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THE USE OF DIETARY VITAMIN E AND POTASSIUM CHLORIDE TO ALLEVIATE THE EFFECTS OF HEAT STRESS ON THE PERFORMANCE OF LAYING HENS

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ABSTRACT

The present study was carried out to investigate the possibility of alleviating the adverse effects of heat stress on productive performance and egg quality of laying hens exposed to heat stress during the summer season, by means of dietary supplementation with potassium chloride (KCl), vitamin E or their combinations. Three hundred and sixty, 20-week-old Hy-Line W-36 pullets were assigned to twelve equal experimental groups of 5 replications of 6 birds each. All birds were kept in community battery cages (6 birds per cage), set up in an open-sided laying house, and exposed to a daily photoperiod of 16 hr and managed similarly. Twelve mash experimental diets containing 4 levels of KCl (0.0, 0.8, 1.6 and 2.4%) and 3 levels of vitamin E (0.0, 150 and 300 mg/kg diet), in a 4×3 factorial arrangement of treatments, were formulated and used. All experimental diets were formulated to contain an average of metabolizable energy (ME) of about 2840 kcal/kg and crude protein (CP) of about 18.7%, and offered to pullets during the summer season from 20 to 32 weeks of age. Then, hens were switched to feed the control diet until the end of study, at 68 weeks of age. The criteria of response were productive performance (feed intake, hen-day egg production rate, egg weight, egg mass and feed conversion efficiency), change in body weight, mortality rate, economic efficiency of production and certain measurements of egg quality. The most important results could be summarized as follows:

Apart from the effect of dietary vitamin E supplementation, feeding the KCl-supplemented diets during the heat stress period (20-32 weeks of age) significantly decreased mortality rate and improved the productive performance and change in body weight of laying hens; similar improvements in their productivity, survivability and economic efficiency of production were observed during the whole experimental period, with no significant differences among the different levels of supplemental KCl in most cases. In addition, hens fed the KCl-supplemented diets during the heat stress period produced eggs of superior quality (as measured by egg weight, egg shell quality and Haugh units) compared with those of the control hens, with no significant differences among the different levels of supplemental KCl in most cases.; however, yolk percent, albumen percent, egg shape index, yolk index and yolk color were not affected. Regardless of the effect of dietary KCl supplementation, feeding the vitamin E-supplemented diets during the heat stress period significantly reduced mortality rate and improved the productive performance of laying hens, with no significant differences between the two levels of supplemental vitamin E. Change in body weight of hens was also improved proportionally to the supplemental level of vitamin E; however, daily feed intake was not affected. Dietary vitamin E supplementation during the heat stress period, independently from the effect of supplemental dietary KCl, produced similar positive carry-over effects on the productive performance, survivability and economic efficiency of production of laying hens during the whole experimental period, with no significant differences between the two levels of supplemental vitamin E. Also, feeding the vitamin E-supplemented diets during the heat stress period brought about significant improvements in egg weight and its components, egg shell quality and Haugh units, particularly with the high supplemental level of vitamin E (300 mg/kg), compared with those of the control hens; however yolk index and yolk color were not affected. There were significant interactions between the supplemental dietary KCl and vitamin E on some traits of egg quality during the heat stress period and on criteria of productive performance and economic efficiency of production during the whole experimental period.

It could be concluded that dietary supplementation with either single doses of 1.6% KCl or 300 mg vitamin E/kg diet, or with a combination of 1.6% KCl and 150 mg vitamin E/kg diet, could be suggested for ameliorating the negative effects of heat stress on laying hens' productive performance, viability and economic efficiency.

Keywords: Dietary KCl, Vitamin E, Heat Stress, Productive Performance of Hens, Egg Quality.

INTRODUCTION

In recent years, nutrition-environment interactions are of great interest in modern poultry production, particularly in tropical and subtropical areas of the world. During summer, high environmental temperature can be extremely hazardous for laying hens, not only due to increased mortality, but also because of reduced productive performance and deteriorated egg quality. Heat stress in laying hens is prompted by combinations of environmental temperature and humidity that prevent the bird's thermoregulatory process from effectively dissipating the heat produced during metabolism (Webster, 1983). The ideal ambient temperature for laying hens has been reported to be around 20°C (North and Bell, 1990). It has been reported that heat stress begins when ambient temperature climbs above 25ºC; since the thermoneutral zone for laying hens is usually located between 20 and 25ºC (Arad *et al.*, 1981).

The researchers have tried to minimize the effects of heat stress by changing the environment and diets of laying hens. Environmental approaches include increasing the airflow over birds to increase heat loss, increasing ventilation rates, or using evaporative cooling systems in enclosed houses and lowering the stocking densities. Since most of these environmental approaches are expensive, the current attempts are mainly directed to dietary manipulations as means for alleviating the negative impact of heat stress on poultry performance. In this regard, several attempts have been made by nutritionists to ameliorate the deleterious effect of the respiratory alkalosis that normally occurs in various poultry species during thermal stress.

Dietary supplementation with some electrolytes (such as sodium bicarbonate, ammonium chloride, potassium chloride, etc.) was suggested to effectively enable the laying birds (Balnave, 1996; Balnave, 2004) or growing birds (Deyhim and Teeter, 1991; Keskin and Durgan, 1997; Raya *et al.,* 2003a,b; Naseem *et al*., 2005) to partially or completely cope with chronic or acute heat stress, *via* correcting the acid-base balance, and increasing water consumption of birds and thus reducing birds' mortality and/or improving their productivity and egg shell quality. In addition, recent publications have demonstrated that dietary supplementation with vitamin E has beneficial effects on the performance of laying hens reared at high ambient temperatures (Bollengier-Lee *et al.*, 1998, 1999; Whitehead and Mitchell, 2000; Kirunda *et al*., 2001; Sahin *et al.*, 2002; Çiftçi *et al*., 2005).

Potassium is known to be required for the maintenance of normal metabolic processes in several species of animals including poultry (Duke, 1970). The NRC (1994) recommends dietary K levels of 0.15 and 0.30% for laying hens and broiler chicks, respectively, under normal conditions. Heat stress has been reported to depress plasma K concentration in chickens (Huston, 1978; Ait-Boulahsen *et al.*, 1989), enhance urinary K excretion, and reduce body K retention (Deetz and Ringrose, 1976; Smith and Teeter, 1987). Indeed, dietary K levels of 0.6% for laying hens (Deetz and Ringrose, 1976) and 1.5% for broiler chicks (Smith and Teeter, 1987) are needed to prevent a potassium imbalance under conditions of chronic heat stress.

Since heat stress affects both feed intake and egg production of laying hens, the aim of the present study was to investigate the possibility of alleviating the adverse effects of heat stress on productive performance and egg quality of laying hens exposed to heat stress during the summer season, by means of dietary supplementation with potassium chloride (KCl), vitamin E or their combinations.

