Anais da Academia Brasileira de Ciências (2017) 89(2): 1259-1268
(Annals of the Brazilian Academy of Sciences)
Printed version ISSN 0001-3765 / Online version ISSN 1678-2690
http://dx.doi.org/10.1590/0001-3765201720150709
www.scielo.br/aabc

Vitamin E and organic selenium for broilers from 22 to 42 days old: performance and carcass traits

DANIEL M.N. ALBUQUERQUE[1], JOÃO B. LOPES[2], MAÍRA S. FERRAZ[3], MABELL N. RIBEIRO[4], SANDRA R.G. SILVA[4], ELVÂNIA M.S. COSTA[4], DANIELA C.P. LIMA[4], JEFFERSON D.M. FERREIRA[4], PEDRO E.B. GOMES[4] and JACKELLINE C.O. LOPES[4]

[1]Instituto Federal de Educação, Ciência e Tecnologia do Piauí, Campus Uruçuí, PI-247, Km 07, Portal dos Cerrados, 64860-000 Uruçuí, PI, Brazil
[2]Departamento de Zootecnia do Centro de Ciências Agrárias, Universidade Federal do Piauí, Campus Universitário Ministro Petrônio Portela, Ininga, 64049-550 Teresina, PI, Brazil
[3]Departamento de Morfologia do Centro de Ciências da Saúde, Universidade Federal do Piauí, Campus Universitário Ministro Petrônio Portela, Ininga, 64049-550 Teresina, PI, Brazil
[4]Programa de Pós-Graduação em Ciência Animal, Centro de Ciências Agrárias, Universidade Federal do Piauí, Campus Universitário Ministro Petrônio Portela, Ininga, 64049-550 Teresina, PI, Brazil

Manuscript received on October 6, 2015; accepted for publication on December 22, 2016

ABSTRACT

This study was conducted to evaluate the effect of vitamin E and selenium on performance, viability, productive efficiency, and yields of carcass, major cuts, and organs of broilers from 22 to 42 days submitted to cyclic-heat stress. The experimental design was randomized blocks, in a 2 × 3 factorial arrangement with two levels of selenium (0.1 and 0.3 mg/kg) and three levels of vitamin E (300, 400, and 500 mg/kg), plus a control treatment. Animals were submitted to a natural condition of high cyclic temperature. Organic selenium levels of 0.1 and 0.3 mg/kg associated with 300, 400, and 500 mg/kg of vitamin E were tested. The level of vitamin E did not affect the performance or production efficiency of broilers in the period from 22 to 33 days and 22 to 42 days. However, the selenium inclusion level of 0.3 mg/kg improved the viability in both phases. The yields of carcass, major cuts, intestine, and heart were not influenced by the levels of selenium and vitamin E, whereas abdominal fat for the selenium level 0.1 mg/kg decreased linearly with the inclusion in vitamin E.

Key words: antioxidant, minerals, nutrition, poultry, productive efficiency, vitamins.

INTRODUCTION

The poultry industry has occupied a prominent position in the list of exports of products marketed in Brazil, producing broilers with high technology and very competitive costs. However, there are some problems in the production process, mainly in the northeast region of Brazil, where the environment at some months of the year becomes incompatible with the comfort zone of these birds.

Heat stress is a major factor affecting the production of broilers in tropical regions, with adverse effects on weight gain, feed intake, feed

Correspondence to: Daniel Medeiros de Noronha Albuquerque
E-mail: piauidaniel@gmail.com

conversion, and mortality of these animals, which consequently influence the business profitability (Quinteiro-Filho et al. 2010).

Under stress, birds tend to change their behavior to ensure their survival in the face of adversity. In the case of heat stress, birds reduce their feed intake, spend more time ingesting water or lying, increase their respiratory rate, and spread their wings in an attempt to lose heat to the environment (Medeiros et al. 2005, Lara and Rostagno 2013).

In such conditions, lipid peroxidation in the tissues is high, causing accumulation of free radicals and antioxidant imbalance. When the stress is prolonged or very aggressive, the body's antioxidant capacity is exceeded, which impairs cellular functions and consequently leads to a decrease in production performance (Maini et al. 2007).

The use of antioxidant vitamins and minerals such as selenium and vitamin E alone or combined, in broiler diets, can minimize the effects of stress caused by high temperatures due to the effect of free-radical sequestration and consequently improve the growth performance of birds (Marmoud and Edens 2005, Choct et al. 2010, Habibian et al. 2013).

