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Impact of heat stress on growth and egg quality of poultry birds

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Abstract
Poultry farming is fast growing business in India with quick and regular return. These birds are very sensitive to environmental changes which directly or indirectly affect the production and reproduction performance of the birds. Heat stress is one of the most important environmental stressors challenging poultry production worldwide. Heat stress affects directly and indirectly metabolic and physiological acclimation which may reduce the growth and egg quality of commercial laying hens. This study was conducted to evaluate the drastic effects of swear heat conditions. In this experiment total 54 chicks of breeds *i.e.* Rhode Island Red, Punjab Red and Kadaknath were housed in cages in each of 3 environmental chambers. This study includes three treatments along with twice replicates and each replicate consists of 18 birds. The treatments consists of control (average temperature (22.5 ºC) and relative humidity (50%), cyclic (daily cyclic temperature (22.5-37 ºC) and humidity (50-15%) and heat stress (constant heat (37 ºC) and humidity (50%) for 5 wk. Standard feeding and management practices were followed during the experimental period. Different growth and egg quality parameters were measured. Body weight and feed consumption were significantly reduced in all three breeds in the heat stress group. Egg production, egg weight, shell weight and shell thickness were significantly inhibited among birds in the heat stress group. These results indicate that heat stress not only adversely affects production performance but also inhibits egg quality.

Keywords: Breeds, egg quality, feed conversion, heat stress, relative humidity, temperature

1. Introduction
Poultry is the most organised sector in animal production system. The growth is 6-8% in layers and 10-12% in broilers per year against the growth of agriculture as a whole which is around 2.5%. Within a span of 25 years, the egg production has gone up to 70 billion from few millions and the broiler production has gone to 3.8 million tonne from nowhere. India is the third-largest egg producer after China and USA and the fourth-largest chicken producer after China, Brazil and USA. The per capita eggs consumption has gone up from 30 to 68 and the chicken from 400 gm to 2.5 kg.

Stress, a response to adverse stimuli, is difficult to define and understand because of its nebulous perception. “Stress is the nonspecific response of the body to any demand”, whereas stress or can be defined as “an agent that produces stress at any time” (Selye, 1976) [15]. Therefore, stress represents the reaction of the animal organism (*i.e.* a biological response) to stimuli that disturb its normal physiological equilibrium or homeostasis.

Heat stress results from a negative balance between the net amount of energy flowing from the animal’s body to its surrounding environment and the amount of heat energy produced by the animal. This imbalance may be caused by variations of a combination of environmental factors (*i.e.* sunlight, thermal irradiation, and air temperature, humidity and movement) and animal characteristics (*i.e.* species, metabolism rate and thermoregulatory mechanisms). Environmental stressors, such as heat stress, are particularly detrimental to animal agriculture (Nienaber and Hahn, 2007) [10]. The issue of environmental stress has quickly become a great point of interest in animal agriculture, particularly due to public awareness and concerns.

The importance of animal responses to environmental challenges applies to all species. However, poultry seems to be particularly sensitive to temperature-associated environmental challenges, especially heat stress. It has been suggested that modern poultry genotypes produce more body heat, due to their greater metabolic activity (Settar 1999 and Deeb and Cahaner 2002) [16, 3]. Few studies are available that address the effects of heat stress and humidity on production and immune parameters.

Therefore, the present study was conducted in order to determine the effects of heat stress and humidity on production performance and the immune responses of laying hens.

