Lycopene regulates production performance, antioxidant capacity, and biochemical parameters in breeding hens

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ABSTRACT: Lycopene is a carotenoid present in vegetables and ripe fruit and has been proved to be the most potent antioxidant among various common carotenoids. This study assessed the effects of lycopene on performance production, tissue lycopene content, antioxidant capacity, and biochemical parameters in 720 Xing-hua breeding hens. Rice-soybean diets were supplemented with different lycopene levels: 0, 20, 40, and 80 mg/kg. Lycopene supplementation significantly increased fertilization rates in hens. Serum and egg lycopene contents and the Roche Yolk Colour Fan score increased with lycopene supplementation through day 7. In the liver, lycopene supplementation significantly increased superoxide dismutase (SOD), total antioxidant capacity (T-AOC), and reduced glutathione to oxidized glutathione ratio (GSH/GSSG). Additionally, lycopene supplementation increased serum SOD, serum T-AOC, serum glutathione peroxidase, and serum GSH/GSSG. Lycopene addition significantly decreased total cholesterol and increased high density lipoprotein cholesterol and triiodothyroxine. It also improved fertilization rates, antioxidant capacity, and metabolism in breeding hens.

Keywords: carotenoid; fertilization rates; oxidative stability; biochemical index; hens

INTRODUCTION

Lycopene is an aliphatic hydrocarbon, which is present in red fruits and vegetables (Sevcikova et al. 2008). Tomatoes, especially deep-red fresh tomatoes, and tomato products are important sources of lycopene. Lycopene, which has no vitamin A activity, is an acyclic isomer of β-carotene (Rao and Agarwal 1999) that contains 11 conjugated double bonds in an all-*trans* configuration (Stahl and Sies 1996). In humans, lycopene protects against several diseases including certain cancers, cardiovascular diseases, and associated coronary artery disease (Rao 2002; Rissanen et al. 2002; Davis et al. 2005; Palozza et al. 2010; Holzapfel et al. 2013). It has been reported that lycopene is also beneficial to animals. Kazim et al. (2006) reported that lycopene supplementation decreases oxidative stress and increases antioxidant capacity in heat-stressed Japanese quails. Several researchers have reported that lycopene has positive effects in rats (Seishiro et al. 2001; Toledo et al. 2003; Herzog et al. 2005; Liang et al. 2012). According to Olson et al. (2008), lycopene fed to laying hens is incorporated in egg yolks and does not adversely affect their immune system. Findings from other studies reveal that lycopene improves the lipid profile of chickens (Sevcikova et al. 2008). Meanwhile, negative effects of high doses of lycopene have been found in broiler chickens (Pozzo et al. 2013).

Few studies have focused on the effects of lycopene in breeding hens. In this study, a rice-soybean meal diet was supplemented with different concentrations of lycopene to assess the effects of lycopene on production performance, tissue lycopene content, antioxidant capacity, and biochemical parameters of breeding hens.

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MATERIAL AND METHODS

Ethical guidelines. This study was conducted according to institutional and national guidelines for the care and use of animals. All animal experimental procedures were approved by the Committee of Animal Experiments of South China Agricultural University. All efforts were made to minimize animal suffering.

Study design. In this study, 720 Xing-hua breeding hens (26 weeks of age) of similar weight (about 1.3 kg) were randomly assigned to four treatments. Xing-hua hen is a superior meat quality breed with meat characterized by early maturity, easy fat, fat distribution uniformity between skin and muscle, etc. The annual average production of Xing-hua hens is 95 eggs with average egg weight of approximately 45 g. Hens were obtained from the College of Animal Science, South China Agricultural University and were raised in cages in a temperature-controlled room (25°C). Every cage had 3 breeding hens. Each treatment was replicated six times and there were 30 breeding hens per replicate. A rice-soybean meal diet was supplemented with different levels of lycopene: 0, 20, 40, and 80 mg/kg of diet (containing 0.06, 10.45, 26.56, and 35.96 mg lycopene/kg in each diet, respectively). The diets were formulated according to the Chinese Feeding Standard of Chickens (2004). The basal composition of the diet is shown in Table 1.