MATERIALS AND METHODS

The present study was undertaken at the Poultry Research Unit; Agricultural Researches and Experiments Station; Faculty of Agriculture, Mansoura University, El-Mansoura, Egypt, from July 2004 to June 2005. Daily ambient temperature (T_a) and relative humidity (RH) were recorded inside the laying house four times per day; at mid-day (12 a.m), afternoon (3 p.m), at mid-night (12 p.m) and at dawn (3 a.m) during the entire experimental period; monthly means of maximum and minimum T_a and RH, are presented in Table 1.

Table 1: Monthly means of maximum and minimum T_a and RH of laying house during the entire experimental period

Month	Maximum T_a (ºC)	Minimum T_a (ºC)	Maximum RH (%)	Minimum RH (%)
July	39.5	28.0	97	47
August	41.8	31.6	98	47
September	40.5	30.4	97	43
October	35.6	28.7	96	39
November	30.2	24.5	97	45
December	24.1	19.5	95	56
January	23.5	17.3	92	42
February	24.0	16.8	92	40
March	26.4	18.5	95	39
April	29.4	21.9	96	37
May	34.6	25.6	97	30
June	35.5	28.0	96	40

Experimental birds and diets:

Three hundred and sixty, 20-week-old Hy-Line W-36 pullets were assigned to twelve equal experimental groups of 5 replications of 6 birds each. All birds were kept in community battery cages (6 birds per cage), set up in an open-sided laying house, and exposed to a daily photoperiod of 16 hr and managed similarly. Twelve experimental diets were formulated and used. Diet one (which served as a control) contained 0.42% K and 0.4% Cl. Diets 2, 3 and 4 contained supplemental KCl levels of 0.8, 1.6 and 2.4%, respectively. Thus, potassium and chloride contents of these diets were 0.8, 1.19 and 1.57% K, and, 0.78, 1.16 and 1.53% Cl, respectively. Diets 5, 6, 7 and 8 contained the same K and Cl levels as diets 1, 2, 3 and 4, respectively, but supplemented with 150 mg vitamin E/kg diet. Diets 9, 10, 11 and 12 contained the same K and Cl levels as diets 1, 2, 3 and 4, respectively, but supplemented with300 mg vitamin E/kg diet. All experimental diets were formulated to contain metabolizable energy (ME) of about 2840 kcal/kg and crude protein (CP) of about 18.7%. All experimental groups of hens were fed their respective diets (in mash form) from 20 up to 32 weeks of age (during the summer season, 2004). Then, all groups of laying hens fed on the experimental diets were switched to feed the control diet until the end of study, at 68 weeks of age. All birds had free access to feed and water throughout the experimental period. Composition and chemical analysis of the experimental diets are shown in Table 2. Chemical analyses of the experimental diets were carried out according to the official methods of analysis of the Association of Official Analytical Chemists (AOAC, 1984).

Productive performance of laying hens:

The productive performance of laying hens was evaluated in terms of live body weights (LBW), change in body weight (CBW), daily feed intake (DFI), hen-day egg production rate (EPR), egg weight (EW), daily egg mass (DEM) and feed conversion efficiency (FCE), as well as mortality rate and economic efficiency of production (EEP). Individual LBW of pullets were recorded at the beginning, during the peak production and at the termination of the experiment (at 20, 32 and 68 weeks of age); thus, CBW was calculated. In addition, during the course of this study daily records of mortality, EPR, EW were maintained. All criteria of productive performance were calculated on a replicate group basis.

Data on the productive performance and mortality rate of laying hens were presented for both the heat stress period (20 to 32 weeks of age) and the whole experimental period (20 to 68 weeks of age) whereas those of EEP were determined only for the whole experimental period. EEP was estimated for each dietary treatment, based on total feeding costs, total purchasing price of the replacement pullets and total revenues (including returns of the retailed eggs and the sold spent hens, which survived at the end of study). Net revenue was calculated as total revenue minus total variable costs of egg production (*i.e.* costs of feeding plus purchasing price of the replacement pullets). EEP was calculated as net revenue times 100 divided by the total variable costs of egg production. Total feed intake per replication and cost per kg feed were used to estimate the feeding costs per replication for the whole experimental period.

Table 2: Composition and chemical analysis of the experimental diets

Feed ingredients (%)	Dietary added KCl level (%)			
	Control	**0.8 KCl**	**1.6 KCl**	**2.4 KCl**
Yellow Corn	61.54	61.42	61.40	61.24
Soybean meal, 44%	6.80	5.80	5.10	4.20
Wheat bran	3.00	2.50	1.80	1.27
Corn gluten meal	15.30	16.10	16.70	17.47
Ground limestone	9.70	9.70	9.70	9.70
Dicalcium phosphate	2.25	2.25	2.25	2.25
Common salt	0.60	0.60	0.60	0.60
Vit.+Min. Premix†	0.30	0.30	0.30	0.30
DL-Methionine	0.10	0.10	0.10	0.10
Lysine-HCl	0.41	0.43	0.45	0.47
KCl	0.00	0.80	1.60	2.40
Total	100	100	100	100
Calculated analysis: (NRC, 1994)				
Metabolizable energy; kcal/kg	2844	2842	2840	2837
Crude protein; %	18.73	18.72	18.70	18.71
Ether extract; %	2.87	2.86	2.85	2.84
Crude fiber; %	2.36	2.24	2.12	2.01
Calcium; %	4.22	4.22	4.21	4.21
Total P; %	0.75	0.74	0.73	0.72
Available P; %	0.47	0.47	0.47	0.47
K; %	0.42	0.80	1.19	1.57
Cl; %	0.40	0.78	1.16	1.53
Na; %	0.26	0.27	0.27	0.28
Lysine; %	0.93	0.93	0.93	0.93
Methionine; %	0.49	0.49	0.50	0.50
Methionine + Cystine; %	0.82	0.83	0.83	0.83
Determined analysis: (AOAC, 1984)				
Dry matter (DM); %	90.44	91.31	91.49	91.39
Crude protein; %	21.87	22.35	22.19	21.62
Ether extract (EE); %	3.62	3.52	3.55	3.49
Crude fiber (CF); %	3.55	3.36	3.03	2.96
Ash; %	7.11	7.88	8.04	8.40
NFE; %	63.85	62.89	63.19	65.53
K; %	0.60	1.20	1.67	2.12

†: Each 3 Kg premix contains: Vit. A, 12,000,000 IU; Vit. D3, 3,000,000 IU; Vit. E, 10,000 mg; Vit. K3, 3,000 mg; Vit. B1, 200 mg; Vit. B2, 5,000 mg; Vit. B6, 3,000 mg; Vit. B12, 15 mg; Biotin, 50 mg; Folic acid 1,000 mg; Nicotinic acid 35,000 mg; Pantothenic acid 10,000 mg; Mn 80 g; Cu 8.8 g; Zn 70 g; Fe 35 g; I 1 g; Co 0.15 g and Se 0.3 g.

