Journal of Veterinary Research Advances
ISSN: 2582-774X

Research Article
Open access

Effect of fogging cooling system on physiological and performance characteristics of broiler chicken under tropical hot conditions

Kamal EGE[1], Muna MMA[2] and Ibrahim Bushara[3]
[1]Department of Animal Production, Faculty of Agriculture Islamic University
[2]Institute of environmental studies, University of Khartoum, Sudan
[3]Department of Animal Production, Faculty of Natural Resources and Environmental Studies, University of Kordofan El-Obied, Sudan

Corresponding author: bushara3030@yahoo.com

Received on: 18/11/2023 Accepted on: 28/05/2024 Published on: 04/06/2024

ABSTRACT

Aim: Main purpose of the study was to improve the micro-environment (ambient temperature and relative humidity) inside traditional open sided broiler housing by using cost effective fogging fogging cooling system during dry and wet seasons.

Method and materials: The experiments utilized open-sided poultry housing (20mx10mx3m) in the research station of animal production in Khartoum North with partitions inside the house to establish 5 chambers prepared for the different treatments. A total of 1920 (Ross-308) birds were randomly allocated to the different treatments each consisted of 384 birds divided into two replicates (192 birds in each).

Results: It showed that house ambient temperature decreased with increasing fogging cooling system treatments but significant differences were not obtained. The interaction effect of birds' age and fogging cooling treatments showed that could better regulate body temperature with advancement of age and that the decrease in body temperature was significant ($P \leq 0.05$) with the increase of the fogging cooling treatments, decreases were more prevalent in wet summer than dry summer.

Conclusion: It was concluded that traditional farms adopting cost-effective fogging cooling system will increase their with better life security.

Keywords: Broiler housing, fogging cooling system, broiler production.

Cite This Article as: Kamal EGE, Muna MMA and Ibrahim Bushara (2024). Effect of fogging cooling system on physiological and performance characteristics of broiler chicken under tropical hot conditions. J. Vet. Res. Adv., 06(01): 41-52.

Introduction

Hot weather is a common problem in tropical countries such as Sudan with summer temperatures above 30°C. High environmental temperature is one of major concerns for broiler producers. In Sudan, many of the poultry producers are raising their flock under conventional housing system exposed to adverse environmental conditions (Elimam, 1991). Small producers use the open–sided system for housing, which is naturally ventilated, and is greatly affected by external hot weather, solar radiation and humidity, wind direction and speed. Broilers are more susceptible than layers which are probably the reason why the management of broilers under high temperatures has received more attention.

Copyright: Kamal et al. Open Access. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

Gwatibaya (2005) stated that, farmers and livestock managers need information about how and why their animals respond to environmental challenges to make best decisions on strategies and tactics to reduce losses during hot weather.

The effects of heat stress in poultry are varied and range from decreased feed intake (NRC, 1994; Yahav, 2000; Sohail *et al*., 2012), reduced weight gain and meat quality in broilers (Imik *et al*., 2012; Zhang *et al*., 2012), reduced rate of lay and egg qualities (Star *et al*., 2008; Deng *et al*., 2012) increased feed conversion ratio (Niu *et al*., 2009; Imik *et al*., 2012) and high mortality rate (Shane, 1988; Yahav, 2000). However for birds to perform at their optimum capacity they need to among other factors to be in homeostatic with their environment through the maintenance of therm-balance. Heat, humidity, ammonia and carbon dioxide in poultry house have a negative effect on broiler performance (Atilgan *et al*., 2010). As the energy costs are becoming more significant, researchers have put more emphasis on investigating the most economical and efficient means of fogging cooling. The fogging fogging cooling system is environmental practices that may alleviate the adverse effects of heat stress in broiler performance. The research concerning the negative impact of the heat stress on broilers performance by adding different levels of fogging fogging cooling system during dry and wet summer season to defect their effects on growth performance, physiology and welfare conditions.

Materials and Methods

The experiments were conducted at the Animal Production Research center, poultry unit Khartoum North (Latitude 15◦ 8// N and longitude 31^0 36′, 34^0 25′ E), during the dry summer season (27th April - 8th June) and wet summer season (7th August -19th September) of the year 2015 to determine the effect of fogging fogging cooling system on broiler performance and physiological characteristics

Birds' housing and Fogging cooling fogging system treatments : The birds' housing used throughout the experimental period was the open-sided usually used by traditional small scale producers. Certain low cost-effective fogging systems were constructed with the objective to improve the micro-environment inside the house. The longitudinal axes of the house were in an east west direction (16°N). The dimensions of the house were 20x10x3 meters. The house was divided into five partitions each with dimensions (4x4x3m). The roof of the house was made of corrugated iron sheets. The long axes and the western sides of the house were made of wire-netting, while the Eastern side is made of iron sheet. The house was constructed from bricks with a side wall of 60 cm height and iron bars covered with wire-netting of 1.25 cm mesh size. The floor made of concrete and the roof made with corrugated iron sheets.

Fogging systems were designed to provide four treatments. The numbers of treatments were five including the control as: T1 (zero nozzles), treatment, T2 (4 nozzles, 2 on each opposite side), T3 (5 nozzles, 2 from one side and 3 from the opposite side), T4 (6 nozzles, 3 from one side and 3 from the opposite side) and T5 (7 nozzles, 3 from one side and 4 from the opposite side).

Birds management

A total number of 1920 chicks, commercial unsexed broiler chicks (Ross308) were obtained from Inmaa Project for Poultry and Feed, Western Omdurman, Khartoum State. Chicks were weighed before being allotted to the experimental treatments and all experiments started from 15 day old to 42 days. 2 weeks of age's per-experimental period considered as a brooding period. Each treatment consisted of 384 birds with 2 replicates each (192 birds/replicate).

The birds were fed with commercial pre starter diet from day one to 7days, followed with starter diet until 21 days of age. Thereafter, they were fed with a finishing diet up to the end of the experiment. The feeds were formulated according to National Research Council (NRC, 1994). Feed and fresh clean tap water was offered *ad libitum* throughout experiment. Parameter measurements were carried for two seasons (dry and wet), for one year. Accumulated mortality rate was obtained by subtracting the number of live birds at the end of experiment from the total number of birds at the beginning of the experiment. The birds were first vaccinated against New castle (ND) and Infectious Bronchitis (IBD) at 7th day of age, and repeated at 17th days. At 11**th** day, they were vaccinated against Bursal disease. (IBD) dosage was repeated at 21 and 29 days of age respectively. Another dosage of (ND) was repeated at age of 27day.