The objective of this study was to determine whether the current levels of selenium and vitamin E present in commercial premixes fulfill the requirements of broilers from 22 to 42 days old submitted to natural cyclic-heat stress by evaluating their effect on performance, rearing viability, production efficiency index, and the yields of the carcass and major cuts of these birds.

MATERIALS AND METHODS

The study was conducted in poultry sheds at the Department of Animal Science, in the Center for Agricultural Sciences at the Federal University of Piauí, located in Teresina - PI, Brazil (05° 02' 40,10" latitude and 42º 47' 03,79"longitude). The climate of the region, according to the Köppen classification, is an AW type (Kottek et al. 2006), consisting of an equatorial savanna with minimum precipitation of 60 mm in the winter.

The experiment was approved by the Ethics Committee on Animal Experimentation of the Federal University of Piauí (CEEA/UFPI) under protocol #087/12.

A total of 1,100 one-day-old chicks of the ROSS line, originally sexed, separated by sex until 21 days, fed diets formulated according to the nutritional requirements of each life stage (Rostagno et al. 2011), were housed in a single shed. At 22 days, 700 chicks were selected by weight, half of each sex, with an average weight of 0.789 ± 0.022kg.

A randomized-block experimental design was adopted, with the block represented by the sheds, in a 2 × 3 factorial arrangement with two levels of selenium (0.1 and 0.3 mg/kg) and three levels of vitamin E (300, 400, and 500 mg/kg), plus a control diet. The form of vitamin E used was DL-α-tocopherol and selenium, in a commercial organic preparation (selenomethionine).

The birds were allotted to seven treatments and five replications, housed in two similar sheds, totaling 35 boxes. The experimental unit consisted of 10 males and 10 females, totaling 20 birds per pen. The experimental diets (Table I) were isonutritive and formulated as recommended by Rostagno et al. (2011). The test ingredients were added substituting the inert material, as follows: T1 - no supplementation of selenium or vitamin E; T2 - 0.1 mg/kg selenium and 300 mg/kg vitamin E; T3 - 0.1 mg/kg selenium and 400 mg/kg vitamin E; T4 - 0.1 mg/kg selenium and 500 mg/kg vitamin E; T5 - 0.3 mg/kg selenium and 300 mg/kg vitamin E; T6 - 0.3 mg/kg selenium and 400 mg/kg of vitamin E; and T7 - 0.3 mg/kg selenium and 500 mg/kg vitamin E.

Black-globe, wet-bulb and dry-bulb temperatures, and humidity were measured daily at 08h and 16h. The maximum and minimum temperatures were recorded only in the morning, and the thermometer was reset afterwards. These data were converted to black globe humidity index (BGHI) as recommended by Buffington et al. (1981).

At the end of the experiment, two animals per plot with the weight closest to the average of the plot were identified for subsequent slaughter. Thus, at 21h on the 42nd day of age, these animals were feed-deprived to be slaughtered in the subsequent morning. At 07h of the next day, the birds were moved to the slaughterhouse, with the following processing line: mechanical stunning, hanging, bleeding, scalding, plucking, and evisceration. Afterwards, the hot carcass and major cuts were weighed. The relative weight of the cuts was determined in relation to the hot carcass weight.

The viability (V) was calculated according to Stringhini et al. (2006), as follows: V (%) = [Total number of birds - (discarded + dead birds) / total number of birds] × 100.

The productive efficiency index (PEI) was determined by the following equation:

PEI = (AWG (g) ×RV) / FC × days housed) × 10,

where: AWG = average weight gain; V = viability; and FG = feed conversion (Stringhini et al. 2006).

The carcass yield and the relative weight of the organs were calculated based on the empty-body weight before slaughter. The yields of the cuts were determined in relation to the hot carcass weight.

Data were subjected to analysis of variance and regression, according to the GLM procedure of the Statistical Analysis System (SAS) software, with α = 0.05. Dunnett's test was applied in the comparison between the control and the other treatments, whereas for the selenium levels, the Student Newman Keuls test (SNK) was performed, both adopting α = 0.05.

TABLE I
Experimental diets for broilers in the grower (22 to 33 days) and finisher (34 to 42 days old) phases.