Egg quality measurements:

When the birds were 28 weeks of age (during the heat stress period), two-hundred and forty freshly collected eggs (20 per treatment) were broken out for egg quality evaluations. These included egg weight, and its components (Keshavarz and Nakajima, 1995), egg shape index (ESI; as egg width times 100 divided by egg length), egg shell thickness (EST; as an average of two measures at corresponding positions on the equator of the egg shell, using a special micrometer), egg specific gravity (ESG; Harms *et* *al.,* 1990), shell weight per unit surface area (SWUSA; as shell weight in mg divided by egg surface area in cm^2, Carter, 1975), Haugh units (HU; Haugh, 1937), yolk index (YI) and yolk color score (YC; by means of the Roche yolk color fan). Using a standard tripod micrometer, two measurements of thick albumen height, away from the chalazae at the highest two points on opposite sides of the yolk, together with egg weight were used to calculate the HU of the individual eggs. The same micrometer was used to estimate the yolk height, while yolk diameter was measured by a steel vernier caliper.

Experimental design and statistical analysis:

A completely randomized design in factorial arrangement of treatments (4×3), with four levels of supplemental dietary KCl and three levels of dietary vitamin E supplementation was used in the present study. Statistical analyses for various variables were performed, using Statgraphics, Version 5.0 STSC software program (Statistical Graphics Corporation, 1991). The differences were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Productive performance of laying hens:

It is interesting to note that means of maximum and minimum T_a, measured within the laying house during the heat stress period (*i.e.* July, August and September, 2004), were 39.5 and 28.0ºC, 41.8 and 31.6ºC, and 40.5 and 30.4ºC and the corresponding means of RH were 97 and 47%, 98 and 47%, and 97 and 43% for these three months, respectively (Table 1).

During the heat stress period (20 to 32 weeks of age), apart from the effect of supplemental dietary vitamin E, DFI of hens was significantly ($P \leq 0.01$) increased in response to dietary KCl supplementation (Table 3). However, no significant differences were observed in DFI of laying hens fed the highest two levels of KCl (1.6 and 2.4%) or between DFI of hens fed the supplemental levels of 0.8 or 1.6% KC. The percent increases in DFI due to the effect of dietary KCl supplementation during the heat stress period were estimated to be 8.29, 9.09 and 10.70% for birds fed diets supplemented with KCl levels of 0.8, 1.6 and 2.4%, respectively. Concurrently, laying hens fed the KCl-supplemented diets achieved significantly ($P \leq 0.01$) higher means of EPR compared with their control counterparts during the period from 20 to 32 weeks of age, regardless of the effect of supplemental dietary vitamin E (Table 3). There were no significant differences in EPR of birds fed the 0.8 or 1.6% KCl-supplemented diets; but hens fed the highest supplemental level of KCl (2.4%) gave superior EPR as compared to that of hens fed the intermediate level (1.6%). Means of EPR for hens fed diets containing supplemental KCl levels of 0.8, 1.6 and 2.4%, were higher by 8.43, 7.23 and 11.32 percentage points, respectively, relative to that of the control hens.

Table 3: Productive performance of laying hens fed diets supplemented with KCl, vitamin E or their combinations during the hot climate of the Egyptian summer (from 20 to 32 weeks of age)

Dietary treatments	DFI (g)	EPR (%)	EW (g)	DEM (g)	FCE (g:g)	LBW (g)20 Weeks old	CBW (g)20-32 Weeks old	Mortality rate (%)20-32 Weeks old
Main factors								
KCl, % (A)								
0.0	87.98^{c}	74.12^{c}	48.75^{b}	36.25^{c}	2.44^{a}	1208	103.7^{d}	16.67^{a}
0.8	95.27^{b}	82.55^{ab}	50.79^{a}	42.04^{ab}	2.28^{b}	1209	129.9^{c}	11.11^{ab}
1.6	95.98^{ab}	81.35^{b}	50.78^{a}	41.36^{b}	2.33^{b}	1210	150.7^{b}	7.78^{b}
2.4	97.39^{a}	85.44^{a}	50.93^{a}	43.57^{a}	2.23^{b}	1213	239.2^{a}	5.56^{b}
SEM[1]	0.56	1.13	0.23	0.60	0.03	2.02	3.86	2.003
Sig. level	**	**	**	**	**	NS	**	**
Vitamin E, mg/kg (B)								
0.0	93.53	78.30^{b}	49.77^{b}	39.12^{b}	2.41^{a}	1207	118.0^{c}	14.17^{a}
150	94.34	81.94^{a}	50.71^{a}	41.64^{a}	2.28^{b}	1211	146.0^{b}	8.33^{b}
300	94.59	82.36^{a}	50.45^{a}	41.65^{a}	2.28^{b}	1212	203.5^{a}	8.33^{b}
SEM[1]	0.48	0.98	0.19	0.52	0.03	1.75	3.35	1.74
Sig. level	NS	**	*	**	**	NS	**	*
A×B Interaction								
1×1	89.09	69.82	47.67	33.41	2.67	1197	64.8	20.00
1×2	87.79	76.14	49.88	38.03	2.32	1212	104.5	13.33
1×3	87.05	76.40	48.69	37.31	2.34	1215	141.7	16.67
2×1	94.74	85.02	50.59	43.13	2.21	1209	92.3	13.33
2×2	95.33	79.92	50.90	40.81	2.34	1211	111.0	10.00
2×3	95.73	82.70	50.88	42.18	2.27	1208	186.3	10.00
3×1	95.01	76.51	50.55	38.73	2.46	1210	123.8	13.33
3×2	95.75	83.54	50.87	42.54	2.25	1209	144.0	6.66
3×3	97.19	83.99	50.92	42.81	2.27	1211	184.3	3.33
4×1	95.30	81.84	50.28	41.22	2.31	1212	191.2	10.00
4×2	98.49	88.15	51.20	45.18	2.18	1211	224.7	3.33
4×3	98.38	86.34	51.30	44.32	2.22	1216	301.7	3.33
SEM[1]	0.97	1.96	0.39	1.03	0.06	3.50	6.70	3.45
Sig. level	NS	*	NS	*	*	NS	**	NS

[a-d]: For each of the main factors, means in the same column having different superscripts differ significantly at P≤ 0.05.
[1]: SEM refers to standard error of the means.

Similarly, hens fed the KCl-supplemented diets attained significantly (P≤0.01) higher means of EW and DEM compared with their control counterparts, with no significant differences in EW among groups fed the KCl supplemented diets (Table 3). No significant differences were detected in DEM of birds fed the 0.8 or 1.6% KCl-supplemented diets; but hens fed the highest supplemental level of KCl (2.4%) exhibited superior DEM as compared to that of hens fed the intermediate level (1.6%). The percent improvements in EW and DEM due to the effect of dietary KCl supplementation were estimated to be 4.55, 4.16 and 4.47%, and15.97, 14.09 and 20.19% for birds fed diets containing supplemental KCI levels of 0.8, 1.6 and 2.4%, respectively, compared with their control counterparts.

