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USING THREONINE, CANTHAXANTHIN AND SODIUM SULPHATE, TO IMPROVE SECOND PRODUCTION CYCLE PERFORMANCE OF AGED HENS DURING SUMMER SEASON

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ABSTRACT: This study testified the hypothesis that L threonine (Thr) and canthaxanthin (Cx) alone or in combination in absence or present of anhydrous sodium sulphate (SS), can improve the performance of local laying hens in their second laying cycle (100- 112 weeks). One hundred and ninety two aged Golden Montazah layer hens that reached 100 weeks of age were chosen and distributed randomly into 8th experimental groups. Each group contained 24 hens divided into 3 replicates of 8 hens each. The 1st group fed control diet, the groups from the 2nd to 8th fed control diet supplemented with Thr, Cx, Cx+Thr, SS, SS+Thr, SS+Cx, or SS+Thr+Cx respectively. Egg production performance, egg quality, plasma protein respiration rate and body temperature were estimated.

The results indicated that Thr supplementation improved significantly egg production percent, egg mass and increased significantly feed intake. Feed conversion ratio improved during the first month by supplemented control diet with Thr, and Cx. Moreover plasma globulins and heat tolerance during summer season improved by Thr supplementation. Combination of Thr and Cx supplementation led to attain more improvement in egg production performance. Compared to the control diet, combination of Thr and Cx supplementation increased egg mass per hen by 25.18 %. However, no improvement was detected in egg production performance of aged Golden Montazah during summer season due to SS supplementation the control diet.

The results proved the hypothesis that egg production performance of aged Golden Montazah hens improved by threonine and/or canthaxanthin supplementation.

Key words: aged hens, threonine, canthaxanthin and sodium sulphate.

INTRODUCTION

Natural molting occurs at the end of summer season when day length decreased with the ending of the first laying cycle (Moore et al., 2004). Procedures for improving local aged hens performance during the second laying cycle were conducted for many reasons. Firstly, the long growing period for local chickens that extended from day- one up to 23 weeks of age (age at sexual maturity) (Youssef, et al., 2014). Prolonged rearing period incur producers a lot of money for feeding their pullets especially with increasing poultry ration cost. Secondly, high mortality rate during growing pullets plus increasing vaccines as well as drugs costs also may increase the total expenses. Therefore, it may be more economic to exploit aged chickens and recover egg production performance during the second laying cycle.

Sodium sulphate (SS) may conserve sulfur amino acids through synthesis taurine and condrutine sulphate directly from SS hence preventing sulfur amino acids from degradation (Youssef, 2002). Moreover, SS able to maintain dietary electrolyte balance on optimal limit in broiler diets (Jarule et al., 2009) when sodium chloride partly replaced by SS in layer diets after 43 wks of age production performance and egg shell measurements improved (Wang et al., 2020). Supplementing SS was safety for laying hens with positively effect on egg production performance and shell quality (Wei 2015). Ali et al (2012) indicated that SS increased the activity of hydrophobic antioxidants and protect it from attachment with free radical throughout its circulation in blood fluid.

Threonine (Thr) contain hydroxyl group that make it polar amino acid and it is essential amino acid for poultry (Shirisha et al., 2018). Chicken requirements from glycine can partially replaced by additional Thr where glycine syntheses from Thr but the reverse pathway did not complete (Kidd and Kerr 1996). Azzam et al., (2011b) suggested that Thr affect maintenance and function of intestinal tract. Moreover, Thr was involved in amylase enzyme synthesis (Block and Weiss 1966). Threonine dietary levels affected laying rate, feed intake, feed conversion and egg mass (Schmidt, et al., 2011). Threonine improves poultry tolerance under high ambient temperatures (Shirisha et al., 2018) where it needed more than NRC (1994) requirements under heat stress conditions (Kidd, 2000). Azzam *et al.* (2012) found that Thr supplementation improved hen performance they added that threonine may possess antioxidant function under hot climate. Lie et al (2016) found that hens fed 0.67% L-Thr resulted in the highest total superoxide dismutases and total antioxidative capacity levels in the liver. (Shils, *et al.* 2006) explained that L-Thr may have an active effect on antioxidant defense systems, and it acts as one of the amino acids that carry a small fraction of copper blood.