2. Materials and methods

2.1 Experiment details

The experiment was conducted at Poultry Unit of *Krishi Vigyan Kendra* (KVK), Bathinda (Punjab, India) during 2017-18. During this study, 54 chicks of Rhode Island Red, Punjab Red and Kadaknath were reared. When the hens were 25 wk of age, they were moved to 1 of 3 environmental chambers of identical size, ventilation, humidity, temperature, light intensity and light schedule. Hens were allowed to adapt to the environmental chambers for 5 wk at a constant temperature of 24 °C and RH of 50% and a photoperiod of 16L:8D at 5.4 lx. When they reached 31 wk of age (peak production), hens in each of the chambers received 1 of 3 different heat treatments for 5 wk. In the first chamber, hens were exposed to 22.5 °C and 50% RH with a heat index of 27 °C, representing an average heat index throughout different seasons (control group). The hens in the second chamber were exposed to cyclic daily temperatures and humidity ranging from 22.5 to 37 °C and from 50 to 15% RH, representing natural cyclic temperatures during hot summer months (cyclic group). Normal temperatures with high humidity (22.5 °C and 50% RH) were maintained approximately 8 h/d, hot and dry conditions (37 °C and 15% RH) were maintained approximately 4 h/d. The other 12 h/d were spent in temperature and RH transition. Hot and dry conditions started increasing at 0800 h and began decreasing at 1800 h. The hens in the third chamber were exposed to constant 37 °C and 50% RH with heat index of 45.0 °C, representing severe heat stress (heat stress group). Each treatment was then replicated twice of 18 chicks each in Completely Randomized Design (CRD). The chicks were routinely vaccinated and reared under strict hygienic conditions maintaining all standard managemental practices. The birds belonging to all the experimental groups were closely observed throughout the experiment, starting from day old till the end of experiment.

2.2 Data recording

The gain or loss in body weight for each bird was recorded at the end of experiment by subtracting the initial body weight from the weight recorded at the end of experiment. The feed and water was offered as per *ad libitum* and the leftover feed was recorded at next morning. Feed consumption was calculated for each group by subtracting the leftover feed from the feed offered. Hen-day egg production and egg quality (including egg weight, shell weight, shell thickness and Haugh units) were measured weekly while birds were housed in the environmental chambers. Body weight was measured before and after the 5-wk temperature and RH treatments. Egg quality was based on 2 d of collection per week. Shell weight was determined after cleaning adhering egg yolk and albumen and drying to a constant weight at room temperature.

2.3 Data analysis

The data were statistically analyzed with the standard procedures of Analysis of Variance (ANOVA), using Completely Randomized Design, as described by Steel and Torrie (1981) [17]. The means were compared for significance of difference with the Duncan's Multiple Range Test for variables. The statistical package (SAS, 2000) [13] was used to perform the analysis.

3. Results and discussion

3.1 Growth performance of birds

Data pertaining to the daily feed consumption in birds of all three breeds *i.e.* Rhode Island Red (RIR), Punjab Red and Kadaknath as significantly affected by heat stress (Table 1). Feed intake was reduced in proportion to the severity and length of heat stress exposure, birds from the heat stress group eat significantly less feed than birds from the cyclic group, which in turn eat significantly less feed than birds from the control group throughout the 5 wk experiment. The reduction in feed intake in response to heat stress confirms earlier studies (Kirunda *et al.* 2001) [7]. In addition, Hurwitz *et al.* (1980) [6] showed that appetite is also decreased as a primary response to high temperature.

The average body weight (BW) for birds of RIR at the conclusion of the 5 wk study were 2,650, 2,310 and 2,010 g, for the birds of Punjab Red 2,840, 2,420, and 2,180 g and for the birds of Kadaknath 2,750, 2,340 and 2,090 g for the control cyclic, heat stress groups, respectively (Table 2). There were higher BW of Punjab Red birds followed by Kadaknath and RIR at the beginning of the study. Scott and Balnave (1988) [14] observed that BW of laying hens was decreased when exposed to high temperature. Furthermore, Emery *et al.* (1984) [4, 5] showed that birds under cycling temperatures, either between 15.6 and 37.7 °C (mean, 26.7 °C) or between 21.1 and 37.7 °C (mean, 29.4° C) lost more BW than those at a constant 23.9 °C. Decreased BW in birds may be due to a reduction in feed consumption.

In addition to decreasing feed intake and body weight, heat stress increased mortality. Mortality for the heat-stressed group (22.5%) was much higher than for the cyclic (4.5%) or control (2.1%) groups. This increase in mortality could be due to inhibition of some immune responses.