Regarding FCE, laying hens fed the KCl-supplemented diets displayed significantly (P≤0.01) better means of FCE compared with their control counterparts, with no significant differences among them (Table 3).

The percent improvements in FCE due to the effect of dietary KCl supplementation were estimated to be 6.56, 4.51 and 8.61% for birds fed diets containing supplemental KCl levels of 0.8, 1.6 and 2.4%, respectively, compared with their control hens.

During the heat stress period, hens fed the KCl-supplemented diets had significantly (P≤0.01) superior positive CBW and significantly lower (P≤0.01) mortality rates as compared to their control hens from 20 to 32 weeks of age, irrespective of the effect of dietary vitamin E supplementation (Table 3). It was observed that the higher the level of added KCl the greater the CBW attained by laying hens from 20 to 32 weeks of age. Means of mortality rate were 16.67, 11.11, 7.78 and 5.56% for laying hens fed diets with supplemental KCl levels of 0.0 (control), 0.8, 1.6 and 2.4%, respectively. The lowest mean of mortality rate was achieved by hens fed the highest level of KCL (2.4%) but was not significantly different from those of hens fed the other levels of added KCl (0.8 and 1.6%). The mortality rates of hens fed the KCl-supplemented diets during the heat stress period (20-32 weeks of age) were decreased by 5.56, 8.89 and 11.11 percentage points for laying hens fed diets containing supplemental KCl levels of 0.8, 1.6 and 2.4%, respectively, as compared with their control (0.0% KCl).

It was interesting to note that feeding the KCl-supplemented diets during the hot climate of the Egyptian summer (20 to 32 weeks of hens' age) had significant positive carry-over effects on DFI, EPR, EW, DEM and FCE during the whole experimental period (20 to 68 weeks of age) compared with the control birds, regardless of the effect of dietary vitamin E supplementation (Table 4). Feeding the KCl-supplemented diets during that period of heat stress (20 to 32 weeks of age) resulted in significantly better means of DFI, EPR, DEM and FCE during the entire experimental period; with no significant differences among them, as compared to their control hens (Table 4). No significant differences were detected in EW of hens fed the highest two levels of dietary KCl (1.6 and 2.4% of the diet) but were significantly heavier than that of hens fed the lowest level of supplemental KCl (0.8% of the diet), as indicated in Table 4. The increases in DFI of the entire experimental period of laying hens which had been fed diets supplemented with KCl levels of 0.8, 1.6 and 2.4%, respectively, during the hot climate of the Egyptian summer, were estimated to be 2.14, 2.72 and 2.54% relative to their control counterparts.

The percent improvements in EPR, EW, DEM and FCE attained during the whole experimental period by laying hens, which had been fed the diets supplemented with KCl levels of 0.8, 1.6 and 2.4% during the hot climate of the Egyptian summer, were estimated to be 5.41, 6.24 and 7.07 percentage points, 1.61, 2.70 and 2.90%, 7.91, 10.02 and 11.27%, and 7.21, 8.17 and 9.62%, respectively, relative to their control counterparts. In addition, hens fed the KCl-supplemented diets during the heat stress period (20-32 weeks of hens' age) achieved significantly (P≤0.01) higher means of EEP and CBW but lower means of mortality rate during the whole experimental period, irrespective of the effect of dietary supplementation with vitamin E (Table 4). The highest EEP and lowest mortality rate for the entire experimental period were attained by laying hens fed the highest supplemental level of KCl (2.4%) but were not significantly different from those of hens fed the other levels of added KCl (0.8 and 1.6%).

Heat stress is one of the important stressors in poultry production. The adverse effects of heat stress include depressed survivability, feed consumption, body weight gain, egg production rate and egg weight in laying hens (Marsden and Morris, 1987; Balnave, 1996; Bollengier-Lee *et al*., 1998; Mashaly *et al.,* 2004).

Table 4: Effects of feeding diets supplemented with KCl, vitamin E or their combinations during the hot climate of the Egyptian summer on productive performance of laying hens during the whole experimental period

Dietary treatments	DFI (g)	EPR (%)	EW (g)	DEM (g)	FCE (g:g)	CBW (g) 20-68 Weeks old	Mortality Rate (%) 20-68 Weeks old	EEP (%) 20-68 Weeks old
Main factors								
KCl, % (A)								
0.0	98.65^{b}	81.47^{b}	58.88^{c}	48.27^{b}	2.08^{a}	303.24^{d}	17.78^{a}	66.05^{b}
0.8	100.76^{a}	86.88^{a}	59.83^{b}	52.09^{a}	1.93^{b}	392.01^{c}	12.22^{ab}	75.52^{a}
1.6	101.33^{a}	87.71^{a}	60.47^{a}	53.11^{a}	1.91^{b}	419.48^{b}	7.78^{b}	78.72^{a}
2.4	101.16^{a}	88.54^{a}	60.59^{a}	53.71^{a}	1.88^{b}	491.68^{a}	5.56^{b}	81.46^{a}
SEM[1]	0.35	1.04	0.11	0.64	0.02	6.69	2.48	2.08
Sig. level	**	**	**	**	**	**	**	**
Vitamin E, mg/kg (B)								
0.0	100.41	82.89^{b}	58.87^{b}	49.01^{b}	2.07^{a}	308.77^{c}	15.83^{a}	67.37^{b}
150	100.95	87.70^{a}	60.41^{a}	53.07^{a}	1.90^{b}	426.89^{b}	8.33^{b}	78.86^{a}
300	100.07	87.87^{a}	60.56^{a}	53.30^{a}	1.88^{b}	469.14^{a}	8.33^{b}	80.09^{a}
SEM[1]	0.30	0.90	0.09	0.56	0.02	5.79	2.15	1.80
Sig. level	NS	**	**	**	**	**	*	**
A×B Interaction								
1×1	100.04	71.51	56.42	40.55	2.47	211.67	23.33	44.71
1×2	98.36	86.27	60.16	52.01	1.89	342.61	13.33	76.59
1×3	97.56	86.65	60.08	52.23	1.86	355.43	16.67	76.85
2×1	100.06	88.92	59.03	52.64	1.90	284.77	16.67	77.59
2×2	101.73	85.48	60.21	51.58	1.97	416.67	10.00	73.09
2×3	100.50	86.24	60.26	52.05	1.93	474.58	10.00	75.89
3×1	100.91	84.65	60.01	50.87	1.98	317.83	13.33	70.80
3×2	101.53	89.30	60.58	54.18	1.87	441.00	6.67	82.41
3×3	101.54	89.17	60.83	54.28	1.87	499.62	3.33	82.96
4×1	100.62	86.48	60.01	52.00	1.93	420.83	10.00	76.36
4×2	102.18	89.74	60.70	54.51	1.87	507.31	3.33	83.35
4×3	100.67	89.40	61.06	54.62	1.84	546.92	3.33	84.68
SEM[1]	0.61	1.81	0.18	1.11	0.04	11.60	4.30	3.61
Sig. level	NS	**	**	**	**	*	NS	**

[a-d]: For each of the main factors, means in the same column having different superscripts differ significantly at P≤ 0.05.
[1]: SEM refers to standard error of the means.