Canthaxanthin (Cx) is lipid-soluble carotenoids act as an antioxidant where it improves antioxidant status and laying performance of breeders hens (Zhang et al., 2011). Moreover, Cx significantly improved feed conversion, average egg weight and laying rate in aged laying hens (Damazia et al., 2018). Umar Faruk et al. (2018) reported that Cx possess antioxidant effect, enhanced immune responses, raise egg mass, so improved flock productivity. Ali, et al. (2018) reported that Cx with or without SS was able to improve egg production performance post-peak period. They also found that addition of sulphate to laying hen diets increased the utilization of Cx and improved egg production performance post-peak period.

Therefore, the current experiment aimed to investigate the effect of supplementing corn-soybean meal diet with sodium sulphate, threonine and/or canthaxanthin on egg production performance during the second laying cycle.

MATERIALS AND METHODS

Experimental treatments:

Total number of 192 aged Golden Montazah layers were distributed randomly into 8 treatments groups, where each group contained 24 hens and each group divided into three replicates with 8 hens per each. To achieve the experimental purpose one inorganic compound (sodium sulphate) and two organic compounds (threonine and canthaxanthin) were supplemented to experimental basal diet. Anhydrous Sodium Sulphate was supplied by the Egyptian Salt and Mineral Company. Canthaxanthin was provided by BASF Germany. Single cage layers were used for hosing each hen individually where each replicate sequentially housed in 8 cages.

A corn-soybean mash meal as a basal experimental layer diet was formulated (Table, 1) to satisfy nutrient requirements (iso-nitrogenous and iso-caloric) of local laying hens (15% CP ; 2700 kcal ME/kg diet) according to the Agriculture Ministry Decree No 1498 (1996) issued by Egyptian Ministry of Agriculture. The first treatment group fed control basal diet. The 2nd group fed basal diet supplemented with 0.20% Thr and the 3rd group fed basal diet supplemented with 3ppm canthanthin (Cx; equal 30 ppm commercial canthanthin). Group 4 fed control diet supplemented with mixture of 0.2% Thr of and 30 ppm Cx together. Treatments group from 5 to 8 fed the previous diets (control, 2nd, 3rd, and 4th) with adding 0.50% SS to form 5th, 6th, 7th and 8th treatment diets.

Management and performance parameters:

Day light was completed using additional morning artificial light before sunrise to reach 16 hours continuous light. Clean water was available continuously without supplemented vitamins source. Temperature and relative humidity inside the layer house recorded daily at 12 pm. Selected hens kept for three months during period extended from 100 to 112 wks of age and fed previous diets under the same conditions. Feed provided at the beginning of each week where the remaining diets weighed at weekend and feed intake was calculated.

Daily produced eggs were counted and weighed separately for each replicate to obtain egg mass. Egg production percent (EP percent) calculated by dividing egg number on number of alive hens. Egg mass per hen per day (EM/H) was calculated by dividing total egg mass of each replicate on number of alive hens. Feed conversion ratio was calculated by dividing feed intake on egg mass (gm feed per gm egg mass).

At the end of the experiment, 7 fresh eggs from each replicate were weighed individually where length and breadth of each egg were measured. Each egg was broken to evaluate egg component percent (yolk, shell and albumen that calculated by subtraction) albumen, yolk height and yolk width were measured. Shells were left to dry for three days in room temperature then weighed and shell thickens measured. Shape index was calculated by divided width on length but yolk index calculated by dividing yolk height by yolk width. Hough unit was calculated from Haught (1937) equation.

Two hens were picked up from each replicate firstly, at 6 am (early in the morning) and were picked up secondly, at 12 am (at afternoon). Body temperature for each hen measured by inserting digital thermometer into rectal for 2 cm depth (end of the mercury limit). Respiration rate was measured by counting moving of breast up and down for 1 minute.

One blood sample was withdrawn individually from one hen per replicate in test tube contained EDTA. To obtain plasma blood samples centrifuged at 3500 rpm for 15 minutes. Plasma were collected to measure total plasma protein and albumin using colorimetric kits produced by bio-diagnostic. Globulin calculated by subtract albumin from total protein. Albumin/ globulin ratio (alb/glo) calculated by dividing albumin values upon globulin values.

Statistical analysis:

Univariate procedure branch of General linear model that pulled down from analyze menu in statistical software package (SPSS, 2007) was employed to conduct two-way ANOVA along with the following statistical model:

$Y_{ijk} = \mu + S_i + T_j + C_k + (S\times T)_{ij} + (S\times C)_{ik} + (T\times C)_{jk} + (S\times T\times C)_{ijk} + e_{ijk}$

Where,

Y_{ijk} = dependent observation.

μ = overall mean.

S_i = effect of SS (i = 1 and 2). (Main effect)

T_j = effect of Thr (j = 1 and 2). (Main effect)

C_k = effect of Cx (k = 1 and 2). (Main effect)

$(S\times T)_{ij}$ = effect of interaction between SS and Thr.