Ingredient	Grower phase	Finisher phase
Corn	63.84	68.23
Soybean meal 48%	29.56	25.70
Vegetable oil	2.82	2.70
Dicalcium phosphate	1.68	1.05
Limestone	0.55	0.74
NaCl	0.48	0.48
L-lysine - HCL (79%)	0.19	0.23
DL-methionine (99%)	0.16	0.15
Mineral and vitamin premix[1,2]	0.40	0.40
Kaolin (inert)	0.30	0.30
Total	100.00	100.00
Calculated values		
Crude protein (%)	19.50	18.00
Metabolizable energy (kcal/kg)	3,100	3,150
Digestible lysine (%)	1.07	1.01
Digestible methionine (%)	0.43	0.40
Digestible threonine (%)	0.66	0.60
Digestible tryptophan (%)	0.21	0.19
Calcium (%)	0.73	0.63
Available phosphorus (%)	0.42	0.29
Sodium (%)	0.21	0.21

[1]Grower: guaranteed levels per kg of product: folic acid - 162.50 mg; pantothenic acid - 2,600.00 mg; chlorohydroxyquinoline-7,500.00 mg; copper- 1,996.00 mg; choline - 71.59 g; iron - 11.26 g; iodine - 187.47 mg; manganese - 18.74 g; niacin- 7,000.00 mg; selenium - 75.00 mg; vitamin A - 140,062.50 IU; 388.00 mg vitamin B1; vitamin B12 - 2,000.00 mcg; vitamin B2 - 1,000.00 mg; vitamin B6 - 520.00 mg; vitamin D3 - 300,012.00 IU; vitamin E - 2,500.00 IU; vitamin K3 - 300.00 mg; zinc - 17.50 g.
[2]Finisher: guaranteed levels per kg of product - pantothenic acid - 3,535.00 mg; copper - 3,250.00 mg; choline - 117.15 g; iron - 20.00 g; iodine - 400.00 mg; manganese - 30.00 g; niacin - 10.21 g; selenium - 100.00 mg; vitamin A - 982,500 IU; vitamin B12 - 2,357.00 mcg; vitamin B2 - 1,212.00 mg; vitamin D3 - 275,000.00 IU; vitamin E - 2,750.00 IU; vitamin K3 - 275.00 mg; zinc 25.00 g.

RESULTS AND DISCUSSION

The average maximum temperature remained above the ideal temperature for broilers in experimental sheds, while the minimum temperature remained on the comfort zone in shed 2, and slightly above in shed 1, as described in Table II. The comfort zone for birds in adulthood is in the range from 15 to 25ºC (Tinôco 2004).

The BGTI observed in this study during the experiment was higher than ideal, as established by Medeiros et al. (2005), who stated that BGTI in the 59-67 range are considered cold; comfortable, between 69 and 77; and considered hot for the birds from 78 to 88. The authors also reported that in typically hot environments, broiler mortality is not affected; however, feed intake was reduced by 43% and weight gain by 67%.

There was no effect of interaction between the levels of supplementation of selenium and vitamin E (P> 0.05) on the performance variables in the life phases from 22 to 33 days (Table III) and 22 to 42 (Table IV). The levels of selenium and vitamin E did not affect (P> 0.05) feed intake, weight gain, feed conversion, or productive efficiency index either both phases. Also, no difference was found when the control treatment was compared with the others (P> 0.05).

The variable viability was influenced by the selenium levels in both phases, with the level of 0.3 mg/kg of this mineral providing the best results.

In the period from 22 to 42 days, the viability with inclusion of 0.3 mg/kg of selenium and 300 and 400 mg/kg of vitamin E differed from the control treatment (P <0.05).

Habibian et al. (2013), in a study with broilers in a cyclic-heat stress environment with temperature ranging from 23.9 to 37°C, supplementing poultry diets with three levels of vitamin E (0, 125, 250 mg/kg) and three levels of selenium (0, 0.5, and 1.0 mg/kg), found lower weight gains, feed intake, and feed conversion in the animals subjected to high temperature. The selenium and vitamin E levels did not affect weight gain or feed intake; however, the vitamin E level of 125 mg/kg improved the feed conversion of birds at 49 days old. In the present study, the levels of selenium and vitamin E did not affect feed intake, weight gain, or feed conversion, possibly because younger birds were used, and these animals do not feel as much the adverse effects of high temperatures.

For the performance variables, the results of this study were similar to those observed by Kim et al. (2010), in that the test diets with a level of selenium and three levels of vitamin E, plus a control diet, did not yield differences in these variables. Peric et al. (2009) also tested different sources and levels of selenium and found no difference in weight gain, feed conversion, mortality, or productive efficiency index.