The improved productive performance; observed under the conditions of this study, of laying hens fed the KCl-supplemented diets may be related, at least partly, to improvements in feed intake of hens reared in hot climate conditions, as it is the case in Egyptian Summer. Alternatively, since laying hens are normally fed high-calcium diets the concurrent supplementation with KCl might produce a certain type of synergism between the two nutrients (*i.e.* calcium and potassium) which led to such improved productivity. It is likely that dietary KCl, like other electrolytes, had a role in correcting the respiratory alkalosis or the acid-base imbalance which can adversely affect the productive performance of heat-stressed hens. Some enhancement of water consumption induced by supplemental dietary KCl must not be ruled out.

The beneficial effects of using electrolytes in diets or drinking water of poultry have been widely investigated. In this regard, Raya *et al.* (2003a) reported that dietary supplementation with KCl at a level of 1.5% enhanced the body weight gain, improved the feed conversion and reduced the mortality rate of broiler chicks reared under heat stress conditions. On the other hand, Teeter and Smith (1986) found that feeding of potassium or ammonium chlorides in the drinking water (0.15 and 0.20%, respectively) with a diet adequate in potassium (7.3 g K/kg DM) improved growth and feed conversion efficiency of heat-stressed broiler chicks. Likewise, Branton *et al*. (1986) reported that drinking water containing 6.3 g $NaHCO_3$/L induced a higher water intake and decreased the mortality of heat-stressed finishing broilers. Balnave and Oliva (1991), working with finishing broilers at a high temperature (30ºC), found that diets supplemented with 16.8 g $NaHCO_3$/kg or drinking water supplemented with 5.6 g $NaHCO_3$/L produced a significant improvement in birds' production response. Ait-Boulahsen *et al.* (1995) reported that KCl improves the thermotolerance of chickens exposed to acute heat stress, suggesting a relationship among supplemental KCl, blood ionized calcium and body temperature. More recently, Naseem *et al.* (2005) reported that supplementing heat-stressed broiler chicks with 1.5% KCl solution improved weight gain and feed conversion ratio compared with the control birds.

During the heat stress period, apart from the effect of dietary KCl supplementation, no significant differences were detected in DFI of laying hens in response to feeding the vitamin E- supplemented diets (Table 3). However, significantly higher means of EPR ($P\leq 0.01$), EW ($P\leq 0.05$), DEM ($P\leq 0.01$) and FCE ($P\leq 0.01$) were achieved by laying hens fed the vitamin E-supplemented diets compared with the control birds (Table 3). No significant differences were observed in means of EPR, EW, DEM and FCE between groups of birds fed the high (300 mg/kg diet) and low level (150 mg/kg diet) of supplemental vitamin E. EPR of hens fed the low (150 mg/kg) and the high (300 mg/kg) level of vitamin E was improved by 3.64 and 4.06 percentage points, respectively, compared with their control hens. The accomplished improvements in EW, DEM and FCE in response to feeding the vitamin E-supplemented diets were estimated to be 1.89 and 1.36%, 6.44 and 6.47%, and, 5.39 and 5.39% for hens fed the low (150 mg/kg) and the high (300 mg/kg) level of vitamin E, respectively, compared with the control hens. In addition, feeding the vitamin E-supplemented diets during the heat stress period achieved similar improvements ($P\leq 0.01$) in 32-wk-old LBW and CBW of hens from 20 to 32 weeks of age, irrespective of the effect of dietary KCl supplementation (Table 3); the improvement was proportional to dietary supplementation level of the vitamin.

Feeding the vitamin E-supplemented diets during the hot climate of the Egyptian summer (20-32 weeks of hens' age) had significant positive carry-over effects ($P\leq0.01$) on EPR, EW, DEM and FCE of laying hens during the whole experimental period (from 20 to 68 weeks of age) as compared to their control hens, regardless of the effect of dietary KCl supplementation (Table 4). However, no significant differences were detected in means of DFI of hens during the same period (20 to 68 weeks of age) in response to feeding the vitamin E-supplemented diets during the heat stress period (20 to 32 weeks of age) as compared to their control counterparts. The best means of EPR, EW, DEM and FCE were attained by birds fed the high supplemental level of vitamin E (300 mg) but were not significantly different from those of birds fed the low level of the vitamin (150 mg/kg). The percent improvements in EPR, EW, DEM and FCE for the whole experimental period (20 to 68 weeks of age) attained by laying hens which had been fed dietary vitamin E levels of 150 and 300 mg/kg during the hot climate of the Egyptian summer (20 to 32 weeks of age) were estimated to be 4.81 and 4.98 percentage points, 2.62 and 2.87%, 8.28 and 8.75%, and, 8.21 and 9.18%, respectively, relative to their control hens.

During the heat stress period (20-32 weeks of age), feeding the vitamin E-supplemented diets had significant ($P \leq 0.05$) positive effects on mortality of laying hens, regardless of the effect of dietary KCl supplementation (Table 3). Means of mortality rate were 14.17, 8.33 and 8.33% for laying hens fed diets containing supplemental vitamin E levels of 0.0 (control), 150 and 300 mg/kg, respectively. The mortality rate of laying hens fed vitamin E-supplemented diets during the heat stress period were decreased by 5.84 percentage points as compared to that of the control hens from 20 to 32 weeks of age. In addition, feeding the vitamin E-supplemented diets during the heat stress period (20-32 weeks of age) produced significant ($P \leq 0.01$) improvements in EEP and CBW but significantly reduced mortality rates of laying hens from 20 to 68 weeks of age, irrespective of the effect of dietary KCl supplementation (Table 4), with no significant differences in mortality rate and EEP between the two supplemental levels of vitamin E.

In agreement with the present results, many recent publications have demonstrated that dietary supplementation with vitamin E has beneficial effects on the performance of laying hens reared at high ambient temperatures (Utomo *et al.,* 1994; Whitehead *et al.,* 1998; Bollengier-Lee *et al.*, 1998, 1999; Whitehead and Mitchell, 2000; Kirunda *et al*., 2001; Sahin *et al.*, 2002; Çiftçi *et al*., 2005).

It is interesting to note that although DFI of laying hens during the entire experimental period was not significantly affected by dietary vitamin E supplementation during the hot climate of the Egyptian summer, productive performance (EPR, EW, DEM and FCE) was positively affected (Table 4). This observation may confirm the postulation that heat stress *per se* has a direct negative effect on the productive performance of laying hens; apart from its depressive effect on feed intake, and that dietary vitamin E supplementation could effectively ameliorate that effect.