The animal trial lasted for 35 days. Hens had *ad libitum* access to feed and water. Furthermore, the animals had 16-h light cycles and natural ventilation. Production performance (i.e. egg number, total egg weight, qualified eggs, cracked eggs, feed intake, and hen mortality) of each replicate was recorded daily and at the end of the animal trial.

Analyses. Production performance (egg number, total egg weight, feed intake, broken eggs, qualified eggs, and hen mortality) of each replicate was recorded daily. Blood samples were taken from two hens in each replicate on days 0, 7, 14, 21, 28, and 35. Lycopene concentration was determined by the method reported by Koutsos et al. (2006). Antioxidant capacity, including total antioxidant capacity (T-AOC), superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), malondialdehyde (MDA), catalase (CAT), and reduced glutathione to oxidized glutathione ratio (GSH/GSSG), was determined using a commercial kit (Nanjing Jiancheng Bio-Engineering Institute, Nanjing, China). The method and principle to determine antioxidant indicators using these kits were described elsewhere (Gao et al. 2013), and activity was normalized to protein concentration as determined by coomassie blue assay. Serum biochemical parameters including triglyceride (TG), total cholesterol (TCHO), high density lipoprotein cholesterol (HDLC), low density lipoprotein cholesterol (LDLC), triiodothyroxine (T3), albumin (ALB), and blood urea nitrogen (BUN) were determined using a commercial kit (Biosino Bio-Technology & Science Inc., Beijing, China). Two eggs in each replicate were sampled on days 0, 7, 14, 21, 28, and 35 to determine yolk colour according to the Roche Yolk Colour Fan (RYCF) and lycopene content.

On day 22, centralized artificial inseminations (25-µl inseminations) were performed once every

Table 1. Basal diet composition and calculated nutrient content

Ingredients (%)		Calculated nutrient content	
Wheat bran	1.585	metabolizable energy (MJ/kg)	11.72
Rice	66.00	crude protein (%)	17.00
Soybean meal	20.18	fat (%)	4.00
Fish meal	2.00	lysine (%)	0.91
Limestone powder	7.35	methionine (%)	0.39
Dicalcium phosphate	1.54	methionine + cysteine (%)	0.64
Premix[1]	1.00	non-phytate P (%)	0.45
DL-Methionine	0.095	Ca (%)	3.30
Sodium chloride	0.25	vitamin E (mg/kg)	7.62

[1]vitamins and minerals content per kg diet: vitamin A 12 000 IU, cholecalciferol 2 400 IU, vitamin E 30 IU, menadione 1.5 mg, riboflavin 9.0 mg, niacin 35 mg, D-pantothenic acid 12 mg, vitamin B_{12} 0.012 mg, biotin 0.2 mg, folacin 1.2 mg, vitamin B_1 2.0 mg, vitamin B_6 4.5 mg, Cu (from $CuSO_4 \cdot 5\ H_2O$) 8.0 mg, Zn (from $ZnSO_4 \cdot H_2O$) 80 mg, Mn (from $MnSO_4 \cdot H_2O$) 100 mg, Fe (from $FeSO_4 \cdot H_2O$) 80 mg, I (from KI) 1.0 mg, and Se (from Na_2SeO_3) 0.3 mg

five days. From day 28 to day 34, 648 eggs (108 eggs for each replicate) were collected from the control group or the 40 mg lycopene/kg diet group, and hatched artificially to determine fertilization rate, hatchability of fertilized eggs, chick birth weight, and healthy chick rate. On day 35, two hens from each replicate were weighed and euthanized. The liver was removed and stored in liquid N_2 for the analysis of lycopene content (Gao et al. 2012).

Statistical analyses. Statistical analysis of data was performed using the SAS software package (Statistical Analysis System, Version 8.1, 2006). Fertilization rate, hatchability of fertilized eggs, chick birth weight, and healthy chick rate were analyzed by the *t*-test between the two treatments. For analyzing production performance, antioxidant capacity, and lipid peroxidation in breeding hens, One-Way ANOVA was performed to test for the effect of dietary lycopene in hens. Differences among means were determined using Tukey's HSD test. Statistical significance was set at $P < 0.05$.