Data collections

Physical measurements: The micro-environment measurements inside and outside the house such as ambient temperature and relative humidity (RH), utilized with Hydro-therm-meter sensors, both parameters measured three times a day (8:00am, 12:00pm and 5:00pm).

Body temperature: Core body temperatures (CBT) were obtained for five birds randomly selected out of each replicate using a digital thermometer with rectal probe (0.1°C accuracy). It was taken three times at different times (8:00am, 12:00pm and 5:00pm). The CBT was taken weekly and given as average for each replicate. The CBT,

Blood parameters: Blood samples were collected from randomly selected birds, 10 from each treatment at 42 of age (a total of 100 samples). Blood samples were collected in a (EDTA) coated test tubes. Separated serum was stored at −20°C for analysis to analyzied for electrolytes for potassium and sodium was determined by automatic analyzer (Kodak Ektachem®; Eastman Kodak Company, Rochester, New York). Also for serum hormone concentrations of cortisol and thyroxine (T4) were analyzed using ELISA kits for total thyroxine (T4) and cortisol, measurements were done at the end of study after the 6th week of age.

Feed intake: The feed intake was determined by weighing feed on weekly basis. At the end of each week, the reject was reweighed and recorded for estimation of average feed intake on grams per bird per week (g/b/wk).

Body weight and body weight gain (g/bird): The chicks were weighed on the first day of arrival then on weekly basis till the end of the experiment. The weekly weight gain was calculated for each chick in gram.

Feed conversion ratio: The feed conversion ratio was calculated by dividing the total grams of weekly feed consumed during the experimental period by the number of grams of weekly weight gain (g feed/ g gain).

Mortality rate (%): Accumulated mortality rate was obtained by subtracting the number of live birds at the end of experiment from the total number of birds at the beginning of experiment.

Carcass characteristics: At the end of the 6th week of age ten birds from each replicate were randomly weighed and fasted from 10.00 pm to 8.00 am before slaughter. Birds were slaughtered and allowed to bleed for 1-2 minutes. After bleeding they were scalded in hot water, hand plucked and washed. The head was removed close to the skull. Feet and shanks were removed at the hock joint. Evisceration was accomplished by a posterior cut to completely remove the internal organs. Edible giblets (liver, heart, kidney, adipose and gizzard) were carefully separated, accurately weighed, and then used ten identified birds were weighed, and frozen at 4°C for 24 hours. The cold carcass weight was recorded, and weight was also done for the cutting parts (thigh, breast, neck wing and backbone). Also dressing carcass was carried out to determine the ratio of hot and cold weight to the live weight.

Economical effectiveness of the use of fogging cooling system versus the traditional system as follows

Total income = Dress weight × Market selling price per kg.

Total feed cost = Quantity feed consumed (kg) × feed cost/kg

Total cost = Feed cost+ Chicks cost+ Managerial cost

Net profit = Total income – Total cost.

Statistical analysis

Data were statistically analyzed by the General Linear Model (GLM) of SAS (1999) using the replicated means of all parameters .Two ways analysis of variance (ANOVA) 2 x 2 factorial arrangement under complete randomized design was used for analysis of means were physical environment , physiological parameters, mortality rates, carcass characteristics and where as CRBD was used for analysis of broilers performance parameters tested using LSD at 5% and 1% levels of confidence (Snedecor and Cochran, 1980).

Results and Discussion

Effect of fogging cooling treatments on ambient temperature of broiler house during dry and wet summer

The ambient temperature inside birds' house was recorded using 4 fogging cooling systems. For dry and wet summer, It showed that T4 had lowest temperature for both dry and wet summer seasons. This was followed by T5, then T3, T2 and T1. The general trends showed that wet summer had lower ambient temperatures than dry summer with increase in fogging cooling systems. The relative humidity (RH) increased with increasing of treatments where T5 gave highest percentage followed by T4, T3, T2 and finally T1 (Table 1). The general trend showed that wet summer had higher % RH than dry summer and level of RH increased with increasing degree of fogging cooling systems.

Effect of fogging cooling treatments on body temperature (°C) of broiler house during dry and wet summer

Body temperature for control was inconsistent with advancement with age but was the highest at the age of 6 weeks, this was similar with T2 and groups in T4 showed lowest ($P \leqq 0.05$) body temperature at age 3 weeks, while for those in T5 showed lowest temperature at 5 weeks. For fogging cooling treatments effect and at 3th week showed progressive decrease ($P \leqq 0.05$) with increase of fogging cooling effect, at age of 4 week similar observations were obtained except that T3 and T5 did not show significant differences. At the age of 5 and 6 weeks, progressive significant decreases ($P \leqq 0.05$) with increase of fogging cooling effects except for between T3 and T5 (Table 2).

During wet summer, effect of age on body temperature for control showed that with body temperature increased significantly ($P \leqq 0.05$) at age 5 weeks then at age 4 and 6, then at age 3 weeks. For T2 body temperature decreased significantly ($P \leqq 0.05$) with age. T3 showed no significant differences and for T4, body temperature decreased significantly between age 3 and 4 weeks, but maintained at age 5 and 6. T5 groups showed no significant differences were obtained with advancement of age. Body temperature did not change between dry and wet season although there was tendency for body temperature to increase in the dry season.

Effect of fogging cooling treatments on electrolytes and *hormones of broiler during dry and wet summer*

During the dry season, serum sodium concentration (mmol/L) was the highest in birds exposed to T5 followed by T4 ($P \leq 0.05$) with no significant differences among the other two treatments and the control. On the other hand, potassium decreased significantly and progressively ($P \leq 0.05$) with the increase in the fogging cooling treatments. Thyroxine (ng/ml) was significantly ($P \leq 0.05$) higher with exposure to both T4 and T5 followed by T3, then T1 and finally T2 with significant ($P \leq 0.05$) differences among the three treatments. Cortisol (µg/L) level decreased with the increase in the fogging cooling effects of the treatments, but significant ($P \leq 0.05$) differences could be only be detected between T2 and the control (Table 3).

In the wet summer similar trend for Na concentrations were observed but here significant progressive increase ($P \leq 0.05$) with increase in fogging cooling effects were obtained. Similar trends were observed for K as in dry summer, decrease in K level with the increase in fogging cooling effects were significant ($P \leq 0.05$), although the differences between T4 and T5 were not significant.

Thyroxine showed significant increase with the increase in fogging cooling effect for T3, T4 and T5, with T4 showing the highest ($P \leq 0.05$) level. Cortisol as in dry summer showed significant progressive decrease with the increase in the fogging cooling effect ($P \leq 0.05$) (Table 3).