Additionally, evaluating different sources of selenium, Gomes et al. (2012) found that selenium supplementation, regardless of the level and source, provided superior performance to the control treatment for the phase from 1 to 33 days.

Increasing levels of vitamin E (0, 75, 150, 225, and 300 mg/kg) in the diet of broilers can provide a linear increase in weight gain, especially when compared with the level without supplementation, as observed by Silva et al. (2011). But this did not occur in the current study, probably because the level of vitamin E premix fulfilled the requirements of these birds in the respective phases under cyclic-heat stress conditions.

Souza et al. (2011) studied different inclusion levels of vitamin C and E in broiler diets and did not observe differences between the tested levels in phases 1 to 21 and 1 to 42 days for the variables feed intake, gain weight, and feed conversion. However, other authors observed an improvement in the performance variables when they included selenium or vitamin E in broiler diets. Maini et al. (2007) observed an improvement of approximately

TABLE II
Mean values for maximum, minimum, black-globe, dry-bulb, and wet-bulb temperatures, relative humidity, and Black Globe Temperature and Humidity Index (BGTI) in the period from 22 to 42 days old.

	Max (ºC)	Min (ºC)	Black globe (ºC)	Dry bulb(ºC)	Wet bulb (ºC)	Humidity (%)	BGTI
Shed 1	32.2	25.6	29.7	30.4	24.6	65.1	79.7
Shed 2	32.6	23.4	29.7	29.6	25.5	72.8	80.2

TABLE III
Performance of broilers from 22 to 33 days old fed different levels of selenium and vitamin E.

	Selenium	Vitamin E			Mean
		300	400	500	
Control		**Feed intake (g/bird)**			
1627.04	0.1	1647.76	1617.14	1575.04	1613.31[a]
	0.3	1624.00	1638.20	1650.00	1637.40[a]
Mean		1635.88	1627.67	1612.52	
CV (%)			2.97		
Control		**Weight gain (g/bird)**			
1010.26	0.1	1039.32	1041.94	1006.66	1029.31[a]
	0.3	1027.66	1009.84	1038.80	1025.43[a]
Mean		1033.49	1025.89	1022.73	
CV (%)			6.02		
Control		**Feed conversion (g/g)**			
1.613	0.1	1.588	1.557	1.568	1.571[a]
	0.3	1.585	1.624	1.590	1.600[a]
Mean		1.587	1.591	1.579	
CV (%)			4.65		
Control		**Productive efficiency index**			
513.82	0.1	537.21	556.27	532.29	541.92[a]
	0.3	543.01	519.1	545.35	535.82[a]
Mean		540.11	537.69	538.82	
CV (%)			11.27		
Control		**Viability (%)**			
98.00	0.1	98.00	99.00	99.00	98.67[b]
	0.3	100.00	100.00	100.00	100.00[a]
Mean		99.00	99.50	99.50	
CV (%)			1.72		

Means followed by the same letter in columns do not differ by the SNK test (P> 0.05).

10% in weight gain and 15% in feed conversion applying treatment with the addition of 200 mg/kg of vitamin E in the diet. The results observed with the use of selenium and vitamin E differ greatly even in this study. This occurrence may be related to the different conditions in which the research

TABLE IV
Performance of broilers from 22 to 42 days old fed different levels of selenium and vitamin E.

	Selenium	Vitamin E 300	400	500	Mean
Control		**Feed intake (g/bird)**			
3039.32	0.1	3068.3	3061.6	2891.8	3007.2[a]
	0.3	3079.7	3025.1	3071.3	3058.7[a]
Mean		3074.0	3043.3	2981.6	
CV (%)			3.30		
Control		**Weight gain (g/bird)**			
1537.00	0.1	1569.6	1593.0	1468.0	1543.5[a]
	0.3	1509.0	1551.2	1558.4	1539.5[a]
Mean		1539.3	1572.1	1513.2	
CV (%)			5.04		
Control		**Feed conversion ratio (g/g)**			
1.978	0.1	1.956	1.924	1.971	1.950[a]
	0.3	2.054	1.952	1.972	1.993[a]
Mean		2.005	1.938	1.972	
CV (%)			4.32		
Control		**Productive efficiency index**			
351.31	0.1	370.71	391.37	347.98	370.02[a]
	0.3	354.09	379.16	373.08	368.78[a]
Mean		362.40	385.27	360.53	
CV (%)			8.32		
Control		**Viability (%)**			
95.00	0.1	97.00	99.00	98.00	98.00[b]
	0.3	100.00*	100.00*	99.00	99.67[a]
Mean		97.00	99.00	98.50	
CV (%)			2.21		

Means followed by the same letter in columns do not differ by the SNK test (P> 0.05).
*Differs from the control treatment by Dunnett's test (P <0.05).

was conducted, mainly due to the daily time of exposure of birds at elevated temperatures as well as different levels and sources used in each study.