(S×C) ik = effect of interaction between SS and Cx.
(T×C) jk = effect of interaction between Thr and Cx.
(S×T×C) = effect of interaction among SS, Thr and CX.
eijk = the residual effect.
According to (Duncan, 1955), compare means procedure of (SPSS, 2007) was used to compare means at F-test ($P \leq 0.05$).

RESULTS AND DISSCUSION

1- Production performance:

Data presented in Table (2) illustrate main effect of SS, Thr and Cx on egg production performance during second production cycle. Regarding SS supplementation, the results show unexpected manner where, the diet contained SS affected negatively on all egg production parameters especially after the first month of the trial. Compared to the control, addition of Thr increased EM/H by 22.48 %. Ali *et al.* (2018), indicated that birds may use amino acid as antioxidants. Moreover Grune *et al.* (1997) reported that amino acid play essential role in antioxidant defenses against free radical attack where protein (the most important fraction in layers diet) degraded to produce amino acids. Supplemented diets with SS caused significant decrease in EP percent and EM/H during the 2nd and 3rd months and entire experimental period. Similarly, significant retardation in feed intake and feed conversion ratio were observed where its means increased significantly ($P < 0.05$) for all months and entire period. The results of SS supplementation clearly disagree with those of Ali *et al.* (2018) who observed significant improvement in egg number, egg mass and feed conversion when hens aged from 39 to 58 wks feed basal diet supplemented with 0.5% SS. The current adverse results may be due to protein and sulfur amino acids percent in control basal diet were satisfied layers requirements. Ali *et al.* (2011) found that SS supplementation improved growth performance of low protein diets and this finding support our postulation where sulfur amino acids satisfied protein requirement during the second laying cycle. Moreover, layers during second cycle reached mature weight and change in body weight unnoticed during the experimental period. Otherwise, trail started at 100 weeks of age and after natural molting occurred and hens coated completely by feathers hence requirements from sulfur amino acids for forming or re-molting feather decreased. Ali *et al*. (2012) indicated that SS increased the activity of hydrophobic antioxidants and/ or protect it from free radical attach during circulation in the blood.

Regarding Thr effects, data showed significant improvement in EP percent during the 2nd, 3rd months and entire period. Similarly, EM/H showed significant improvement during all months and entire period however, improvement in feed conversion was significantly during the first month only. On the other hand, feed intake increased significantly for all months and entire period. These results agree with Azzam *et al.*, (2011a) who presented data demonstrated that egg production increased by about 5% when Thr supplementation increased from 0 to 0.3%. Moreover, the results of Thr supplementation were in full agreement with Schmidt *et al.*, (2011) who observed significant improvement in laying rate, egg mass and feed conversion during the second laying cycle. Results of Thr explain that clear improvement in second production cycle may be due to many reasons. Firstly, requirements of Thr according to NRC (1994) may be insufficient to satisfy laying hen requirements and increasing it to 130% above NRC may be needed where, (Kallam, 2016) reported that changes in production systems and environment temperature led to update Thr requirements in laying hen diets. Secondly, part from Thr may convert to glycine (Kidd and Kerr, 1996). Thirdly, Thr may improve digestion where Li *et al.*, (2016) reported that Thr above NRC limit may increase activities of digestive enzymes, improve antioxidant capacity and increase antibody production.

Threonine has antioxidant activity where Li *et al.*, (2016) reported that Thr above NRC limit increased activities of antioxidant capacity. In hot climates Thr supplementation recorded the highest serum and liver superoxide dismutases values and certainly has antioxidant function (Azzam *et al.*, 2012). The current experiment was carried out in hot climate where the house temperature ranged from 35°C to 39°C through the experimental period.

Inclusion of Cx into the basal diets caused significant increase in EP percent and EM/H during the 1st, 3rd months and entire period (Table, 2). Compared to the control diet, addition of Cx increased EM/H by 19.21%. These results agree with those obtained by Ali *et al.* (2018) who found that addition of Cx increased egg number by 23.35 %. Also, results of this study were in full agreement with Umar Faruk *et al*., (2018) who reported that Cx can increase numerically EP percent and significantly EM/H. According to Bonilla *et al*., (2017) effect of Cx in improving egg production performance clearly appears as hen aged and this is may be due to free radicals increased by increasing hen age under high ambient temperature (Ali *et al.,* 2012) where Cx possess antioxidant activity (Zhang et al., 2011) therefore egg production performance improved in aged hens (Damazia *et al*., 2018). Feed intake increased significantly when aged layers feed diet supplemented with Cx (Table, 2). These results are in full agreement with those of Umar Faruk *et al.,* (2018) who reported that increase in feed intake with Cx supplementation. Increasing feed intake by Cx supplementation may be due to increasing EM/H that may be need more feed for egg production.