Sodium (Na) and potassium (K), showed opposite trends in response to the fogging cooling effects of the treatments, while Na increased with the increase of the fogging cooling effects, K decreased with decrease of the fogging cooling effects of the treatments. A general trend for T4 response to fogging cooling treat was that there was clear rise at T3 which did not changed much with T4 and T5 maintaining same values in dry and wet summer. For cortisol the trend was different for both seasons where there was steady decrease with the increase in the fogging cooling effect maintained at T4 and T5 (Table 3).

Effect of fogging cooling system treatments on body weight gain (g/bird/week) of broilers during dry and wet summer seasons.

Body gain as affected by fogging cooling treatments during the dry summer at the third week was recorded (Table 4). The gains were significant ($P \leqq 0.05$) among all treatments with T4 showing the highest gain followed by T5, T3 and T2. The control (T1) showed the lowest gain. At 4th week of age similar results were obtained with higher gains, but here T4 showed the highest gain. At 5th week of age similar results were obtained as age 3rd week. Same observations were obtained for the 5th week. For the 6th week similar observations were obtained as for the 4th week that is T4 was better than T5. Generally, it is observed that there was a steady increase in body gain from 3rd to 4th and 5th weeks but a decrease was observed in the 6th week. For the control there was a sudden high increase in the 5th week maintained in the 6th week.

Table 1. Effect of fogging cooling treatments on ambient temperature (°C) and average Relative humidity (%) of broiler house during dry and wet summer

Treatments		dry summer season					wet summer season			
		Weeks					Weeks			
		3rd	4th	5th	6th	means	3rd	4th	5th	6th
T1	**AT**	38.8	38.8	38.5	38.7	38.7	36.6	36.5	36.3	36.2
	RH	34.7	30.9	32.9	33.9	33.1	53.2	53.6	54.9	55.1
T2	**AT**	37.3	37.5	37.3	37.2	37.3	35.4	35.5	35.4	35.3
	RH	38.6	35.9	36.3	38.0	37.2	56.1	55.2	56.3	56.8
T3	**AT**	37.3	37.1	35.1	33.9	35.9	33.7	33.7	33.5	33.6
	RH	52.9	48.3	50.1	51.4	50.7	59.0	59.9	59.5	59.9
T4	**AT**	30.0	32.0	31.1	31.9	31.3	29.0	29.0	28.0	28.0
	RH	59.9	56.1	58.5	58.0	58.1	61.0	61.1	62.9	63.0
T5	**AT**	31.5	33.5	32.0	32.5	32.4	31.1	31.1	31.2	31.0
	RH	66.0	63.6	64.8	65.6	65.0	68.3	68.2	69.0	69.6

AT=ambient temperature RH=Relative humidity

Table 2. Effect of fogging cooling treatments on body temperature(°C) of broiler house during dry and wet summer

Treatments	seasons	Age/weeks			
		3rd	4th	5th	6th
T1	**Dry**	43.65 ±0.07 b	43.55 ±0.07 c	43.75 ±0.07 a	43.50 ±0.00 c
	Wet	42.55 ±0.07 c	42.65 ±0.07 b	42.75 ±0.07 a	42.65 ±0.21 b
T2	**Dry**	42.60 ±0.14 e	42.55 ±0.21 ef	42.65 ±0.21 e	42.80 ±0.14 d
	Wet	42.25 ±0.07 d	42.10±0.14 e	42.15 ±0.07 e	42.05 ±0.07 f
T3	**Dry**	41.80 ±0.14 g	41.75 ±0.07 gh	41.80 ±0.00 g	41.85 ±0.07 g
	Wet	41.65 ±0.07 g	41.65 ±0.07 g	41.55 ±0.07 gh	41.60 ±0.00 g
T4	**Dry**	41.45 ±0.07 j	41.30 ±0.14 k	41.35 ±0.21 k	41.35 ±0.07 k
	Wet	41.25 ±0.07 i	41.15 ±0.07 j	41.00 ±0.00 k	41.05 ±0.07 k
T5	**Dry**	41.75 ±0.07 gh	41.70 ±0.00 h	41.60 ±0.00 i	41.75 ±0.07 gh
	Wet	41.55 ±0.07 gh	41.55 ±0.07 gh	41.55 ±0.07 gh	41.55 ±0.07 gh
Means ±SE	**Dry**	41.25 ± 0.10*	42.17±0.10*	42.23±0.10*	42.25±0.07*
	Wet	41.85±0.07*	41.82±0.08*	41.80±0.06*	41.78±0.08*

abce Values in same row and columns with different superscripts differ at P<0.05

Table 3. Effect of fogging cooling treatments on electrolytes and hormones of broiler during dry and wet summer

Treatments	seasons	Sodium (mmol/L)	Potassium (mmol/L)	thyroxine (T_4) (ng/ml)	Cortisol (μg/L)
T1	**Dry**	140.30 ±11.14 D	4.00 ±0.00A	2.47 ±0.04 C	2.05 ±0.07 A
	Wet	139.10±0.00 e	4.07±0.04 a	2.39±0.01 d	1.90±0.00 a
T2	**Dry**	141.00 ±11.14 D	3.52 ±0.05 B	2.25 ±0.07 D	1.45 ±0.07 B
	Wet	140.20±0.00 d	3.62±0.04 b	2.17±0.04 e	1.40±0.03 b
T3	**Dry**	145.40 ±14.14 D	2.72 ±0.01 C	3.12 ±0.04 B	1.08 ±0.01 C
	Wet	142.40±0.14c	2.85±0.07 c	3.12±0.01 c	1.04±0.01 c
T4	**Dry**	151.10 ±14.14 B	2.00 ±0.02 B	3.30 ±0.00 A	1.03 ±0.01 C
	Wet	155.15±0.07 b	2.07±0.04 d	3.24±0.01 a	1.00±0.00 d
T5	**Dry**	161.35 ±21.21 A	1.50 ±0.03 E	3.25 ±0.0 A	1.00 ±0.00 C
	Wet	160.25±0.07 a	2.00±0.00 d	3.23±0.02 b	0.99±0.00 e
Means ±SE	**Dry**	147.83±13.15 **	2.75±0.02 *	2.88±0.03 **	1.32±0.03 **
	Wet	147.42±0.06 **	2.99±0.04 *	2.83±0.02*	1.27±0.01 **

ABCDE and *abce* Values in same row with different superscripts differ at P<0.05 or P<0.01, lower superscript at P<0.05, upper superscript at P<0.01: * significant at P<0.05, ** significant at P<0.01

Table 4. Effect of fogging cooling system treatments on body weight gain (g/bird/week) of broilers during dry and wet summer seasons