An evidence for a beneficial effect of vitamin E on egg production of hens was presented by Utomo *et al.* (1994). However, the biochemical mode of action of vitamin E underlying its beneficial effect on egg production is still not clearly understood. Bollengier-Lee *et al.* (1998) observed a reduction in the circulating concentration of yolk precursors, particularly vitellogenin, coincided with a depression in egg production in heat-stressed hens and found that supplemental vitamin E increased the plasma vitellogenin concentrations. They also concluded that dietary supplementation with vitamin E improves egg production in stressed hens by facilitating the release of vitellogenin from the liver and increasing the circulating supply of this precursor protein for yolk formation. In addition, Bollengier-Lee *et al.* (1999) recommended an optimal supplemental dietary level of vitamin E of 250 mg/kg, provided before, during and after heat stress, for partially alleviating the depressive effect of heat stress on egg production. They also reported that dietary supplementation with this dose of vitamin E was proved to be sufficient to reduce the drop in the concentration of vitamin E in plasma and liver of laying hens which may provide an adequate pool of vitamin E to overcome the effect of heat stress. Vitamin E has been reported as an excellent biological chain-breaking antioxidant that protects cells and tissues from lipo-peroxidative damage induced by free radicals (McDowell, 1989). More recently, Whitehead and Mitchell (2000) speculated that vitamin E may achieve this effect by protecting cell membranes from oxidative damage and improving transport characteristics across membranes. Alternatively, vitamin E may act directly in a novel mechanism to facilitate the transport of vitellogenin across hepatocyte membranes. Moreover, vitamin E can also modulate other types of stress on laying hens, particularly during the peak of egg production.

Analysis of variance detected no significant interactions between supplemental dietary KCl and vitamin E on DF, EW or mortality rate of laying hens during the heat stress period (20-32 weeks of hens' age); however, the interactions between the two dietary factors were significant for EPR, DEM and FCE, as well as CBW of laying hens from 20 to 32 weeks of age. On the other hand, significant interactions were observed between supplemental dietary KCl and vitamin E on the productive performance of laying hens during the entire experimental period (20 to 68 weeks of age), as measured by EPR, EW, DEM and FCE as well as CBW and EEP. But DFI and mortality rate were not affected by the interactions between the two dietary supplements.

Egg quality of laying hens during the heat stress period:

As shown in Table 5, feeding the KCl-supplemented diets during the hot climate of the Egyptian summer significantly ($P \leq 0.01$) improved the EW, shell percentage (SP; $P \leq 0.05$), EST ($P \leq 0.05$), ESG ($P \leq 0.05$), SWUSA and HU of eggs as compared to their control counterparts, regardless of the effect of dietary vitamin E supplementation. However, other egg quality traits were not significantly affected by supplemental dietary KCl. The highest means of EW and SWUSA were achieved by hens fed the highest level of supplemental KCl (2.4% of the diet) which were not significantly different from those of birds fed the other levels of KCl (0.8 and 1.6). Birds fed the 1.6%KCl-diets exhibited the highest means of SP and ESG which were not significantly different from those of birds fed the 2.4%KCl-diets. The highest means of EST and HU were attained by hens fed the highest supplemental level of KCl (2.4% of the diet) which were significantly superior versus those of birds fed the lowest level of added KCl (0.8% of the diet), but were not significantly different from those of hens fed the intermediate level of supplemental KCl (1.6% of the diet). The estimated improvements in EW, SP, EST, ESG, SWUSA and HU of eggs in response to feeding the KCl-supplemented diets were 6.78, 7.14 and 8.66%, 0.30, 0.48 and 0.38 percentage points, 5.88, 8.82 and 11.76%, 0.18, 0.27 and 0.18%, 4.49, 6.04 and 5.72%, and, 3.13, 6.96 and 8.51% for laying hens fed the supplemental dietary KCl levels of 0.8, 1.6 and 2.4%, respectively, relative to their control hens.

Heat stress has been reported to reduce feed intake, egg production, egg weight and certain egg quality traits in laying hens (*e.g*. Kirunda *et al.*, 2001; Sahin *et al.,* 2002; Mashaly *et al.,* 2004). The improvements observed herein, in some traits of egg quality of laying hens fed the KCl-supplemented diets during the hot climate of the Egyptian summer suggest that KCl supplementation could alleviate the negative impact of heat stress on egg quality. In line with most of the above mentioned reports, the harmful effects of heat stress on egg quality traits, observed under the conditions of the present study, were more evident on egg weight and eggshell quality than those exerted on the other criteria of egg quality. Yet, the exact mode of action of KCl in improving eggshell quality of laying hens exposed to heat stress is not clearly understood. Dietary KCl supplementation might have a role in correcting the blood acid-base perturbations (particularly, respiratory alkalosis) occurring during heat stress and thus modulating a certain type of the physiological alterations responsible for the reduced eggshell quality. On the other hand, the depressed albumen quality (as measured by HU) under heat stress conditions of the present study is in line with other publications (*e.g.* Kirunda *et al.*, 2001; Sahin *et al.,* 2002; Sahin and Kucuk, 2003).

No reports could be found in the scientific literature concerning the use of dietary KCl supplementation as an anti-heat stress way for laying hens. On the other hand, attempts to improve eggshell quality through dietary supplementation of certain electrolytes have been made. For example, Balnave and Muheereza (1997) reported an improvement in eggshell quality of laying hens reared at high temperatures in response to dietary supplementation with sodium bicarbonate (1.0%).

In broiler chicks, beneficial effects have been reported due to dietary or water supplementation with potassium or sodium salts (Branton *et al*., 1986; Teeter and Smith, 1986; Balnave and Oliva, 1991; Ait-Boulahsen *et al.*, 1995; Soutyrine *et al.*, 1998; Raya *et al.*, 2003a, b; Naseem *et al.*, 2005). Such supplemental electrolytes, including KCl, might stimulated water intake and/or enhanced the thermotolerance of birds exposed to heat stress. Alternatively, these electrolytes may have a potential for correcting the respiratory alkalosis or the acid-base imbalance which can adversely affect the productive performance of heat-stressed birds.

Apart from the effect of dietary KCl supplementation, feeding the vitamin E-supplemented diets during the hot climate of the Egyptian summer significantly ($P \leq 0.01$) improved EW, SP, YP, AP, ESI ($P \leq 0.05$), EST ($P \leq 0.05$), ESG ($P \leq 0.05$), SWUSA and HU ($P \leq 0.05$) of eggs as compared to their control counterparts (Table 5). However, YI and YC were not significantly affected by supplemental dietary vitamin E. The highest means of EW, YP and HU were achieved by hens fed the low level of supplemental vitamin E

(150 mg/kg diet) which were not significantly different from those of birds fed the high level of the vitamin (300 mg/kg diet). However, hens fed the high supplementary level of vitamin E exhibited significantly superior means of SP, AP, EST and ESG as opposed to those of hens fed the low level of the vitamin. Even though birds fed the high supplementary level of vitamin E achieved the highest means of ESI and SWUSA they were not significantly higher than those of hens fed the low supplemental level of vitamin E.