The best values that recorded for all production parameters within treatment groups otherwise interaction (Table, 2 continued) was recorded when Thr was mixed with Cx especially with absence of SS. Compared to control diet, addition of Thr +Cx increased EM/H by 25.18% . These results agree with Ali *et al.* (2018) who found that addition of tyrosine plus Cx increased egg number by 31.63 % compared to their control. This may be due to each of Thr and Cx possess more critical roles in antioxidant activities as free radicals increase with increasing age (aging) according to Finkel and Holbrook, (2000). Under high ambient temperature, increasing in free radicals production observed by increasing hens age (**Ali *et al.* 2012)** so combination effect between Thr and Cx appeared clear improvement in egg production performance.

2- Egg quality:

All egg quality parameters did not show significant differences neither between treatment groups nor between main effects except for egg shell weight percent for Thr supplementation (Table, 3). This result is in full agreement with Schmidt, *et al.,* (2011) and Nunes *et al.,* (2015) who found significant increase in shell weight percent when Thr supplemented to control diet. Increase in egg shell weight percent may be due to decreasing albumen weight percent with constant of yolk weight percent. Decreasing albumen weight percent agree with the next results of plasma protein fraction that will discuss later. Decreasing albumen weight percent agree with (Agustini *et al.,* 2014) who reported that greatest insert of Thr related with the lowest albumen weight percent.

Yolk weight percent and shell thickness were not influence significantly by Thr supplementation (Table, 3). This result in a full agreement with Nunes *et al.,* (2015) who reported that dietary Thr did not affect on yolk weight percent and shell thickness. Nevertheless, Thr constitute the highest values of amino acid percentage in yolk protein (48 mg/g protein) (Sakanaka *et al.,* 2004). The current results of Cx disagree with previous results Ali et al. (2018) who found Cx significantly increased shell thickness compared to control diet at late egg production cycle. The difference between this study and previous Ali et al. 2018 may be due to different egg production cycle.

3- Heat tolerance and plasma proteins:

Ambient temperatures were 29°C, 35°C and 39°C during 1st, 2nd and 3rd month of current experiment. On the other hand the relative humidity were 48%, 54% and 52.5 during 1st, 2nd and 3rd month. Table (4) showed that a numerical slight decrease in rectal body temperature was observed for hens fed diet supplemented with Thr at early morning or at afternoon. The result of body temperature agrees with Trevisi *et al.* (2015) who reported that rise in body temperature prevented by Thr supplementation they could not explain this finding. This is may be due either to Thr turned over to glycine (Kidd and Kerr 1996) hence, glycine able to decrease body temperature (Miura 2004).

Chickens fed diet supplemented with Thr regardless other components exhibited significant decrease in respiration rate when it recorded in early morning or in afternoon (Table, 4). In contrast feeding layers hen diet supplemented with SS regardless other components caused insignificant increase in respiration rate in afternoon. So the treatments that contained Thr combined with SS (interaction) did not achieve additional significant improvement compared with the control treatment.

Only plasma globulin and A/G ratio (Table, 5) showed significant effects by Thr supplementation but other ingredients did not influence other plasma protein component. Increasing globulin combined with Thr supplementation may be due to Thr found in globulin in high ratio compared with other protein (Azzam *et al.,* 2011b). Azzam *et al.,* (2011a) found that increasing Thr supplementation from 0 up to 0.3% caused duplication in total

plasma globulin for hens reared in high ambient temperature.

The data in Table (2) revealed that all parameters of egg production performance were improved during the 2nd and 3rd month of experiment phase when ambient temperature ranged between 35°C to 39 °C. More Thr is required under heat stress conditions (Kidd, 2000). moreover dietary Thr requirements according (NRC, 1994) were insufficient for layer during summer seasons (Azzam *et al.,* 2011b). On the other hand, Thr concentration in γ-globulin was very high (Azzam and El-Gogary 2015) so Thr deficiency inhibit antibody activity (Kidd 2000) and in-ovo Thr injection induced more formation of immunoglobulin (Kadam *et al.*, 2008)

CONCLUSION

In conclusion supplemented threonine and canthaxanthin or its combination revealed clear improvement in egg production performance of Golden Montazah during the second laying cycle when reared under hot summer conditio

Table (1): Composition and calculated analysis of the control diet.