Treatments	seasons	Age/weeks			
		3rd	4th	5th	6th
T1	**Dry**	15.00±0.00 E	20.00±0.00 E	440.00±0.00 D	405.00±7.07 C
	Wet	25.00±0.00 e	42.50±3.54 d	510.00±14.14 c	425.00±7.07 c
T2	**Dry**	30.00±0.00 D	80.00±0.00 D	459.00±7.07 C	411.00±7.07 C
	Wet	62.50±3.54 d	130.00±14.14 c	555.00±7.07 b	510.00±14.14 b
T3	**Dry**	60.00±7.07 C	125.00±7.07 C	469.00±14.41 C	430.00±7.07 C
	Wet	110.00±14.14 c	185.00±7.07 b	660.00±28.28 b	550.00±14.14 b
T4	**Dry**	115.00±7.07 A	250.00±14.1 4 A	660.60±7.07 B	550.00±7.07 A
	Wet	215.00±7.07 a	355.00±7.07 a	750.00±14.14 a	615.00±7.07 a
T5	**Dry**	85.00±7.04 B	185.00±7.07 B	695.00±0.00 A	465.00±0.00 B
	Wet	145.00±7.07 b	310.00±14.14 a	605.00±7.07 b	555.00±7.07 b
Means ±SE	**Dry**	61.00±4.24**	132.00±5.66**	544.72±5.66**	452.20±5.66**
	Wet	111.5±6.36**	204.50±10.61**	616.00±14.14**	531.00±9.90**

ABCDE and *abce* Values in same columns with different superscripts differ at P<0.05 or P<0.01, lower and upper superscript at P<0.01: ** significant at P<0.01

For the wet summer, similar trends are observed as for dry summer but here body gain was highest in response to T4 throughout age and was highest in 5th week. Also as observed in dry summer there was a decline in gain at 6th week of age, similarly control group showed a sudden increase in weight gain at 5th week with a minor drop in 6th week (Table 4). Comparison between dry and wet summer for body weight gain showed no significance differences.

Effect of fogging cooling system treatments on Feed intake (g/bird/week) of broilers during dry and wet summer seasons

Food intake during dry summer was affected by fogging cooling treatments and was significantly higher (P≦0.05) in response to T4 and T5, compared to T3 and T2, however, the control (T1) differed significantly from the control. It was generally noticed that feed intake increased with advancement of age and increased steadily from weeks 3 to 6. A sudden high increase was observed in the 5th week and steady increase in week 6. Same was observed in the control which was nearly above of that of treatment T2 and T3.

During the wet summer, feed intake increased with increase of fogging cooling treatments but T4 showed highest (P≦0.05) intake compared with T5 and T3, while T2 showed fewer intakes (P≦0.05), while the control showed the lowest intake (P≦0.05). There was a steady increase in food intake with advancement of weeks for all treated group and control. Comparison between dry and wet summer for feed intake showed no significance differences (Table 5).

Effect of fogging cooling system treatments on feed conversion ratio (b/wk) of broilers during dry and wet summer seasons

Feed conversion ratio is the ratio of weight gain to food intake, the lower ratio was conversion of food to weight gain. Batter ratio (P≦0.05) was obtained for T4 with birds' advancement in age, next comes T5 (P≦0.05) then T3 (P≦0.05) and finally T2 (P≦0.05). The control group showed less feed conversion which did not changed with advancement of age.

For wet summer, as dry summer, same trends were obtained where T4 showed best conversion ratio (P≦0.05), then T5, T3 and T2 with significant differences (P≦0.05). However with advancement of age efficiency of conversions was slightly decreasing. The control group showed least efficiency which decreased with age (Table 6). General wet season had better (P≦0.05) values over dry season, however, control showed significant changes for food intake or food conversion ratio.

Effect of fogging cooling system treatments on broilers live-weight, hot and cold carcass (g/bird), hot and cold dressing (%) during dry and wet summer seasons.

When comparing dry and wet summer, significant decreases (P≦0.05) in live weight, hot and cold carcass (g/bird), hot and cold dressing (%) in wet compared to dry summer. For live-weight in dry season, control had lowest weight (P≦0.05), while T4 showed highest weight. For wet season, there was a significant (P≦0.05) progressive increase, but T4 showed increase (P≦0.05). For hot carcass weight during summer, there was a progressive significant increase from T3 to T5; however, T4 showed highest weight (P≦0.05). For wet season, progressive significant increase from T2 to T5, but still T4 showed highest value. The cold carcass dressing (%) showed similar trends as for hot carcass weight for both hot and wet seasons. As for cold dressing no significant differences for dry season could be detected when compared with control, for both dry and wet seasons (Table 7).

Table 5. Effect of fogging cooling system treatments on feed intake (g) of broilers during dry and wet summer seasons

Treatments	seasons	Age/weeks			
		3rd	4th	5th	6th
T1	**Dry**	700±0.00 C	735±7.07 E	1777±3.54 D	2755±7.07 D
	Wet	687±3.54 d	777±3.54 e	1795±35.36 e	2657±53.03 d
T2	**Dry**	710±0.00 C	870±0.00 D	1780±0.00 D	2632±17.68 D
	Wet	725±7.07 c	919±12.43 d	1970±14.142 c	2952±13.81 c
T3	**Dry**	725±7.07 B	967±17.68 C	1862±17.68 C	2650±13.35 D
	Wet	765±35.36 b	1100±42.43 c	2280±7.07 b	3306±24.83 b
T4	**Dry**	745±7.07 A	1167±10.61 A	2285±0.00 B	3302±17.68 A
	Wet	825±7.78 a	1370±28.28 a	2560±49.50 a	3604±48.08 a
T5	**Dry**	730±0.00 A	1062±17.68 B	2322±17.68 A	3222±38.89 B
	Wet	773±19.09 b	1279±14.41 b	2297±21.21 b	3330±56.57 b
Means	**Dry**	722±2.83 **	960.2±10.61**	2005.2±7.78**	2912.2±18.93**
±SE	**Wet**	755±14.57**	1089±20.16**	2180.4±25.46**	3169.8±39.26**

ABCDE and *abce* Values in same columns with different superscripts differ at P<0.01, lower and upper superscript at P<0.01: ** significant at P<0.01

Table 6. Effect of fogging cooling system treatments on feed conversion ratio (b/wk) of broilers during dry and wet summer seasons