RESULTS

Effects of lycopene on production performance of breeding hens. There were no significant differences in average daily feed intake, laying rate, egg to feed ratio, average egg weight, hen mortality, broken egg rate, and qualified egg rate among the groups (Table 2). The 40 mg/kg lycopene group had higher fertilization rates and hatchability of eggs set than the other groups ($P < 0.05$); however, there were no significant differences in hatchability rate, chick birth weight, or healthy chick rate among the groups.

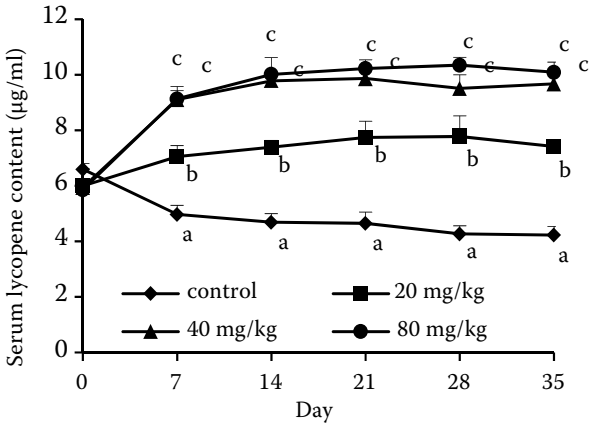

Figure 1. Effects of dietary lycopene on serum lycopene content of breeding hens

[a–c]values with different superscripts significantly differ ($P < 0.05$)

Effects of lycopene on tissue lycopene content of breeding hens. With increasing lycopene supplementation levels (≤ 40 mg/kg), serum lycopene increased (Figure 1). The liver lycopene content on day 35 increased with increasing lycopene supplementation levels ($P < 0.05$) (Figure 2). There were no significant differences in the egg lycopene content among the lycopene-supplemented groups. The supplemented groups had higher egg lycopene content than the control group ($P < 0.05$) (Figure 3).

Table 2. Effects of dietary lycopene on production performance rates of breeding hens

Items	Groups				Pooled SEM	*P*
	control	20 mg/kg	40 mg/kg	80 mg/kg		
ADFI (g)	95.36	94.69	96.21	95.81	0.95	0.235
Laying rate (%)	65.83	65.23	66.15	67.64	1.03	0.158
Egg to feed ratio	0.26	0.26	0.25	0.26	0.01	0.378
Average egg weight (g)	34.83	34.8	34.25	33.77	0.38	0.489
Hen mortality (%)	1.11	1.11	1.67	1.11	0.22	0.095
Broken egg rate (%)	1.76	1.52	1.27	1.85	0.24	0.321
Qualified egg rate (%)	95.10	95.24	94.96	96.52	1.49	0.841
Fertilization rate (%)	89.98[a]	–	93.40b	–	0.60	0.027
Hatchability of fertilized eggs (%)	95.87	–	96.70	–	0.42	0.542
Hatchability of eggs set (%)	86.27[a]	–	90.32[b]	–	0.51	0.019
Chick birth weight (g)	25.31	–	26.42	–	0.28	0.218
Healthy chick rate (%)	99.23	–	99.08	–	0.30	0.870

ADFI = average daily feed intake

[a,b]values with different superscripts are significantly different ($P < 0.05$)

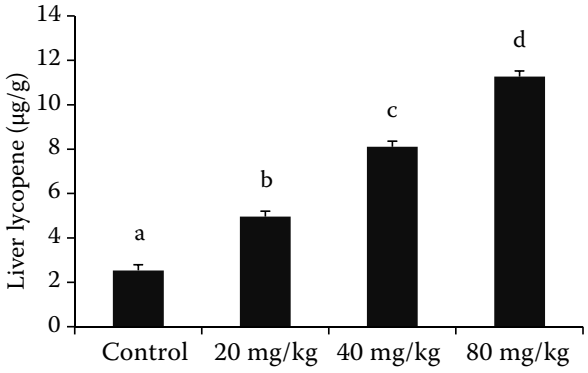

Figure 2. Liver lycopene content of breeding hens following lycopene supplementation for 35 days

[a–d]values with different superscripts significantly differ ($P < 0.05$)

On days 7–35, the supplemented groups had higher RYCF scores than the control group ($P < 0.05$) (Figure 4). Additionally, RYCF scores were higher in the 40 and 80 mg/kg lycopene groups than in the 20 mg/kg lycopene group at the same time point ($P < 0.05$). Therefore, lycopene increased egg yolk colour and egg lycopene content.