Ingredients	**%**
Yellow corn	64.70
Soybean meal (46%)	20.30
Wheat bran	4.80
Lime stone	8.00
Di-calcium phosphate	1.45
Nacl	0.30
Vitamin& Min. Mix*	0.40
DL- methionine	0.05
Total	100
Calculated analysis**	
CP%	15.06
ME Kcal /kg	2705.3
Crude fiber%	3.15
Crude fat %	2.93
Calcium %	3.35
Available phosphorus %	0.402
Lysine %	0.795
Methionine %	0.332
Methionine + Cysteine%	0.588
Sodium%	0.14

* Vitamin and mineral mix contain per 4kg vit A 15 000 000, vit D_3 3 300 000 IU, vit E 80 000mg, Vit K3 4000mg , vit B1 2200 mg, vit B2 12 000mg, vit B6 5500 mg, vit B12 20 mg, pantothenic acid 20 000 mg, Niacin 40 000mg, Biotin 300 mg, Folic acid 1500mg, Choline chloride 1000 gm, Selenium 300 mg, Copper 10000 mg, Iron 60 000 mg, Manganese 100 000mg, Zinc 80 000mg, Iodine 2000 mg, Cobalt 100 mg and $CaCO_3$ to 3000g.

**According to Egyptian Feed Composition Tables for Animal and Poultry Feedstuffs (2001)

Table (2): Effect of sodium sulphate, cxthaxanthin and/or threonine on egg production performance (main effects).

Parameters	Month	SS				Thr				Cx			
		without	**with**	**SE. ±**	**P value**	**without**	**with**	**SE. ±**	**P value**	**without**	**with**	**SE. ±**	**P value**
Egg production percent	1st	42.71	46.01	1.210	0.054	43.18	45.55	1.210	0.165	40.28^{b}	48.44^{a}	1.210	0.0001
	2nd	60.88^{a}	56.60^{b}	0.983	0.002	53.30^{b}	64.18^{a}	0.983	0.001	58.22	59.26	0.983	0.454
	3rd	58.98^{a}	48.49^{b}	0.963	0.001	49.94^{b}	57.53^{a}	0.963	0.001	52.20^{b}	55.27^{a}	0.963	0.024
	Overall	54.19^{a}	50.37^{b}	0.655	0.001	48.81^{b}	55.75^{a}	0.655	0.001	50.23^{b}	54.33^{a}	0.655	0.001
Average egg weight (gm)	1st	54.09	54.18	0.18	0.719	54.31	53.95	0.18	0.158	54.31	53.95	0.180	0.335
	2nd	53.26	53.38	0.447	0.849	53.85	52.78	0.447	0.092	53.48	53.15	0.447	0.597
	3rd	53.49	53.19	0.136	0.09	53.49	53.19	0.136	0.117	53.39	53.29	0.136	0.621
	Overall	53.48	53.72	0.167	0.311	53.88	53.31	0.167	0.015	53.71	53.48	0.167	0.34
Egg mass / hen / day (gm)	1st	23.18^{b}	25.03^{a}	0.67	0.049	23.55	24.66	0.669	0.001	21.96^{b}	26.25^{a}	0.669	0.243
	2nd	32.45^{a}	30.17^{b}	0.591	0.006	28.69^{b}	33.93^{a}	0.591	0.001	31.1	31.52	0.591	0.614
	3rd	31.27^{a}	25.95^{b}	0.510	0.001	26.68^{b}	30.54^{a}	0.510	0.001	27.75^{b}	29.47^{a}	0.510	0.018
	Overall	28.97	27.05	0.363	0.001	26.31^{b}	29.71^{a}	0.363	0.001	26.94^{b}	29.08^{a}	0.363	0.001
Feed intake	1st	105.0^{a}	103.8^{b}	0.001	0.001	103.8^{b}	105^{a}	0.001	0.001	101.3^{b}	107.5^{a}	0.001	0.001
	2nd	107.28	106.65	0.238	0.061	104.43^{b}	109.5^{a}	0.238	0.001	106.01^{b}	107.92^{a}	0.238	0.001
	3rd	105.41^{a}	104.04^{b}	0.119	0.001	101.70^{b}	107.74^{a}	0.119	0.001	104.20^{b}	105.24^{a}	0.119	0.001
	Overall	105.90^{a}	104.81^{b}	0.101	0.001	102.46^{b}	108.25^{a}	0.101	0.001	104.65^{b}	106.05^{a}	0.101	0.001
Feed conversion	1st	6.08^{a}	5.47^{b}	0.196	0.028	6.31^{a}	5.24^{b}	0.196	0.001	5.73	5.83	0.196	0.719
	2nd	3.81^{b}	4.20^{a}	0.124	0.026	3.99	4.02	0.124	0.073	4.27	3.74	0.124	0.831
	3rd	3.62^{b}	4.84^{a}	0.114	0.001	4.39	4.07	0.114	0.051	4.3	4.16	0.114	0.366
	Overall	4.51^{b}	4.84^{a}	0.092	0.011	4.79	4.55	0.092	0.058	4.87	4.47	0.092	0.053