Treatments	seasons	Age/weeks			
		3rd	4th	5th	6th
T1	Dry	2.00±0.00 A	2.04±0.06 A	2.23±0.04 A	2.29±0.02 A
	Wet	1.92±0.01 a	1.94±0.01 a	1.97±0.00 a	1.99±0.00 a
T2	Dry	1.97±0.00 A	1.98±0.00 A	1.99±0.00 A	2.05±0.07 A
	Wet	1.83±0.01 b	1.85±0.00 a	1.87±0.01 a	1.89±0.01 a
T3	Dry	1.85±0.00 B	1.87±0.00 AB	1.89±0.00 A	1.94±0.01 A
	Wet	1.73±0.01 b	1.75±0.00 b	1.77±0.00 b	1.80±0.14 a
T4	Dry	1.66±0.01 C	1.67±0.00 C	1.68±0.00 B	1.73±0.01 B
	Wet	1.51±0.01 d	1.52±0.03 d	1.55±0.01 d	1.59±0.01 d
T5	Dry	1.75±0.01 B	1.76±0.00 B	1.79±0.00 A	1.83±0.00 A
	Wet	1.62±0.03 c	1.63±0.04 c	1.65±0.03 b	1.71±0.01 c
Means ±SE	Dry	1.85±0.01 **	1.86±0.01 **	1.92±0.01 **	1.97±0.02 **
	Wet	1.77±0.01 **	1.74±0.02 **	1.76±0.01 **	1.80±0.03 **

ABC and *abce* Values in same columns with different superscripts differ at P<0.05 or P<0.01, lower and upper superscript at P<0.01: ** significant at P<0.01

Table 7. Effect of fogging cooling system treatments on broilers live-weight, hot and cold carcass , hot and cold dressing (%) during dry and wet summer seasons

Treatments	seasons	Live weight (g/bird)	Hot carcass weight (g/bird)	Cold carcass weight (g/bird)	Hot dressing (%)	Cold dressing (%)
T1	Dry	1205±7.07 D	704±5.66 B	693±1.41 D	58±0.13	57±0.45
	Wet	1336±25.46 d	835±7.07 d	826±5.66 cd	62±0.66	61±0.76
T2	Dry	1285±35.36 D	750±14.14 B	742±14.14 C	58±0.51	57±0.49
	Wet	1562±81.32 c	967±45.96 c	958±44.55 c	61±0.28	61±0.34
T3	Dry	1366±79.90 C	786±51.62 BC	778±51.62 C	57±0.41	56±0.45
	Wet	1837±10.61 b	1127±3.54 b	1120±4.95 cd	61±0.16	60±0.35
T4	Dry	1910±7.07 A	1087±3.50 A	1081±3.54 A	57±0.01	56±0.03
	Wet	2267±9.9 e	1325±7.07 a	1322±3.54 a	58±0.57	58±0.41
T5	Dry	1762±10.61 B	1012±10.61 AB	1002±14.14 AB	57±0.27	56±0.47
	Wet	1947±17.68 a	1175±7.07 b	1168±7.07 b	60±0.19	60±0.07
Means ±SE	Dry	1505.6±28.0 **	867.8±17.82 *	859.2±16.97 **	57.4±0.27 NS	56.4±0.38 NS
	Wet	1789.8±28.99 **	1085.8±14.14 *	1078.8±13.15 **	60.4±0.37 NS	60±0.39NS

ABCDE and *abce* Values in same columns with different superscripts differ at P<0.05 or P<0.01, lower superscript at P<0.05a, uppe superscript at P<0.01: * significant at P<0.05 ** significant at P<0.01, NS=Not significant

Table 8. Effects of fogging cooling system treatments and season on carcass peculiarities (thigh, breast, wing, backbone, and neck)

Treatments	Seasons	Thigh (g)	Breast (g)	Wing (g)	Backbone (g)	Neck (g)
T1	Dry	86±0.00 C	160±0.00 C	76±1.41 C	150±0.71 C	132±3.54 C
	Wet	405±7.07 e	405±7.07 d	160±0.00 d	422±0.00 de	411±0.00 d
T2	Dry	89±1.41 BC	190±0.00 B	81±1.41 B	181±1.41 BC	141±1.41 B
	Wet	435±7.07 d	422±3.54 c	180±0.00 c	477±3.54 d	476±1.41 c
T3	Dry	93±2.12 B	221±1.41 A	85±0.71 B	191±2.12 B	147±3.54 B
	Wet	485±7.07 c	460±14.14 b	206±2.12 b	526±2.12 c	547±0.71 b
T4	Dry	111±3.54 A	229±3.54 A	100±0.00 A	212±3.54 A	200±0.00 A
	Wet	515±7.07 a	505±7.07 a	225±3.54 A	559±3.54 a	566±1.41 a
T5	Dry	107±0.71 A	222±1.41 A	95±0.00 A	200±0.00 A	192±3.54 AB
	Wet	500±0.00 b	487±3.54 ab	217±0.71 a b	542±1.41 ab	552±2.12 ab
Means ±SE	Dry	97.2±1.56 **	204.4±1.22 *	87.4±0.71 **	186.8±1.56 **	162.4±2.41 **
	Wet	468±5.66 **	455.8±7.07 *	197.6±1.27 **	505.2±2.12 **	510.4±1.13 **

ABCDE and *abce* Values in same columns with different superscripts differ at P<0.05 or P<0.01, lower superscript at P<0.05, upper superscript at P<0.01: * significant at P<0.05, ** significant at P<0.01

Live weight and some carcass peculiarities

Effects of fogging cooling treatments and season on carcass (thigh, breast, wing, backbone and neck)

Comparisons for the effects of season and fogging cooling treatments for carcass peculiarities showed that wet seasons had better values than the dry seasons, the effect of fogging cooling for the thigh weight, T4 and T5 showed increased significant (P≦0.05) increase in the dry season, for the wet season there was a significant (P≦0.05) progressive increase from T1 to T5. For breast the increase was only significant (P≦0.05) between T1 and T2 for the dry season, for the wet season the increase in weight was significant (P≦0.05) and progressive. For the wing weight and in the dry season, significant increase (P≦0.05) was obtained between T1 and T2, however, T5 showed a significant decrease (P≦0.05) compared with T4. In the wet season, the wing weight showed significant (P≦0.05) progressive increase. The backbone weight showed significant (P≦0.05) progressive increase through the fogging cooling treatments, however, T5 showed significant (P≦0.05) decrease compared to T4 as was shown in the dry summer, for the wet summer, same observations were obtained. For the neck weight same observations were obtained as for the backbone (Table 8).