3.2 Quality of eggs

Data pertaining to the egg production in birds of different breeds such as Rhode Island Red (RIR), Punjab Red and Kadaknath as influenced by heat stress was shown in Table 2. Egg production in this study was inversely related to high temperature. Egg production in all three breeds were significantly decreased through all 5 wk for hens exposed to the constant hot temperature compared with those in the cyclic or control chambers. Similar results were also found by Kirunda *et al.* (2001) [7], who reported that egg production in White Leghorns decreased when they were exposed to high environmental temperature. The decrease in egg production in birds was most likely due to the decrease in feed consumption, reducing the available nutrients for egg production. Daniel and Balnave (1981) [2] indicated that feed intake is reduced prior to subsequent loss in egg production. Heat stress not only reduces feed intake but has been reported to also reduce digestibility of different components of the diet (Bonnet *et al.* 1997) [1]. Furthermore, it has been reported that exposure to high temperature decreased plasma protein concentration (Zhou *et al.* 1998) [18] and plasma calcium concentration (Mahmoud *et al.* 1996) [9], both of which are required for egg formation.

Exposure of hens to high temperatures also resulted in a significant decrease in egg quality of birds of three breeds (*i.e.* RIR, Punjab Red and Kadaknath). Egg weight, shell weight and shell thickness were all significantly decreased when the birds were exposed to heat stress (Table 3). Eggs from hens housed in the hot chamber weighed significantly less than eggs from the cyclic chamber and eggs from the cyclic chamber weighed significantly less than eggs from the control chamber throughout the 5 wk experiment. Similar results were also found by Emery *et al.* (1984) [4, 5] and Kirunda *et al.* (2001) [7] who observed that either high environmental or cyclic temperatures decrease egg weight.

The adverse effect of high environmental temperature on eggshell quality has been well documented (Mahmoud *et al.* 1996) [9]. Shell weight and thickness of eggs from the cyclic hens was less than the control but greater than the heat-stressed hens. The decrease in shell quality in the current study may be partially due to a reduction in plasma calcium. It has been reported that plasma calcium level was significantly decreased in laying hens (Mahmoud *et al.* 1996) [9] and in turkeys (Kohne and Jones 1976) [8] when the birds were exposed to high temperatures. In addition, it has been shown that calcium use (Odom *et al.* 1986) and calcium uptake by duodenal epithelial cells (Mahmoud *et al.* 1996) [9] are decreased by exposure to high environmental temperatures.

Finally, eggs from birds housed in the hot chamber, in general, had higher Haugh units than those from birds in either the control or cyclic chambers (Table 4). Kirunda *et al.* (2001) [7] reported that Haugh units of eggs from heat-stressed birds were reduced after heat exposure. An explanation could be that the reduced egg production of the heat-stressed hens imparted greater quality to fewer eggs (Patterson *et al.* 1988) [12]. Hens fed low energy, high wheat middling diets were observed to produce fewer eggs but with greater interior quality.

Table 1: Effect of heat stress on daily feed consumption in poultry birds

Treatment group[1]	Daily feed consumption (g/bird/day)											
	RIR				Punjab Red				Kadaknath			
	Weeks of treatment											
	1	3	5	Mean	1	3	5	Mean	1	3	5	Mean
Control	125.5^{a}	128.3^{a}	126.8^{a}	126.9^{A}	120.4^{a}	122.2^{a}	120.7^{a}	121.1^{A}	126.9^{a}	128.7^{a}	128.2^{a}	127.9^{A}
Cyclic	118.2^{b}	118.9^{b}	119.2^{b}	118.8^{B}	109.3^{b}	109.8^{b}	108.1^{b}	109.1^{B}	115.4^{b}	115.5^{b}	115.6^{b}	115.5^{B}
Heat stress	102.3^{c}	100.5^{c}	99.3^{c}	100.7^{C}	100.2^{c}	99.5^{c}	99.2^{c}	99.6^{C}	105.7^{c}	105.5^{c}	105.2^{c}	105.5^{C}

$^{a–c}$Means for the same parameter within the same column with different letters are significantly different (P<0.05).
$^{A–C}$Means for the same parameter with different letters are significantly different (P<0.05).
[1]Treatment groups were: control = 22.5 °C and 50% RH; cyclic = 22.5 to 37 °C and 50 to 15% RH; heat stress = 37 °C and 50% RH.