SS: Sodium sulphate Thr: Threonine Cx: Canthaxanthin .

a,b: Means in the same row within the same substance with different superscripts are differ significantly along with P value.

Table (2): Continued, Effect of sodium sulphate, cxthaxanthin and/or threonine on egg production performance (treatments effect).

Parameters	Month	Control	Thr	Cx	Cx × Thr	SS	SS× Thr	SS× Cx	SS× Thr × Cx	SE. ±	P value
Egg production percent	1st	33.11^{d}	44.45^{c}	45.61^{c}	47.69^{bc}	41.66^{cd}	41.90^{cd}	52.32^{a}	48.15^{b}	2.410	0.045
	2nd	53.24^{d}	65.51^{a}	59.73^{c}	65.05^{a}	50.00^{F}	64.13^{ab}	50.23^{f}	62.04^{b}	1.966	0.040
	3rd	52.55^{cd}	60.66^{b}	59.73^{b}	62.97^{a}	40.27^{f}	55.32^{c}	47.22^{d}	51.16^{cd}	1.926	0.025
	Overa	46.3^{cd}	56.87^{b}	55.03^{b}	58.57^{a}	43.98^{d}	53.78^{b}	49.92^{c}	53.78^{b}	1.310	0.008
Average egg weight (gm)	1st	54.59	54.74	53.95	53.05	54.67	53.02	54.04	54.98	0.36	0.088
	2nd	53.85	53.09	53.48	52.61	54.58	52.41	53.49	53.02	0.894	0.475
	3rd	52.88	52.79	53.67	53	54.35	53.52	53.06	53.43	0.272	0.071
	Overa	53.77	53.54	53.7	52.89	54.53	52.98	53.53	53.81	0.335	0.111
Egg mass / hen / day (gm)	1st	18.24^{d}	24.36^{b}	24.64^{b}	25.48^{ab}	22.96^{c}	22.29^{c}	28.37^{a}	26.50^{ab}	1.340	0.028
	2nd	28.45^{c}	34.95^{a}	32.12^{b}	34.3^{a}	27.43^{cd}	33.58^{ab}	26.77^{d}	32.90^{b}	1.183	0.020
	3rd	27.76^{c}	31.89^{b}	32.00^{ab}	33.43^{a}	21.92^{f}	29.44^{bc}	25.04^{d}	27.41^{c}	1.020	0.039
	Overa	24.82^{d}	30.40^{ab}	29.59^{b}	31.07^{a}	24.10^{d}	28.44^{b}	26.73^{c}	28.94^{b}	0.726	0.033
Feed intake	1st	100.00	105.00	105.00	110.00	100.00	110.00	100.00	105.00	0.001	0.001
	2nd	103.68	107.99	106.83	110.63	100.83	111.53	106.39	107.85	0.475	0.001
	3rd	100.69	105.28	105.14	110.51	100.63	110.21	100.35	104.96	0.237	0.001
	Overa	101.46	106.09	105.66	110.38	100.49	110.58	102.25	105.94	0.201	0.001
Feed conversion	1st	7.26	5.51	5.63	5.93	5.52	6.97	4.50	4.90	0.393	0.006
	2nd	4.24	3.59	3.75	3.65	4.30	3.81	4.78	3.91	0.248	0.018
	3rd	4.00	3.51	3.44	3.54	5.43	4.27	4.68	4.97	0.227	0.018
	Overa	5.17	4.2	4.27	4.38	5.09	5.01	4.65	4.59	0.184	0.004

SS: Sodium sulphate Thr: Threonine Cx: Canthaxanthin .

a,b: Means in the same row with different superscripts are significantly different at ($p<0.05$).

Table (3): Effect of sodium sulphate, Cxthaxanthin, threonine and its interaction on egg quality.