Effects of fogging cooling system treatments and season on internal organs

For the internal organs the effect of season was very clear with the better improvement of the wet season over the dry season, but significant differences were not detected of all peculiarities. For the gizzard significant differences were obtained for all treatments except for the control (T1). For the kidneys the control as other fogging cooling treatments all showed significant (P≤0.05) difference between dry and wet season. For the fogging cooling effect, and during the dry season, the treatments showed significant (P≤0.05) increase compared to the control, however, T4 showed significant (P≤0.05) increase compared to all other treatments. For the wet season, T4 showed significant (P≤0.05) increase compared to other treatments. For the liver weight, the effect of season was not significant, although there was a tendency for the weight to increase in the wet season. For the fogging cooling effect, T4 and T5 showed significant (P≤0.05) increase compared to the other treatments including the control. For the wet season, same observations were obtained. For the heart weight, season effect was highly significant (P≤0.05) where wet season showed higher (P≤0.05) weights than the dry season. The effect of fogging cooling and during the dry season no significant differences were detected was detected. During the wet season, there was a significant (P≤0.05) progressive increase from T1 to T5, however, T4 was higher (P≤0.05) than T5. For the adipose, wet season weights were significantly (P≤0.05) higher than dry season. The fogging cooling effect that there were significant (P≤0.05) increases from T2 to T5 although significant differences were not detected between T2 and T3 or T4 and T5, although the weight was higher (P≤0.05) withT4 (Table 9).

Effect of fogging cooling treatments and age on broilers' mortality rate of broiler during dry and wet summer

The effects of age and fogging cooling system treatments on the mortality rate of broiler were recorded. Mortality rate was significantly (P≤0.05) higher for the control group (T1) at age 3 weeks and 6 weeks. The effect of fogging cooling treatments did not show significant differences in mortality rates. As comparing among treatments, significant difference was only obtained for T2 where mortality rate was significantly higher (P≤0.05) compared to other treatments throughout the age groups.

During wet summer, the mortality rate for the control did not change with age but was significantly (P≤0.05) higher than T4 at 3rd week and for both T4 and T5 at 4th, 5th and 6th week of age. As the effect of fogging cooling system treatment, mortality rate was the lowest (P≤0.05) with T4 and T5 at the 3rd and 6th age compared to the other treatments (Table 10).

Economical cost-effectiveness of fogging cooling system treatments application

The economical cost effectiveness of application of fogging cooling treatment was calculated as compared to the traditional farms. The calculations took into consideration such information about production (cycle/year), mean cost for the bird, total income from the bird and net profit. Cycles (3-4) and net profit were nearly the same for all the farms in all localities (3 - 4 SDG). Net profit after fogging cooling treatments application for both dry and wet seasons (table 3.9.2). Comparing traditional and fogging cooling treatment system showed that the number birds increased, and body weight (Table 11).

Table 9. Effect of fogging cooling system treatment on internal organs weight during dry and wet summer seasons

Treatments	seasons	Gizzard (g)	Kidney (g)	Liver (g)	Heart (g)	Adipose (g)
T1	**Dry**	21.50±2.12 E	7.25±0.35 C	29.00±1.41 D	8.65±0.21 D	8.00±0.00CD
	Wet	24.00±1.41 d	10.00±0.00 C	31.00±1.41 d	18.00±0.00 e	27.00±1.41e
T2	**Dry**	27.50±3.54 D	8.25±0.35 B	37.50±3.54 BC	9.75±0.35BC	9.00±0.00C
	Wet	37.50±3.54 c	10.00±0.00 c	39.50±10.61 c	22.50±3.54d	42.50±3.54d
T3	**Dry**	31.00±1.41 C	8.50±0.00 B	41.50±0.71 B	10.75±0.35 B	10.00±0.0AB
	Wet	42.50±3.54 b	12.00±0.00 b	45.00±1.41 b	32.50±3.54c	47.50±3.54c
T4	**Dry**	43.00±1.41 A	9.15±0.07 A	55.00±0.00 A	12.25±0.35A	12.00±0.00A
	Wet	59.00±1.41 a	15.00±0.00 a	59.00±0.00 a	40.50±0.71 a	63.00±1.41 a
T5	**Dry**	39.00±1.41 B	8.75±0.07 AB	53.50±0.71 A	11.50±0.0AB	11.00±0.00A
	Wet	57.50±0.71 ab	14.00±0.0 ab	57.00±1.41 a	37.50±0.71a	61.50±0.71 b
Means ±SE	**Dry**	32.4±1.82 **	8.20±0.17 **	43.2±1.27 **	10.58±0.25 **	10±0.00 **
	Wet	43.8±2.12 **	12.2±0.00 **	46.3±2.97 **	30.2±1.70 **	48.3±2.12 **

ABCDE and *abce* Values in same columns with different superscripts differ at P<0.01, lower and upper superscript at P<0.01: ** significant at P<0.01

Table 10. Effect of fogging cooling treatments and age on broilers' mortality rate of broiler during dry and wet summer

Treatments	seasons	Age/weeks			
		3rd	4th	5th	6th
T1	**Dry**	3.91 ±0.71 A	2.86 ±0.71 A	2.86 ±0.71 A	3.12 ±0.71 A
	Wet	1.82 ±0.71 a	1.30 ±0.71 a	2.60 ±1.41 a	2.08 ±1.41 a
T2	**Dry**	2.34 ±0.71 AB	2.34 ±0.71 AB	2.34 ±0.71 AB	2.86 ±1.41 B
	Wet	1.30 ±0.71 ab	1.04 ±0.00 ab	1.30 ±0.71 ab	1.30 ±0.71 b
T3	**Dry**	1.82 ±0.71 C	1.30 ±0.71 C	1.30 ±0.71 C	1.30 ±0.71 C
	Wet	1.30 ±0.71 ab	0.78 ±0.71 b	1.04 ±0.00 c	1.30 ±0.71 b
T4	**Dry**	0.78 ±0.00 E	0.26 ±0.71 E	0.50 ±1.41D	0.52 ±0.71 D
	Wet	0.26 ±0.71 d	0.26 ±0.71 c	0.52 ±0.14 d	0.26 ±0.71 d
T5	**Dry**	1.04 ±0.71 CD	0.52 ±1.41 D	0.52 ±1.41D	1.30 ±0.00 C
	Wet	1.04 ±0.00 c	0.78 ±0.71 b	0.78 ±0.14 d	0.78 ±0.00 c
Means ±SE	**Dry**	1.98±0.57 *	1.46±85 *	1.50±0.99 *	1.82±0.71 *
	Wet	1.14±0.57 **	0.83±0.57 **	1.25±0.48 **	1.14±0.71 **

ABC and *abce* Values in same in columns with different superscripts differ at P<0.05 or P<0.01, lower superscript at P<0.05, upper superscript at P<0.01: * significant at P<0.05, ** significant at P<0.01