For the carcass-yield related variables, the major cuts, and abdominal fat (Table V), it was found that there was no interaction between levels of selenium and vitamin E. The yields of carcass and major cuts were not affected by dietary selenium and vitamin E. However, for abdominal fat, an interaction between the levels of selenium and vitamin E was detected. The addition of vitamin E at the selenium level 0.1 mg/kg influenced the abdominal fat linearly, represented by the following equation: y = 1.871 to 0.002 x (R^2=0.94). The selenium levels evaluated with three levels of vitamin E did not affect the amount of abdominal fat (P> 0.05).

The results of this study agree in part with those obtained by Sevcíková et al. (2006), who found no effects of the level (0 to 0.3 mg/kg) or

TABLE V
Yields of carcass, abdominal fat, and major cuts of broilers fed different levels of selenium and vitamin E.

	Selenium	Vitamin E 300	Vitamin E 400	Vitamin E 500	
Control			**Carcass yield (%)**		**Mean**
83.02	0.1	82.14	81.43	82.91	82.16[a]
	0.3	81.82	81.84	82.19	81.95[a]
Mean		81.98	81.64	82.55	
CV (%)			1.88		
Control			**Breast (%)**		
30.29	0.1	30.41	29.31	29.79	29.84[a]
	0.3	29.58	29.37	29.73	29.56[a]
Mean		30.00	29.34	29.76	
CV (%)			5.22		
Control			**Thigh (%)**		
12.70	0.1	12.59	12.73	12.86	12.73[a]
	0.3	12.9	12.83	12.96	12.90[a]
Mean		12.75	12.78	12.91	
CV (%)			6.15		
Control			**Drumstick (%)**		
14.01	0.1	13.66	14.13	12.21	13.33[a]
	0.3	13.84	14.00	14.00	13.95[a]
Mean		13.75	14.07	13.11	
CV (%)			5.37		
Control			**Abdominal fat (%)**		
1.067	0.1[1]	1.255[a]	1.147[a]	0.864[a]	1.089
	0.3	0.970[a]	1.265[a]	1.143[a]	1.126
Mean		1.113	1.206	1.004	
CV (%)			32.71		

Means followed by the same letter in columns do not differ by the SNK test (P> 0.05).
[1]Linear effect.

source (yeast+Se and algae Chlorella+Se) of selenium on the absolute weight of variables breast, thigh, or abdominal fat of chickens cut at 42 days old. Also, Choct and Naylor (2004) found no differences in the absolute weight of carcass, breast, or thigh+drumstick in broilers slaughtered at 38 days testing different sources of selenium (0.1 mg organic or inorganic selenium) and vitamin E levels (50 and 100 mg/kg).

The relative weight of abdominal fat with the selenium level of 0.1 mg/kg decreased linearly with the increase in vitamin E, as shown in Figure 1. This demonstrates that vitamin E strongly influences the lipid metabolism.