Effects of lycopene on antioxidant capacity of breeding hens. Lycopene supplementation increased SOD and T-AOC ($P < 0.05$) in serum (day 21) and liver (day 35) relative to the control group. GSH/GSSG increased ($P < 0.05$) in serum on days 21, 28, and 35, and in liver on day 35 (Table 3). Additionally, 20, 40, and 80 mg/kg lycopene increased serum GSH-Px activity ($P < 0.05$) only on day 14 compared to the control group. Lycopene supplementation did not affect CAT or MDA significantly.

Effects of lycopene on serum biochemical parameters of breeding hens. Lycopene supplementation significantly ($P < 0.05$) decreased serum TCHO on days 14 and 35, and increased the serum HDLC content ($P < 0.05$) on days 35 (Table 4). In addition, 20 mg/kg lycopene significantly ($P < 0.05$) increased T3. There were no significant differences in TG, LDLC, ALB, or BUN among the groups.

DISCUSSION

Lycopene is a bioactive carotenoid, which has been used in the poultry industry. The results of this study revealed that dietary lycopene did not significantly improve production performance rates. This result is in accordance with the results obtained by Pozzo et al. (2013). Interestingly, fertilization rates and hatchability of eggs set significantly ($P < 0.05$) increased with lycopene supplementation. This result shows the importance of a maternal diet rich in lycopene on antioxidant system (vitamins, carotenoids, enzymes) as lycopene is an effective antioxidant to oppose lipid peroxidation during chick embryonic development. Mangiagalli et al. (2010) reported that the fertility rates of lycopene-supplemented broilers increased compared to unsupplemented broilers. Lycopene, which is an antioxidant, increases sperm concentration by 66%; lycopene therapy could be used in the management of idiopathic male infertility (Gupta and Kumar 2002). Other studies have reported that carotenoid supplementation increases egg production and reduces maternal condition, parenting ability and survival, and egg quality (Blount et al. 2004; Englmaierova et al. 2013).

Supplementation with 20, 40, and 80 mg/kg lycopene significantly increased serum and egg yolk lycopene content relative to the control group

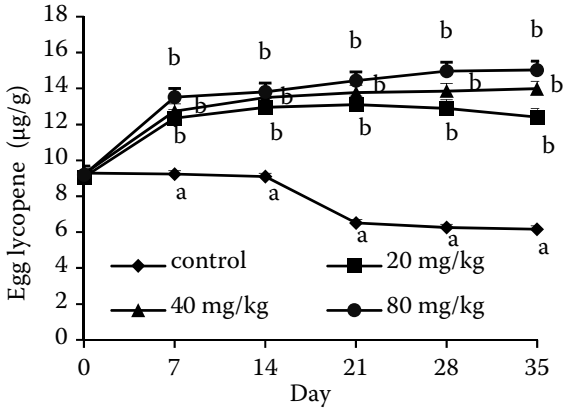

Figure 3. Effects of dietary lycopene on egg lycopene content

[a,b]values with different superscripts significantly differ ($P < 0.05$)

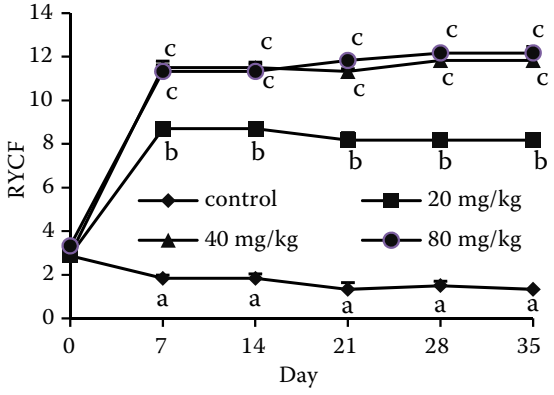

Figure 4. Effects of dietary lycopene on egg Roche Yolk Colour Fan (RYCF)

[a–c]values with different superscripts significantly differ ($P < 0.05$)

