as GA content in the feed increased. Overall percentages of saturated and monounsaturated fatty acids decreased significantly, while that of polyunsaturated fatty acid increased significantly as GA content in the feed increased (p<0.01). In addition, polyunsaturated fatty acid of the 10% GA treatment broilr meat (39.86%) was significantly higher than those of other treatment groups (p< 0.01). Although we could not confirm the reason for the changes in the fatty acid composition observed with the addition of GA in the feed in this experiment, we speculate that some active components in the garlic could have affected Δ^6 and/or Δ^5 desaturase and elongase activities. The activity of desaturase increased in the presence of insulin. Chang and Johnson (17) reported that the amount of insulin increased in rats fed garlic-added feed. However concentration of insulin was not determined in this study; nevertheless, it is possible that the increased insulin level caused by the feeding of GA-added feed to the broiler might have affected the desaturase activity. In addition, the increased creatine content of the blood plasma (Table 7) could affect the desaturase activity by producing ATP (an activator of desaturase activity) in the muscle or other tissues.

Table 9. Fatty acid compositions of broiler meat produced from garlic added diets feeding for 6 weeks

Fatty acids (%)	Dietary treatments				
	Garlic (%)				
	0 (control)	2	4	6	10
C 14:0	0.71^{a}	0.66^{b}	0.62^{c}	0.67^{b}	0.62^{c}
C 14:1	0.20^{a}	0.15^{b}	0.12^{b}	0.15^{b}	0.17^{ab}
C 16:0	20.58^{a}	20.90^{a}	19.62^{b}	19.06^{b}	17.71^{c}
C 16:1	5.89^{a}	5.73^{a}	5.08^{b}	4.88^{b}	4.18^{c}
C 18:0	6.51^{a}	6.09^{ab}	5.63^{b}	5.80^{b}	6.32^{a}
C 18:1	33.94^{a}	34.82^{a}	33.51^{ab}	32.70^{b}	30.72^{c}
C 18:2	28.56^{c}	27.70^{a}	31.52^{b}	32.49^{b}	35.90^{a}
C 18:3	2.16^{c}	2.83^{b}	2.67^{b}	2.95^{a}	2.99^{a}
C 20:1	0.49^{ab}	0.50^{ab}	0.47^{ab}	0.54^{a}	0.41^{b}
C 20:4	0.96^{a}	0.62^{c}	0.76^{b}	0.76^{b}	0.98^{a}
SFA[1)]	27.80^{a}	27.65^{a}	25.87^{b}	25.53^{b}	24.65^{c}
MUFA[2)]	40.52^{ab}	41.20^{a}	39.18^{b}	38.27^{c}	35.48^{d}
PUFA[3)]	31.68^{c}	31.15^{c}	34.95^{b}	36.20^{b}	39.87^{a}

[1)]Saturated fatty acid.
[2)]Monounsaturated fatty acid.
[3)]Polyunsaturated fatty acid.
[a-d]Means within the same row with different superscripts are significantly different (p< 0.01).

In conclusion, garlic-added to the feed was effective in decreasing the levels of total plasma cholesterol and total cholesterol of the broiler meat. However, Se level of the broiler meat was not significantly changed with the addition of garlic. The fatty acid compositions in broiler meat after fed experimental diets were not similar to those of experimental diets fed, suggesting that some active components of garlic affect the fatty acid and cholesterol metabolisms.

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