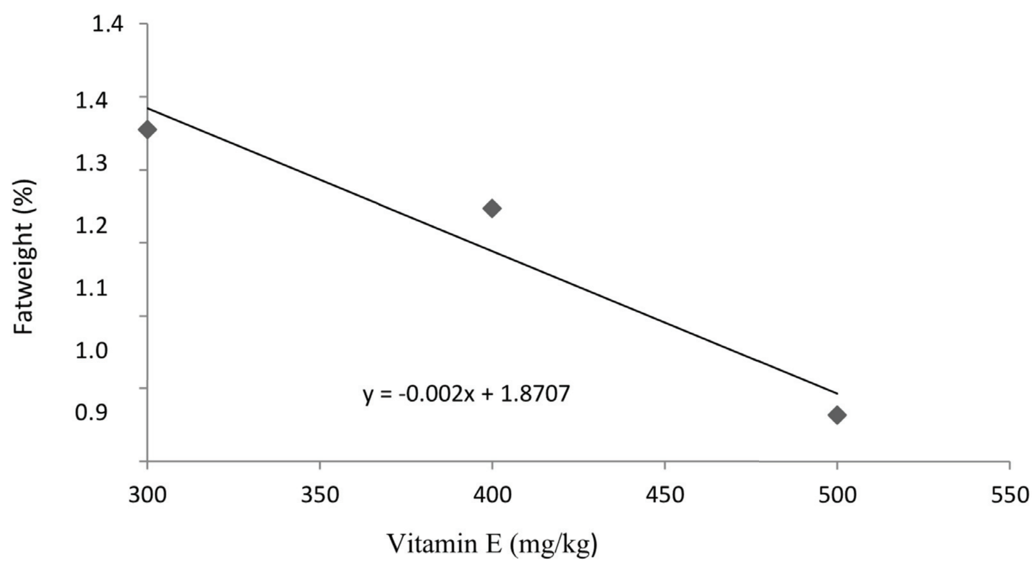

Figure 1 - Effect of vitamin E on the relative weight of abdominal fat of broilers at 42 days of age.

TABLE VI
Relative weight of organs of broilers at 42 days old fed different levels of selenium and vitamin E.

	Selenium	Vitamin E			
		300	**400**	**500**	
Control			**Liver (%)**		**Mean**
1.919	0.1	2.023	2.440*	2.182	2.215[a]
	0.3	2.294	2.511*	2.175	2.327[a]
Mean		2.159	2.476	2.179	
CV (%)			19.77		
Control			**Gizzard (%)**		
2.214	0.1	2.153	2.605	2.245	2.334[a]
	0.3	2.436	2.456	2.556	2.483[a]
Mean		2.295	2.531	2.401	
CV (%)			17.07		
Control			**Intestine (%)**		
4.782	0.1	5.086	5.183	5.510	5.260[a]
	0.3	5.095	5.197	5.100	5.131[a]
Mean		5.091	5.190	5.305	
CV (%)			18.50		
Control			**Heart (%)**		
0.447	0.1	0.451	0.457	0.512	0.473[a]
	0.3	0.472	0.434	0.433	0.446[a]
Mean		0.462	0.446	0.473	
CV (%)			21.32		

Means followed by the same letter in columns do not differ by the SNK test (P> 0.05).
*Differ from the control treatment by Dunnett's test (P <0.05).

Concerning the evaluated organs (Table VI), also no interaction between levels of selenium and vitamin E was found (P> 0.05). Selenium levels did not affect the relative weights of liver, gizzard, intestine, or heart (P> 0.05).

The results of this study are consistent with those observed by Sevcíková et al. (2006), who found no effect of the level and source of selenium on the absolute weight of the liver and giblets (liver, heart and gizzard together). The results also agree with Haug et al. (2007), who found no differences in the weights of liver and heart of broilers at 22 days, fed diets supplemented with 0.50 and 0.84 mg/kg of organic selenium.

CONCLUSIONS

The current level of selenium and vitamin E present in the mineral and vitamin premixes fulfills the requirements for performance of broilers from 22 to 33 days and 22 to 42 days of age reared in a high temperature environment.

The selenium supplementation level of 0.3 mg/kg improves the rearing viability of broilers in the periods from 22 to 33 and 22 to 42 days of age.

The relative weight of abdominal fat with the selenium level of 0.1 mg/kg decreases linearly with the increase in vitamin E.

ACKNOWLEDGMENTS

The authors would like to thank Fundação de Amparo à Pesquisa do Estado do Piauí (FAPEPI) for funding this research.

REFERENCES

BUFFINGTON DE, COLLAZO-AROCHO A, CANTON GH, PITT D, THATCHER W AND COLLIER RJ. 1981. Black globe-humidity índex (BGHI) as comfort equation for dairy cows. Trans ASAE 24: 711-714.

CHOCT M AND NAYLOR AJ. 2004. The effect of dietary selenium source and vitamin E levels on performance of male broilers. Asian Australas J Anim Sci 17: 1000-1006.

CHOCT M, NAYLOR AJ AND REINKE N. 2010. Selenium supplementation affects broiler growth performance. Br Poult Sci 45: 677-683.

GOMES FA, BERTECHINI AG AND MESQUITA FR. 2012. Desempenho e características físico-químicas da carne do peito de frangos de corte recebendo diferentes fontes e níveis de selênio. Enc Bios 8: 315-336.