Table 3. Effects of lycopene on superoxide dismutase (SOD), total antioxidant capacity (T-AOC), reduced glutathione to oxidized glutathione ratio (GSH/GSSG), catalase (CAT), glutathione peroxidase (GSH-Px), and malondialdehyde (MDA) in serum and liver of breeding hens (mean values with standard errors, n = 6)

Antioxidant parameters	Groups				Pooled SEM	P
	control	20 mg/kg	40 mg/kg	80 mg/kg		
Serum SOD (U/ml)						
Day 0	126.53	126.72	126.28	127.31	8.25	0.901
Day 7	125.79	127.34	127.39	128.94	6.06	0.513
Day 14	126.86	128.72	129.08	129.58	5.99	0.395
Day 21	126.45^{a}	135.20^{b}	135.63^{b}	138.97^{b}	3.75	0.412
Day 28	126.63	130.22	127.13	130.65	5.04	0.254
Day 35	129.86^{a}	127.49^{a}	128.64^{a}	136.24^{b}	3.16	0.041
Liver SOD (U/mg protein)						
Day 35	393.96^{a}	425.63^{b}	435.25^{b}	432.15^{b}	13.21	0.029
Serum T-AOC (U/ml)						
Day 0	12.29	13.27	13.46	12.58	0.91	0.772
Day 7	13.11	13.62	14.20	13.86	0.86	0.648
Day 14	12.66	12.93	13.26	12.99	0.75	0.903
Day 21	10.82^{a}	12.15^{b}	12.79^{b}	12.84^{b}	0.97	0.028
Day 28	11.37	12.86	12.76	12.99	0.84	0.620
Day 35	11.76	12.87	12.27	12.18	0.90	0.419
Liver T-AOC (U/mg protein)						
Day 35	8.39^{a}	11.96^{b}	12.20^{b}	12.73^{b}	0.71	0.012
Serum GSH/GSSG						
Day 0	16.45	16.01	15.45	16.90	0.98	0.154
Day 7	15.78	18.20	18.97	19.67	0.92	0.196
Day 14	17.47	19.37	19.59	20.03	1.13	0.279
Day 21	16.06^{a}	24.03^{b}	25.38^{b}	26.87^{b}	1.05	0.015
Day 28	16.29^{a}	25.69^{b}	25.28^{b}	26.32^{b}	0.97	0.004
Day 35	17.31^{a}	25.19^{b}	25.91^{b}	25.97^{b}	0.74	0.010
Liver GSH/GSSG						
Day 35	6.01^{a}	8.15^{b}	8.26^{b}	8.23^{b}	0.27	0.008
Serum CAT (U/ml)						
Day 0	7.22	5.89	5.79	6.21	0.50	0.356
Day 7	5.77	6.91	5.53	5.49	1.22	0.321
Day 14	5.71	6.47	6.46	5.59	1.23	0.648
Day 21	5.20	5.95	6.33	5.96	0.98	0.726
Day 28	6.32	6.27	5.17	5.21	0.72	0.185
Day 35	5.63	5.79	5.12	4.89	0.95	0.427
Liver CAT (U/mg protein)						
Day 35	16.12	17.36	17.12	17.25	1.65	0.598
Serum GSH-Px (U/ml)						
Day 0	836.75	817.94	897.43	800.03	74.32	0.544
Day 7	897.43	943.07	958.97	951.28	58.35	0.422
Day 14	870.94^{a}	1007.69^{b}	1046.15^{b}	1023.93^{b}	85.92	0.012
Day 21	925.44	953.10	864.46	883.47	70.62	0.238
Day 28	803.30	832.23	849.58	889.25	70.49	0.707
Day 35	878.51	866.94	983.47	919.99	65.48	0.691

Table 3 to be continued

Antioxidant parameters	Groups				Pooled SEM	*P*
	control	20 mg/kg	40 mg/kg	80 mg/kg		
Liver GSH-Px (U/mg protein)						
Day 35	752.70	769.46	809.10	792.31	54.27	0.584
Serum MDA (nmol/ml)						
Day 0	12.39	11.54	12.37	13.02	1.20	0.458
Day 7	12.08	13.42	12.95	12.80	1.03	0.852
Day 14	12.50	12.98	13.14	13.89	1.41	0.781
Day 21	12.26	14.23	14.61	14.97	3.04	0.547
Day 28	13.05	12.86	14.03	11.36	3.28	0.395
Day 35	15.21	11.19	12.92	13.31	2.34	0.107
Liver MDA (nmol/mg protein)						
Day 35	9.36	9.23	9.10	8.99	0.61	0.288