Table 2: Effect of heat stress on body weight in poultry birds

Treatment group[1]	Body weight (g)					
	RIR		Punjab Red		Kadaknath	
	Start of experiment	End of experiment	Start of experiment	End of experiment	Start of experiment	End of experiment
Control		2650^{a}		2840^{a}		2750^{a}
Cyclic	2500	2310^{b}	2700	2420^{b}	2600	2340^{b}
Heat stress		2010^{c}		2180^{c}		2090^{c}

$^{a–c}$Means for the same parameter within the same column with different letters are significantly different (P<0.05).
$^{A–C}$Means for the same parameter with different letters are significantly different (P<0.05).
[1]Treatment groups were: control = 22.5 °C and 50% RH; cyclic = 22.5 to 37 °C and 50 to 15% RH; heat stress = 37 °C and 50% RH.

Table 3: Effect of heat stress on egg production in poultry birds

Treatment group[1]	Egg production (%)																	
	RIR						Punjab Red						Kadaknath					
	Weeks of treatment																	
	1	2	3	4	5	Mean	1	2	3	4	5	Mean	1	2	3	4	5	Mean
Control	52.3^{a}	55.8^{a}	55.9^{a}	56.1^{a}	53.2^{a}	54.7^{a}	49.5^{a}	52.6^{a}	52.9^{a}	53.4^{a}	52.1^{a}	52.1^{a}	51.9^{a}	53.5^{a}	53.8^{a}	54.2^{a}	53.9^{a}	53.5^{a}
Cyclic	48.5^{a}	50.9^{a}	51.2^{a}	51.8^{a}	50.1^{a}	50.5^{a}	47.2^{a}	47.5^{a}	47.7^{a}	47.2^{a}	46.6^{a}	46.8^{a}	47.6^{a}	48.9^{a}	48.5^{a}	48.2^{a}	47.7^{a}	48.2^{a}
Heat stress	41.2^{b}	41.5^{b}	40.8^{b}	40.1^{b}	39.7^{b}	40.7^{b}	40.3^{b}	40.9^{b}	39.8^{b}	39.2^{b}	39.5^{b}	39.9^{b}	41.5^{b}	40.8^{b}	40.9^{b}	41.8^{b}	41.5^{b}	41.3^{b}

Means in the column with similar superscripts are not significantly different at $P<0.05$.
$^{a–c}$Means for the same parameter within the same column with different letters are significantly different (P < 0.05).
$^{A–C}$Means for the same parameter with different letters are significantly different (P < 0.05).
[1]Treatment groups were: control = 22.5 °C and 50% RH; cyclic = 22.5 to 37 °C and 50 to 15% RH; heat stress = 37 °C and 50% RH

Table 4: Effect of heat stress on egg quality in poultry birds

Treatment group[1]	Egg weight (g)			Shell weight (g)			Shell thickness (×0.01mm))			Albumen height (mm)		
	RIR	PR	KN	RIR	PR	KN	RIR	PR	KN	RIR	PR	KN
Control	56.4^{a}	56.9^{a}	57.1^{a}	5.02^{a}	5.05^{a}	5.08^{a}	34.5^{a}	34.8^{a}	34.9^{a}	6.20^{a}	6.16^{a}	6.10^{a}
Cyclic	54.8^{b}	55.1^{b}	55.8^{b}	4.88^{b}	4.90^{b}	4.95^{b}	31.9^{b}	32.1^{b}	32.3^{b}	6.23^{a}	6.09^{a}	6.02^{a}
Heat stress	50.2^{c}	51.4^{c}	51.5^{c}	3.31^{c}	3.47^{c}	3.60^{c}	27.9^{c}	28.5^{c}	28.9^{c}	6.58^{a}	6.55^{a}	6.58^{a}

Means in the column with similar superscripts are not significantly different at $P<0.05$.
$^{a–c}$Means for the same parameter within the same column with different letters are significantly different (P < 0.05).
$^{A–C}$Means for the same parameter with different letters are significantly different (P < 0.05).
[1]Treatment groups were: control = 22.5 °C and 50% RH; cyclic = 22.5 to 37 °C and 50 to 15% RH, heat stress = 37 °C and 50% RH.

4. Conclusion

It was concluded that heat and RH stress of three breeds of hens i.e. Rhode Island Red (RIR), Punjab Red and Kadaknath caused poor growth of birds and also increased the percentage of mortality. This increase in mortality could be due to inhibition of immune responses. Our results could be helpful in establishing guidelines for temperature control in laying hen houses, especially during the summer months when birds are most susceptible to heat stress.

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