Table 5: Egg quality traits[§] during the hot climate of the Egyptian summer of laying hens fed diets supplemented with KCl, vitamin E or their combinations

Dietary treatments	EW[1] (g)	SP[2] (%)	YP[3] (%)	AP[4] (%)	ESI[5] (%)	EST[6] (mm)	ESG[7]	SW: USA[8] (mg/cm^2)	YI[9] (%)	YC[10]	HU[11]
Main factors											
KCl, % (A)											
0.0	49.55^{b}	12.25^{b}	25.11	62.63	80.73	0.34^{c}	1.099^{b}	97.17^{b}	40.75	8.10	81.45^{c}
0.8	52.91^{a}	12.55^{ab}	24.56	62.87	81.58	0.36^{b}	1.101^{ab}	101.53^{a}	41.13	8.33	84.00^{b}
1.6	53.09^{a}	12.73^{a}	25.23	62.03	80.79	0.37^{a}	1.102^{a}	103.04^{a}	41.39	8.07	87.12^{a}
2.4	53.84^{a}	12.63^{a}	24.88	62.47	81.26	0.38^{a}	1.101^{a}	102.73^{a}	41.80	8.07	88.38^{a}
SEM[1]	0.41	0.11	0.19	0.21	0.33	0.002	0.0006	1.006	0.35	0.12	0.70
Sig. level	**	*	NS	NS	NS	**	*	**	NS	NS	**
0.0	50.84^{b}	12.41^{b}	24.36^{b}	62.11^{b}	80.49^{b}	0.36^{b}	1.1004^{b}	99.26^{b}	41.04	8.10	83.95^{b}
150	53.28^{a}	12.47^{b}	25.47^{a}	62.23^{b}	81.26^{ab}	0.36^{b}	1.1007^{b}	101.03^{ab}	41.65	8.27	86.15^{a}
300	52.93^{a}	12.74^{a}	25.01^{a}	63.16^{a}	81.51^{a}	0.37^{a}	1.1023^{a}	103.06^{a}	41.11	8.05	85.62^{a}
SEM[1]	0.35	0.09	0.16	0.18	0.29	0.002	0.0005	0.87	0.31	0.10	0.60
Sig. level	**	**	**	**	*	*	*	**	NS	NS	*
A×B Interaction											
1×1	46.13	11.86	26.52	61.61	81.91	0.34	1.097	92.17	39.97	8.10	78.52
1×2	52.02	12.21	23.72	64.05	81.67	0.34	1.099	98.23	40.88	8.10	82.61
1×3	50.49	12.67	25.10	62.22	78.60	0.35	1.101	101.11	41.40	8.10	83.24
2×1	51.99	12.66	24.79	62.54	82.00	0.36	1.101	101.83	40.69	8.20	83.77
2×2	53.87	12.27	24.11	63.60	81.75	0.37	1.099	99.85	41.79	8.50	84.71
2×3	52.88	12.73	24.77	62.49	80.99	0.36	1.102	102.90	40.92	8.30	83.53
3×1	52.47	12.48	25.31	62.19	81.61	0.37	1.100	100.77	41.70	8.00	86.80
3×2	53.70	12.87	25.18	61.94	80.23	0.37	1.103	104.52	42.00	8.10	88.31
3×3	53.12	12.82	25.21	61.96	80.52	0.37	1.102	103.84	40.47	8.10	86.26
4×1	52.76	12.64	25.24	62.10	80.51	0.37	1.101	102.26	41.79	8.10	86.69
4×2	53.52	12.51	24.41	63.06	81.38	0.37	1.100	101.53	41.95	8.40	89.00
4×3	55.24	12.75	24.98	62.25	81.87	0.38	1.102	104.40	41.67	7.70	89.45
SEM[1]	0.71	0.19	0.32	0.37	0.58	0.004	0.0011	1.74	0.62	0.22	1.21
Sig. level	**	NS	**	*	**	NS	NS	NS	NS	NS	NS

[§]: Measured when the hens were 28 weeks of age.

[1-12]: Denote to egg weight, shell %, yolk %, albumen %, egg shape index, egg shell thickness, egg specific gravity, shell weight per unit surface area, yolk index, yolk color score, Haugh units and standard error of the means, respectively.

[a-b]: For each of the main factors, means in the same column having different superscripts differ significantly at P≤ 0.05.

The estimated improvements in EW, SP, YP, AP, ESI, EST, ESG, SWUSA and HU of eggs were 4.80 and 4.11%, 0.06 and 0.33 percentage points, 1.11 and 0.65 percentage points, 0.12 and 1.05 percentage points, 0.96 and 1.27%, 0.0 and 2.78%, 0.027 and 0.17%, 1.78 and 3.83%, and, 2.62 and 1.99% for laying hens fed the supplemental dietary vitamin E levels of 150 and 300 mg/kg, respectively, relative to their control hens. The perusal of the present results indicated that the beneficial effect of dietary vitamin E supplementation on egg quality traits during the hot climate of the Egyptian summer, was more pronounced for egg weight and its components, and SWUSA than it did for the other traits of egg quality.

It is well known that poultry can not synthesize vitamin E; therefore their requirements for vitamin E must be met from dietary sources. However, it is generally accepted that the vitamin E requirements of poultry increase with increased stresses, particularly heat stress (Daghir, 1995). In a study conducted by Whitehead *et al*. (1998), laying hens were maintained in controlled environment housing at 22ºC, then held for one month at 32ºC, and finally returned to 22ºC; they found that dietary vitamin E level of 315 IU/kg resulted in higher rates of lay and better feed conversion during the hot period and in the following months, suggesting that the NRC (1994) recommendations of 5 IU/kg for laying hens is too low for birds held in hot climates.

On the other hand, the current results are in line with the findings of Sahin *et al.* (2002), who reported that egg weight, egg specific gravity, egg shell thickness and Haugh units of laying Japanese quails were positively influenced by vitamin E supplementation. In partial agreement with the present results, Kirunda *et al*. (2001) found that exposure to high temperature significantly depressed egg weight, Haugh units, vitelline membrane strength, yolk and albumen dry weights, and yolk color. They also observed that dietary supplementation of heat-stressed hens with 60 IU vitamin E/kg improved vitelline membrane strength, and yolk and albumen dry weights but did not improve egg weight, yolk color or yolk index. Puthpongsiriporn *et al*. (2001) demonstrated that supplementation of hen diets with vitamin E could alleviate some of the deterioration in egg quality caused by rearing hens at high environmental temperatures; they found that egg mass, percent egg yolk and Haugh units were improved by dietary vitamin E supplementation. Çiftçi *et al*. (2005) studied the effects of dietary supplementation with vitamin E and vitamin C, either singly or in combination, on the productive performance and egg quality of laying hens exposed to chronic heat stress. They observed that egg weight and percentage of egg yolk was markedly enhanced in the supplemented birds while other egg components, Haugh units and eggshell quality were not affected.