[a,b]values with different superscripts are significantly different ($P < 0.05$)

on days 7 and 35; a steady lycopene content was reached on day 21. This is consistent with changes of carotenoid concentrations in hens (Karadas et al. 2005; Gao et al. 2012; Kotrbacek et al. 2013). Liver lycopene content increased with increasing lycopene supplementation levels, the highest lycopene concentrations in liver were in hens fed the highest levels of lycopene – the results are in accordance with those reported by Englmaierova et al. (2011). Olson et al. (2008) reported that hens with 257 or 650 mg/kg lycopene supplementation in diet had significantly greater lycopene liver concentrations as compared with those fed 65 mg/kg lycopene; however, the egg yolk lycopene content was lower in the 650 mg/kg lycopene supplementation group relative to the 257 mg/kg group.

The health benefits of tomatoes are probably attributed to lycopene, which has a similar structure to the antioxidant β-carotene. Yeh and Hu (2000) reported that lycopene and β-carotene behave similarly under *in vitro* oxidative conditions. Srinivasan et al. (2007) reported that lycopene offers protection against gamma radiation damage. In this study, the lycopene-supplemented group had higher serum SOD on day 21 than the control group. Furthermore, 80 mg/kg of lycopene increased SOD on day 35, which indicates that high supplementation levels increase antioxidant capacity in a longer period of time compared to low supplementation levels. In the lycopene-supplemented groups, T-AOC increased on day 21 but not on days 28 or 35, which indicates that breeding hens may modulate the activities of antioxidant enzymes by utilizing other antioxidants such as α-tocopherol. Cell redox status depends on the relative amounts of reduced and oxidized compounds; GSH/GSSG mainly reflects the antioxidant stress in the body (Haddad 2004). The results of this study revealed that lycopene increased GSH/GSSG and GSH-Px activity, which supports the use of lycopene for increasing antioxidant capacity in birds. Similar results have also been reported in hamsters (Bhuvaneswari et al. 2001). CAT activity and MDA level were not affected by lycopene in hens, as revealed by the present results (Serpeloni et al. 2010; Gao et al. 2013), but some papers have also reported that CAT activity was affected by carotenoids in rodents (He et al. 1997; Palozza et al. 2010; Sangeetha and Baskaran 2010), and MDA level was decreased by carotenoids supplementation (Dixon et al. 1994; Matos et al. 2001; Palombo et al. 2007; Gao et al. 2013), which could be attributed to time, environment, animal species, dosage, and type of carotenoids used and the oxidant stress challenge. Moreover, on day 35, lycopene significantly increased SOD, T-AOC, and GSH/GSSG in liver.

There are five major lipoproteins in chickens responsible for lipid transport. Among them high HDL levels have been associated with improved cardiovascular health (Sirtori 2006), whereas high LDL levels increase the risk of heart disease (Annema and Tietge 2011; Redondo et al. 2011). The results of this study showed that lycopene supplementation significantly decreased TCHO and increased HDLC, but did not affect TG or LDLC. Similar results have been reported by Loane et al. (2010) and Renzi et al. (2012). Therefore, lycopene could reduce cholesterol synthesis and improve the cardiovascular

Table 4. Effects of lycopene on triglyceride (TG), total cholesterol (TCHO), high density lipoprotein cholesterol (HDLC), low density lipoprotein cholesterol (LDLC), triiodothyroxine (T3), albumin (ALB), and blood urea nitrogen (BUN) in serum of breeding hens (mean values with standard errors, n = 6)