Table 11. Cost-effectiveness of fogging cooling treatments compared with traditional farms in Sudanese pounds (SDG)

Item	Traditional framing system	fogging cooling treatment system
fogging cooling unit price/ SDG	0	1450
Mean cost bird	20.0-22.5	26.0-27.0
Total income /bird	24.0-26.0	32.0-34.0
number of bird /m²	9	12
Body weight /bird/g	1700	1775 - 2223
Mortality rates%	5-10	0.40 - 1.82
Production cycles/year	3-4	6-7
Cycle duration/wk	7-8	6
Net profit SDG/bird	3-4	6-7

Body temperature was around 42 °C for the control, and T1 but decreased to 41°C with increasing fogging cooling effects but as birds being homoeotherms, they have the ability to regulate their body temperature through evaporative fogging cooling dissipation mechanism to prevent heat stress (Nääs *et al*., 2010) which was found to work best under hot climate (Datta, *et al.*, 1987). Age effects would reflect that birds with advancement of age birds are better to regulate their body temperature.

The fogging cooling treatments were established to provide different fogging cooling effects as birds will be kept at thermoneutral zone allowing them to express better performance with various degrees, however, T4 fogging cooling treatment (5 nozzles) was the best in giving optimum production, feed intake, feed conversion ratio, weight gain including carcasses characteristics, although internal organs were inconsistent with birds' response to fogging cooling treatments. Similarly, it was shown that the efficiency of the misting fogging system was less than or equal to the efficiency of the nozzles depending on number of nozzles (Bottcher *et al*., 1991), that could substantially reduced the air-conditioning fogging cooling energy requirement in buildings and provide other important environmental benefits (Bom, *et al.*, 1999; Dartnall, *et al.*, 2008). On the other hands, some studies showed the negative effects of high temperature on breast muscles (Leenstra and Cahaner, 1992) as well as on thigh muscles (Zhang *et al*., 2012) with high fat deposition (Filho *et al*., 2006). Internal organs showed similar trends showing higher weights with wet summer compared with dry summer and showed the best weights with T4.

It should be noted that in this study as wet summer had lower temperature this could have effectively affected the efficiency of fogging cooling effect. T5 with 7 nozzles could have produced high humidity that affected the dissipation mechanism of heat dissipation. Similarly, it was pointed out that evaporative fogging cooling systems work best in warm areas with low relative humidity (Costelloe and Finn, 2003; Heidarinejad *et al.*, 2009). In our case T4 was better than T5.

Weight gain with advancement of age increased and with decrease of ambient temperature due to fogging cooling treatment which could be related to the requirement of the birds with growth in weight and to better conversion ratio. Similarly, (Lu *et al*., 2007) have shown that feed consumption and body weight gain of broilers reared at temperature of 21°C (from 5-8 weeks of age) were significantly higher than for those reared at 34°C.

The increase in Thryroxine with increase of fogging cooling effect could be related with higher feed consumption and hence higher metabolic rate. Similarly it was shown that both (tetra-iodothyronine (T4) and tri-iodothyronine (T3). play important roles in regulating metabolism and thermogenesis in chickens (Tao *et al*., 2006). Cortisol on the hand, showed decreased levels with increase effect of fogging cooling treatments. Cortisol is a hormone associated with stress, so fogging cooling effects reduced the stress on birds.

In this study, sodium concentration increased with increase in fogging cooling systems while potassium decreased. Similar studies showed that elevation in body temperature increased plasma sodium and chloride and decreased plasma potassium and phosphate with decreased total mineral retention during heat stress (Sahin and Kucuk, 2003; Ozbey and Ozcelik 2004). Also lower rates of potassium retention were obtained in broilers raised at high cyclic ambient temperature (24 to 35°C) compared with birds housed at 24°C (Belay and Teeter, 1996). This could be related to the fact that electrolytes and water balances in the body are maintained within strict limits and under thermoneutrality where plasma sodium and potassium, play a major role in establishing the osmotic balance of the body fluids (Bowen and Washburn, 1985; Deyhim and Teeter 1995). Moreover, sodium (Na) is involved in the maintenance of osmotic pressure of body fluid and the protection against excessive body fluid loss (Barros *et al*., 1998**)**.

Mortality rates were the highest with control group, the lowest was for T4 which decreased with growing age. Similarly it was shown that increased heat stress, could be associated with reduced feed consumption, reduced growth rate and leading to increased mortality rate (Yahav *et al*., 1995; Hai *et al*., 2000; Abu-Dieyeh, 2006; Eberhart and Washburn, 1993; Yalcin *et al*., 1997; Cooper and Washburn, 1998). However, it could also be related with the inability to regulate body temperature.

The field survey for small scale poultry producers who used an open sided poultry housing in the three area of Khartoum state showed that the micro-environments were better in winter then wet and finally dry summer, with better feed consumption and body weight in winter then wet and finally dry summer. Same observations were obtained for mortality rates. Production cycles were 3-4 cycles. With introduction of fogging cooling systems especially the T4, body weight was improved from 1910 to 2267 g/bird when compared with 1700g as maximum body weight during winter without fogging cooling systems.

The effectiveness of introducing fogging cooling systems for the traditional housing showed that cycles of birds' production, increased from 3 to 7 that is the traditional farmer could have 7 batches during the compared with his usual production (3). Body weights increased from 1700 to 2223 g. net profit increased from 3 - 4 to 6 - 7 Sudanese pounds per bird per batch.

Conclusion

It was concluded that hot climate is a major limiting factor of broiler production in tropical and subtropical regions. The use of fogging cooling system during dry and wet seasons may result in large economic benefits to smallholder because its work perfect in all seasons and if traditional farms adopting cost-effective fogging cooling system will increase their with better life security.

Reference

Abu-Dieyeh ZHM (2006). Effect of high ambient temperature per se on growth performance of broilers. Int. Poult. Sci., 5: 19-21.

Atilgan AA, Coskan HOz and Eisler (2010). The vacuum system which is new approach to decreas ammonia level use in broiler housing in winter season.Kafkas Uni .Vet. Fak. Derg, 16:257-262.

Barros JMS, Gomes PC, Albino LFT and Nascimento AH (1998). Sodium levels over performance parameters of broilers chicken from 1 to 21 days of age. Avian conference of science and technology, Brazil.

Belay T and Teeter RG (1996). Effects of ambient temperature on broiler mineral balance partitioned into urinary and faecal loss. J. of British Poultry Science, 37(2): 423-433.