Significant supplemental dietary KCl by vitamin E interactions were observed for EW, YP, AP and ESI, whereas other egg quality traits were not affected.

Conclusion

It could be concluded that dietary supplementation with either single doses of 1.6% KCl or 300 mg vitamin E/kg diet, or with a combination of 1.6% KCl and 150 mg vitamin E/kg diet, could be suggested for ameliorating the negative effects of heat stress on laying hens' productive performance, viability and economic efficiency.

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إستخدام فيتامين هـ وكلوريد البوتاسيوم في الغذاء كوسيلة لتخفيف تأثيرات الإجهاد الحراري على المظاهر الإنتاجية لدجاج البيض

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أجريت هذه الدراسة لبحث إمكانية تخفيف تأثيرات الإجهاد الحراري على المظاهر الإنتاجية وجودة البيض للدجاج البياض المعرض للإجهاد الحراري خلال فصل الصيف عن طريق تدعيم الغذاء بكلوريد البوتاسيوم أو فيتامين هـ أو كليهما معا. تم توزيع عدد 360 دجاجة بياضة عمر 20 أسبوعا من سلالة الهاي لاين دبليو-36 عشوائيا إلى 12 معاملة تجريبية بكل منها خمسة مكررات (بكل منها 6 دجاجات) وتم تسكين الدجاج في بطاريات ذات أقفاص جماعية (قفص/مكررة) موضوعة في عنبر مفتوح تحت برنامج إضاءة مكون من 16 ساعة إضاءة و8 ساعات إظلام مع تثبيت عوامل الرعاية الأخرى. تم تكوين 4 علائق تجريبية في صورة مجروش ناعم مزودة بكلوريد البوتاسيوم بنسب صفر (عليقة المقارنة)، 0.8، 1.6، 2.4% من الغذاء علي التوالي ثم دعمت كل منها بفيتامين هـ بمعدل صفر أو 150 أو 300 ميللجم/كجم وبالتالي تم تكوين 12 عليقة تجريبية. واحتوت جميع العلائق التجريبية علي نفس مستوي الطاقة الممثلة (حوالي2840 كيلو كالوري/ كجم) والبروتين الخام (حوالي18.7%)، وتم تغذية الطيور عليها من عمر 20 حتى 32 أسبوعا (خلال فصل الصيف) وبعد ذلك تم وقف المعاملات الغذائية وغذيت جميع الطيور على عليقة المقارنة حتي نهاية فترة الدراسة عند عمر 68 أسبوعا. وتم توفيرالغذاء والماء بحرية أمام الطيور طوال فترة التجربة. واشتملت معايير الاستجابة للدجاج خلال فترة الإجهاد الحراري (20-32 أسبوعا من العمر) على المظاهر الإنتاجية ومعدل النفوق والتغير في وزن الجسم وبعض صفات جودة البيض كما تم قياس نفس المعايير (بإستثناء إختبار جودة البيض) خلال الفترة التجريبية الكلية (20-68 أسبوعا من العمر) علاوة على تقدير الكفاءة الإقتصادية للإنتاج للفترة التجريبية الكلية. ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلي: بصرف النظر عن تأثير تدعيم الغذاء بفيتامين هـ، أدت التغذية على العلائق المدعمة بكلوريد البوتاسيوم خلال فترة الإجهاد الحراري إلى حدوث نقص معنوي في معدل النفوق بينما تحسنت المظاهر الإنتاجية وأوزان الدجاج معنويا مقارنة بالطيور التي غذيت على العليقة غير المدعمة-كما لوحظت نفس التأثيرات الإيجابية على حيوية الدجاج والمظاهر الإنتاجية وأوزان الدجاج وكذلك الكفاءة الإقتصادية للإنتاج خلال الفترة التجريبية الكلية، مع عدم وجود فروق معنوية بين مستويات إضافة كلوريد البوتاسيوم للغذاء في معظم الأحيان. كما أعطت الدجاجات التي غذيت على العلائق المدعمة بكلوريد البوتاسيوم خلال فترة الإجهاد الحراري بيضا ذات جودة أفضل (وزن البيضة وجودة القشرة وجودة البياض معبرا عنها بوحدات هوف) مقارنة بالطيور التي غذيت على العليقة غير المدعمة، مع عدم وجود فروق معنوية بين مستويات إضافة كلوريد البوتاسيوم للغذاء في معظم الأحيان. بغض النظر عن تأثير تدعيم الغذاء بكلوريد البوتاسيوم، أدت التغذية على العلائق المدعمة بفيتامين هـ خلال فترة الإجهاد الحراري إلى حدوث نقص معنوي في معدل النفوق بينما تحسنت المظاهر الإنتاجية وكذلك أوزان الدجاج معنويا مقارنة بالطيور التي غذيت على العليقة غير المدعمة ولم يتأثر إستهلاك العلف اليومي-كما إمتدت التأثيرات الإيجابية لتدعيم الغذاء بفيتامين هـ خلال فترة الإجهاد الحراري على حيوية الدجاج والمظاهر الإنتاجية وأوزان الدجاج وكذلك على الكفاءة الإقتصادية للإنتاج خلال الفترة التجريبية الكلية، مع عدم وجود فروق معنوية بين مستويي إضافة فيتامين هـ للغذاء في معظم الأحيان. كما نتج عن التغذية على العلائق المدعمة بفيتامين هـ خلال فترة الإجهاد الحراري تحسنا معنويا في وزن البيضة ومكوناتها وكذلك في جودة القشرة وجودة البياض مقارنة بمتوسطات الدجاجات التي غذيت على العليقة غير المدعمة، وبصفة خاصة مع المستوى المرتفع من فيتامين هـ (300 ميللجم/كجم من الغذاء) بينما لم يتأثر كل من معامل الصفار ولون الصفار. كان لإضافة كلوريد البوتاسيوم مع فيتامين هـ في علائق الدجاج البياض خلال فترة الإجهاد الحراري أثرا معنويا على بعض صفات جودة البيض وكذلك على معايير المظاهر الإنتاجية والكفاءة الإقتصادية للإنتاج خلال الفترة التجريبية الكلية.

نستنتج من هذه الدراسة أنه يمكن التوصية بتدعيم علائق دجاج البيض خلال الطقس الحار بكلوريد البوتاسيوم بمستوى 1.6% من الغذاء أو بفيتامين هـ بمعدل 300 ميللجم/كجم أو بالإثنين معا (1.6% كلوريد البوتاسيوم + 150 ميللجم فيتامين هـ /كجم) من أجل تخفيف الآثار السيئة للإجهاد الحراري علي المظاهر الإنتاجية وحيوية الطيور والكفاءة الإقتصادية للإنتاج.