Serum biochemical parameters	Groups				Pooled SEM	P
	control	20 mg/kg	40 mg/kg	80 mg/kg		
TG (mmol/l)						
Day 0	6.85	6.52	6.96	6.05	1.01	0.765
Day 7	10.80	10.65	11.96	11.73	1.45	0.902
Day 14	11.12	12.14	11.83	11.68	1.65	0.782
Day 21	10.25	10.37	11.26	11.74	1.13	0.814
Day 28	10.97	10.25	10.71	10.65	1.36	0.956
Day 35	13.49	12.65	12.87	12.64	2.30	0.913
TCHO (mmol/l)						
Day 0	2.93	2.97	2.93	3.09	0.52	0.921
Day 7	3.82	3.58	3.60	3.46	0.38	0.512
Day 14	4.34^{a}	3.43^{b}	3.46^{b}	2.79^{b}	0.62	0.041
Day 21	3.16	2.79	2.86	2.83	0.33	0.754
Day 28	3.41	3.37	2.83	2.91	0.40	0.217
Day 35	4.73^{a}	3.64^{b}	3.80^{b}	3.68^{b}	0.35	0.031
HDLC (mmol/l)						
Day 0	0.71	0.60	0.60	0.57	0.05	0.805
Day 7	0.66	0.85	0.77	0.72	0.04	0.916
Day 14	0.57	0.66	0.68	0.58	0.05	0.834
Day 21	1.04	1.05	1.07	1.00	0.15	0.754
Day 28	1.12	1.15	1.19	1.26	0.17	0.649
Day 35	1.22^{a}	1.67^{b}	1.74^{b}	1.70^{b}	0.14	0.009
LDLC (mmol/l)						
Day 0	0.91	0.91	0.92	0.92	0.05	0.895
Day 7	0.91	0.83	0.83	0.82	0.04	0.692
Day 14	0.88	0.83	0.80	0.80	0.07	0.924
Day 21	0.93	0.83	0.83	0.80	0.06	0.205
Day 28	0.89	0.84	0.81	0.81	0.05	0.527
Day 35	0.88	0.85	0.81	0.80	0.04	0.287
T3 (nmol/l)						
Day 0	1.31	1.19	1.38	1.28	0.11	0.257
Day 7	0.96	1.02	0.94	1.18	0.13	0.129
Day 14	1.24^{a}	1.52^{b}	1.22^{a}	1.31^{a}	0.14	0.024
Day 21	0.95	1.02	1.19	1.16	0.09	0.471
Day 28	1.09	1.17	1.16	1.19	0.11	0.596
Day 35	1.15	1.18	1.28	1.18	0.25	0.871
ALB (g/l)						
Day 0	13.36	13.06	12.75	13.25	1.05	0.215
Day 7	14.56	15.14	14.30	14.64	0.12	0.660
Day 14	11.73	13.18	13.13	13.20	1.06	0.325
Day 21	10.80	12.25	11.23	10.91	0.84	0.454
Day 28	10.81	11.98	11.35	11.20	0.99	0.518
Day 35	10.55	10.96	11.13	10.70	1.23	0.649
BUN (mmol/l)						
Day 0	0.53	0.51	0.51	0.55	0.07	0.902
Day 7	0.53	0.56	0.65	0.58	0.08	0.241
Day 14	0.58	0.40	0.66	0.67	0.08	0.524
Day 21	1.08	1.06	1.05	1.05	0.10	0.746
Day 28	1.09	0.91	0.83	0.78	0.11	0.134
Day 35	1.00	0.78	1.00	0.95	0.10	0.291

^{a,b}values with different superscripts are significantly different ($P < 0.05$)

system. T3 is a thyroid hormone, which plays important roles in thermogenesis regulation (Tao et al. 2006), DNA and protein synthesis, and glucose and lipid metabolism. The 20 mg/kg lycopene group had significantly higher T3 levels, which suggests that lycopene may regulate metabolism in chickens by regulating T3 levels. Serum ALB and BUN were not affected by lycopene supplementation.

CONCLUSION

Dietary lycopene enhanced fertilization rates in breeding hens. The lycopene content in serum and egg yolk increased on day 7, reaching a steady lycopene content on day 21. Liver lycopene content increased with increasing lycopene supplementation levels. Lycopene supplementation improved the serum antioxidant capacity of breeding hens. In addition, lycopene affected serum levels of TCHO, HDLC, and T3. These results suggest that lycopene may play an important role in modulating physiological functions in breeding hens.

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