HABIBIAN M, GHAZI S, MOEINI MM AND ABDOLMOHAMMADI A. 2013. Effects of dietary selenium and vitamin E on immune response and biological blood parameters of broilers reared under thermoneutral or heat stress conditions. Int J Biometeorol 57: 741-752.

HAUG A, EICH-GREATOREX S, BERNHOFT A, WOLD JP, HETLANDH CHRISTOPHERSEN OA AND SOGN T. 2007. Effect of dietary selenium and omega-3 fat acids on muscle composition and quality in broilers. Lipids Health Dis 6.

KIM YJ, PARK WY AND CHOI LH. 2010. Effects of dietary α-tocopherol, selenium, and their different combinations on growth performance and meat quality of broiler chickens. Poult Sci 89: 603-608.

KOTTEK M, GRIESER J, BECK C, RUDOLF B AND RUBEL F. 2006. World Map of the Köppen-Geiger climate classification updated. Meteorol Z 15: 259-263.

LARA LJ AND ROSTAGNO MH. 2013. Impact of Heat Stress on Poultry Production. Anim 3: 356-369.

MAINI S, SHUKLA SK, RASTOGI SK, KORDE JP AND MADAN AK. 2007. Evaluation of oxidative stress and its amelioration through certain antioxidants in broilers during summer. J Poult Sci 44: 339-347.

MARMOUD KZ AND EDENS FW. 2005. Influence of organic selenium on hsp70 response of heat-stressed and enteropathogenic Escherichia coli-challenged broiler chickens (*Gallus gallus*). Comp Biochem Physiol C Toxicol Pharmacol 141: 69-75.

MEDEIROS CM, BAÊTA FC, OLIVEIRA RFM, TINÔCO IFF, ALBINO LFT AND CECON PR. 2005. Efeitos da temperatura, umidade relativa e velocidade do ar em frangos de corte. Reveng 13: 277-286.

PERIC L, MILOŠEVIĆ N, ŽIKIĆ D, KANAČKI Z, DŽINIĆ N, NOLLET L AND SPRING P. 2009. Effect of selenium sources on performance and mear characteristics of broiler chickens. J Appl Poult Res 18: 403-409.

QUINTEIRO-FILHO WM, RIBEIRO A, FERRAZ-DE-PAULA V, PINHEIRO ML, SAKAI M, SÁ LR, FERREIRA AJ AND PALERMO-NETO J. 2010. Heat stress impairs performance parameters, induces intestinal injury, and decreases macrophage activity in broiler chickens. J Poult Sci 89: 1905-1914.

ROSTAGNO HS, ALBINO LFT, DONZELE JL, GOMES PC, OLIVEIRA RF, LOPES DC, FERREIRA AS, BARRETO SLT AND EUCLIDES RF. 2011. Tabelas Brasileiras para aves e suínos: Composição de alimentos e exigências nutricionais. Viçosa: Imprensa Universitária, 252 p.

SEVCÍKOVÁ S, SKŘIVAN M, DLOUHÁ G AND KOUCKÝ M. 2006. The effect of selenium source on the performance and meat quality of broiler chickens. Czech J Anim Sci 51: 449-457.

SILVA IA, ABREU MLT, LEAL ABG, SOUZA IOT, LIMA DCP AND TEIXEIRA MPF. 2011. Vitamina E para frangos de corte estressados por calor. Reunião Anual da Sociedade Brasileira de Zootecnia, 48ª, 2011, Belém. Proceedings... Belém: RBZ.

SOUZA MG, OLIVEIRA RFM, DONZELE JL, MAIA APA, BALBINO EM AND OLIVEIRA WP. 2011. Utilização das vitaminas C e E em rações para frangos de corte mantidos em ambiente de alta temperatura. R Bras Zootec 40: 2192-2198.

STRINGHINI JH, ANDRADE ML, ANDRADE L, XAVIER AS, CAFÉ MB AND LEANDRO NSM. 2006. Desempenho, balanço e retenção de nutrientes e biometria dos órgãos digestivos de frangos de corte alimentados com diferentes níveis de proteína na ração pré-inicial. R Bras Zootec 35: 2350-2358.

TINÔCO IFF. 2004. A granja de frangos de corte. In: Mendes AA et al. (Eds), Produção de frangos de corte Campinas: FACTA, p. 55-84.