Main effects												
Parameters	**SS**				**Thr**				**Cx**			
	witho	**with**	**SE. ±**	**P**	**withou**	**with**	**SE. ±**	**P**	**withou**	**with**	**SE. ±**	**P**
Shape index	77.94	77.37	1.039	0.702	76.51	78.79	1.039	0.128	77.18	78.1	1.039	0.528
Yolk index	36.30	35.90	0.692	0.685	36.10	36.1	0.692	0.993	35.62	36.5	0.692	0.333
Haugh unit	85.34	87.05	1.517	0.430	85.24	87.16	1.517	0.377	84.47	87.9	1.517	0.114
Shell thickness	35.42	34.00	0.969	0.308	35.58	33.83	0.969	0.209	34.67	34.7	0.969	0.952
Albumen weight%	58.14	57.77	0.579	0.653	58.51	57.4	0.579	0.182	57.60	58.3	0.579	0.392
Yolk weight%	30.91	31.2	0.545	0.711	31.02	31.08	0.545	0.936	31.34	30.7	0.545	0.451
Shell weigh%	10.95	11.04	0.269	0.828	10.47^{b}	11.52	0.269	0.009	11.05	10.9	0.269	0.753

	Treatment effects.									
Parameters	**Control**	**Thr**	**Cx**	**Cx × Thr**	**SS**	**SS× Thr**	**SS× Cx**	**SS× Thr × Cx**	**SE. ±**	**P value**
Shape index	76.86	76.38	77.55	80.95	76.21	79.28	75.42	78.56	2.000	0.520
Yolk index	34.42	36.79	36.85	37.14	36.51	34.76	36.63	35.69	1.384	0.462
Haugh unit	84.79	85.03	85.10	86.45	82.26	85.79	88.81	91.35	3.035	0.808
Shell thickness	37.50	35.17	36.00	33.00	32.33	33.67	36.5	33.50	1.939	0.508
Albumen weight%	58.48	56.64	58.25	59.20	58.41	56.88	58.91	56.89	1.158	0.323
Yolk weight%	31.57	31.54	30.59	29.94	31.48	30.79	30.45	32.06	1.089	0.348
Shell weigh%	9.95	11.81	11.17	10.87	10.11	12.33	10.64	11.05	0.539	0.823

SS: Sodium sulphate Thr: Threonine Cx: Canthaxanthin .

a,b: Means in the same row within the same substance with different superscripts are differ significantly along with P value.

Table (4): Effect of sodium sulphate, Cxthaxanthin, threonine and its interaction on body temperature and respiration rate.

Parameters	Main effects											
	SS				Thr				Cx			
	without	with	SE. ±	P value	without	with	SE. ±	P value	without	with	SE. ±	P value
Body temperature 6	41.55	41.52	0.034	0.552	41.56	41.53	0.034	0.932	41.55	41.52	0.034	0.445
Respiration rate 6	27.46	27.04	0.534	0.584	28.54[a]	25.96[b]	0.534	0.001	27.29	27.21	0.534	0.913
Body temperature 12	41.80	41.80	0.027	0.914	41.82	41.79	0.027	0.449	41.80	41.80	0.027	0.955
Respiration rate 12	44.58	45.54	0.544	0.144	46.88[a]	43.25[b]	0.544	0.001	45.75	44.38	0.544	0.039

	Treatments effect.								
Parameters	**control**	**Thr**	**Cx**	**Cx × Thr**	**SS**	**SS×Thr**	**SS× Cx**	**SS× Thr × Cx**	**SE. ±**	**P value**
Body temperature 6	41.62	41.58	41.47	41.53	41.52	41.50	41.55	41.52	0.069	0.552
Respiration rate 6	29.33[a]	25.67[c]	28.17[ab]	26.67[b]	28.50[ab]	25.67[c]	28.17[ab]	25.83[c]	1.067	0.0415
Body temperature 12	41.83	41.75	41.83	41.80	41.82	41.80	41.78	41.80	0.054	0.824
Respiration rate 12	49.17[a]	41.33[d]	45.17[b]	42.67[c]	47.67[ab]	44.83[bc]	45.50[b]	44.17[bc]	1.087	0.034

SS: Sodium sulphate Thr: Threonine Cx: Canthaxanthin .

a,b: Means in the same row within the same substance with different superscripts are differ significantly along with P value.

Table(5): Effect of sodium sulphate, Cxthaxanthin, threonine and its interaction on plasma proteins.