Bom GJ, Foster R, Dijkstra E and Tummers M (1999). Evaporative Air-conditioning: Applications for Environmentally Friendly fogging cooling, World Bank Technical Paper No. 421 (Energy Series), The World Bank, Washington, D.C.

Bottcher RW, Baughman GR, Gates RS and Timmons MB (1991). Characterizing efficiency of misting systems for poultry. Transaction of the ASAE. 586 - 590.

Bowen SJ and Washburn KW (1985). Thyroid and adrenal responses to heat stress in chickens and quail differing in heat tolerance. Poultry Sci. 64: 149–154

Cooper MA and Washburn KW (1998). The relationships of body temperature to weight gain, feed consumption and feed utilization in broiler under heat stress. Poultry Sci., 77: 237-242.

Costelloe B and Finn D (2003). Indirect evaporative fogging cooling potential in air-water systems in temperate climates, Energy and Buildings, 35(2003): 573-591.

Dartnall WJ, Alex R and Vasilios G (2008). Air-conditioning employing indirect evaporative fogging cooling can be shown to derive its energy from the solar source, In Proceedings of 2008 ASME International Mechanical Engineering Congress and Exposition, October 31- November6, 2008, Boston, Massachusetts, IMECE2008- 67890, 12 pages.

Datta S, Sahgal PN, Subrahmaniyam S, Dhingra SC and Kishore VVN (1987). Design and operating characteristics of evaporative fogging cooling systems, International Journal of Refrigeration, 10 (4): 205-208.

Deng W, Dong XF, Tong JM and Zhang Q (2012). The probiotic Bacillus licheniformis ameliorates heat stress-induced impairment of egg production, gut morphology and intestinal mucosal immunity in laying hens. Poult. Sci., 91: 575-582.

Deyhim F and Teeter RG (1995). Effect of heat stress and drinking water salt supplements on plasma electrolytes and aldosterone concentration in broiler chickens. Int J Biometeorol 38: 216–217.

Eberhart DE and Washburn KW (1993). Variation in body temperature response of naked neck and normally feathered chickens to heat stress. Poultry Sci. 72: 1385-1390.

Elimam BB (1991). Effect of Housing System on the Performance of Broiler Chicks. M.Sc thesis. Institute of Anim. Production. Uof K. pp 58.

Filho DE, Rosa PS, Feigniredo DF, Dhalke F, Macari M and Furlan RL (2006) Dietas de baixa proteina no desenpenho de frangos criados en diferentes temperatures. Pesquiso Agrope Cuora Braziliera 41: 101-106.

Gwatibaya S (2005). Production and physiological responses of lactating Holstein dairy cows to the provision of shade in sub-tropic. Zimbabwe. M.Sc Thesis : Unverity of Zimbabwe. Department of physics. Harare. 94 pp.

Hai L, Rongand D and Zhang ZY (2000). The effect of thermal environment on the digestion of broilers. J. Anim. Physiol. Anim. Nutr., 83:57-64.

Heidarinejad G, Bozorgmehr M, Delfani SE and smaeelian J (2009). Experimental investigation of two-stage indirect/direct evaporative fogging cooling system in various climatic conditions, Building and Environment, 44 (2009): 2073-2079.

Imik H, Atasever MA, Urgar S, Ozlu H, Gumus R and Atasever M (2012) Meat quality of heat,stress exposed broilers and effect of protein and vitamin E. Br. Poult. Sci., 53: 689–698. 56.

Leenstra F and Cahaner A (1992). Effects of low, normal and high temperatures on slaughter yield of broilers from lines selected for high weight gain, favorable feed conversion and high or low fat content. Poultry Sci. 71:1994–2006.

Lu Q, Wen J and Zhang H (2007). Effect of chronic heat exposure on fat deposition and meat quality in two genetic types of chicken. Poult. Sci., 86: 1059–1064.

Nääs Irenilza de Alencar, Romanini, Carlos Eduardo Bites, Neves, Diego Pereira., Nascimento, Guilherme Rodrigues do and Vercellino, Rimena do Amaral (2010). Broiler surface temperature distribution of 42 day old chickens. Scientia Agricola 67: 497-502.

NRC (1994). Nutrient requirements of poultry National Academy Press. Washington, DC. Ninth Revised Edition, 19-34, USA.

Ozbey O and Ozcelik M (2004). The effect of high environmental temperature on growth performance of Japanese quails with different body weight. Int. J.Poult. Sci., 3: 468-470.

Sahin K and Kucuk O (2003). Zinc supplementation alleviates heat stress in laying Japanese quail. The Journal of Nutrition 133: 2808–2811.

SAS Institute (1999) Statistics. User's Guide Version 8. SAS Institute, Inc., Cary, NC.

Shane SM (1988). Factors influence health and performance of poultry in hot climate. Poult. Biol., 1: 247-269.

Snedecor GW and Cochran WG (1980). Statistical methods. 7th Edition the IOWA State. University Press.Ames, Iowa., USA.

Sohail MU, Hume ME, Byrd JA, Nisbet DJ, Ijaz A, Sohail A, Shabbir MZ and Rehman H (2012). Effect of supplementation of prebiotic mannan-oligosaccharides and probiotic mixture on growth performance of broilers subjected to chronic heat stress. Poult. Sci., 91:2235–2240.

Star L, Juul-Madsen HR, Decuypere E, Nieuwland MG, Reilingh de Vries G, Brand van den H, Kemp B and Parmentier HK (2008). Effect of early life thermal conditioning and immune challenge on thermotolerance and humoral competence in adult laying hens. Poult. Sci., 88: 2253-2261.

Tao X, Zhang ZY, Dong H, Zhang H and Xin H (2006). Responses of thyroid hormones of market-size broilers to thermoneutral constantand warm cyclic temperatures. Poult. Sci., 85: 1520-1528.

Yahav S (2000). Relative humidity at moderate ambient temperatures: its effect on male broiler chickens and turkeys. Br. Poult. Sci. 41: 94-100.

Yahav S, Goldfeld S, Plavnik I and Hurwitz S (1995) Physiological responses of chickens and turkeys to relative humidity during exposure to high ambient temperature. Journal of Thermal Biology, 20: 245-253.

Yalcin S, Settar P, Ozkan S and Cahaner A (1997). Comparative Evaluation of Three Commercial Broiler Stocks in Hot Versus Temperate Climates, J. Poultry Science 76(7): 921–929

Zhang ZY, Jia GQ, Zuo JJ, Zhang Y, Lei J, Ren L and Feng DY (2012) Effects of constant and cyclic heat stress on muscle metabolism and meat quality of broiler breast fillet and thigh meat. Poult. Sci., 91: 2931–2937.

******