Parameters	**SS**				**Thr**				**Cx**			
	without	**with**	**SE.**	**P**	**withou**	**with**	**SE. ±**	**P value**	**witho**	**with**	**SE.**	**P**
Total protein	6.34	6.73	0.30	.391	6.48	6.59	0.309	.818	6.32	6.75	0.30	.358
Albumin	3.54	3.88	0.15	.160	3.85	3.57	0.157	.236	3.66	3.77	0.15	.645
Globulin	2.80	2.85	0.16	.834	2.63^{b}	3.02^{a}	0.036	.137	2.66	2.98	0.16	.215
A/G ratio	1.29	1.39	0.05	.211	1.50^{a}	1.19^{b}	0.044	.003	1.42	1.27	0.05	.064

Parameters	**Treatments effect.**									
	control	**Thr**	**Cx**	**Cx × Thr**	**SS**	**SS× Thr**	**SS× Cx**	**SS× Thr ×**	**SE. ±**	**P value**
Total protein	6.24	6.82	6.30	5.99	6.11	6.77	6.64	7.42	0.618	0.577
Albumin	3.85	3.81	3.34	3.17	3.89	3.87	3.56	4.22	0.313	0.396
Globulin	2.39	3.02	2.97	2.82	2.22	2.89	3.09	3.20	0.335	0.826
A/G ratio	1.64	1.28	1.13	1.13	1.76	1.34	1.16	1.32	0.104	0.475

SS: Sodium sulphate Thr: Threonine Cx: Canthaxanthin .
a,b: a,b: Means in the same row within the same substance with different superscripts are differ significantly along with P value.

aged hens, threonine, canthaxanthin and sodium sulphate.

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الملخص العربي

استخدام الثريونين ، الكانزاكسنسين وكبريتات الصوديوم لتحسين اداء الموسم الانتاجي الثاني للدجاج العتاقي خلال فصل الصيف.

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تختبر هذه الدراسة فرضية ان الثريونين و أو الكانزاكسنسين مع أو بدون كبريتات الصوديوم يمكنهما تحسين اداء الدجاج البياض المحلي خلال الموسم الإنتاجي الثاني (100- 112 اسبوع). لذلك تم اختيار 192 دجاجة من دجاج المنتزه الذهبي العتاقي والذي وصل عمره الى 100 اسبوع وزعت الى 8 مجاميع تجريبية. احتوت كل مجموعة على 24 دجاجة قسمت الى 3 مكرارات يحتوي كل مكرر عاى 8 دجاجات. غذيت المجموعة الاولى على عليقة المقارنة بينما غذيت المعاملات من 2-8 على (0.20٪ ثريونين)، (3 جزء في المليون الكانزاكسنسين)، (0.20٪ ثريونين + 3 جزء في المليون الكانزاكسنسين)، (0.50٪ كبريتات صوديوم)، (0.50٪ كبريتات صوديوم + 0.20٪ ثريونين) ،،(0.50٪ كبريتات صوديوم + 3 جزء في المليون الكانزاكسنسين) و (0.50٪ كبريتات صوديوم + 0.20٪ ثريونين + 3 جزء في المليون الكانزاكسنسين) على الترتيب. سجلت درجة الحرارة والرطوبة النسبية عند الظهيرة. تم تقدير اللاداء الإنتاجي للدجاج البياض و جودة البيض وبروتينات البلازما ومعدل التنفس ودرجة حرارة الجسم.
اوضحت النتائج تحسن ملحوظ في النسبة المئوية لإنتاج البيض، وكتلة البيض، وزيادة الغذاء المستهلك معنوياً طوال فترة التجربة وتحسن في معامل التحويل الغذائي خلال الشهر الأول من التجربة باضافة الثريونين والكانزاكسنسين. كما تحسن ايضاً جلوبيولينات البلازما ومقدرة الطائر على التائقلم خلال فصل الصيف باضافة الثريونين. ادى اضافة خليط من الثريونين و الكانزاكسنسين الى زيادة بمقدار 25.18٪ في كتلة البيض للدجاجة في اليوم مقارنة بكتلة البيض للدجاج المغذى عاى عليقة المقارنة. لم يحدث اي تحسن في اداء انتاج البيض للدجاج المنتزة الذهبي المغذى على علائق تحتوي على كبريتات صوديوم خلال فصل الصيف مقارنة بعليقة المقارنة.
وبهذا تشير النتائج الى تحسن اداء دجاج المنتزه الذهبي العتاقي خلال الموسم الانتاجي الثاني باضافة الثريونين و الكانزاكسنسين وبدون اضافة كبريتات الصوديوم خلال فصل الصفي.
الكلمات الدالة: الدجاج العتاقي، ثريونين، الكانزاكسنسين وكبريتات الصوديوم.