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Effectiveness of Various Cooling Systems during High Environmental Temperature on Production and Welfare Indices of Laying Pullets in Cage System of Rearing

Asif Ali Ganie[1*], Daljeet Kaur[1], Sarbjeet Singh Nagra[2], Sangeeta Chopra[3] and Shashi Nayyar[4]

[1]Department of Livestock Production Management, GADVASU, Ludhiana, INDIA
[2]CAU, Imphal, Manipur, INDIA
[3]Indian Agriculture Research Institute, New Delhi, INDIA
[4]Department of Veterinary Physiology and Biochemistry, GADVASU, Ludhiana, INDIA

**Corresponding author: AA Ganie; Email: asifaliganie@gmail.com*

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ABSTRACT

The present study was conducted to determine the effect of different cooling systems; Fan Fogger (FF) and Fan Pad (FP) on micro environment of poultry house, thermal comfort, welfare, egg production and egg quality parameters of laying hens. This experiment was conducted on 144, White Leghorn laying pullets (32 weeks old) during hot-dry summer months (May - July) under cage system of housing. The FP and FF cooling systems significantly dropped the mean shed temperature and increased the relative humidity. Thus better THI leads to increase in egg production by 5.48% and 0.73% under FP and FF systems over the control group. However, specific gravity, H.U, egg shell thickness, yolk index and yolk colour were not significantly influenced by cooling treatments. Significantly lower levels of antioxidant enzymes viz. LPO, Catalase, G6PD, GPx and SOD was registered in cooling groups. Both the cooling devices contribute towards the bird welfare by altering the behavioural expression from agonistic to non agonistic activities. Under this study, it was concluded that Fan-Pad system could have better application in improving egg production and bird welfare in laying pullets during summer season.

Keywords: Fan Fogger, Fan Pad, Egg Production and Bird Welfare

Heat stress is one of the major causes for production losses encountered in poultry production, especially in the hot regions of India. The higher susceptibility of poultry birds to heat stress is due to its high body temperature (41ºC), being much close to the lethal temperature, which is just around 4ºC above the normal body temperature. Poultry birds have insulated feathers and lack sweat glands, so it becomes difficult for them to dissipate heat. Moreover, high metabolic heat production due to high growth rate and egg production in modern poultry breeds further aggravate the situation.

High metabolic heat production along with high ambient temperature decreases feed intake and body weight by 15% and 23%, respectively, in broiler birds (Yalcin *et al.,* 1997). At high ambient temperature (31ºC), body temperature of bird rises and the respiratory rate increases (panting) to dissipate heat by evaporative cooling leading to a condition, called as respiratory alkalosis (Teeter *et al*., 1985). Respiratory alkalosis has been related to negative mineral balance for K^+ as well as Na^+ (Belay *et al.,* 1992). There is a decline of about 1.72% in feed intake for every degree celsius rise in ambient temperature from 18 to 32 ºC and the decline is much faster when the temperature further rises from 32 to 38 ºC (Rama Rao *et al.*, 2002). In young broiler stock, nearly 8% mortality and over 10% growth loss occur due to heat stress (Sandercock *et al*., 2001).

In egg laying birds, heat stress caused depressed body weight (Scott and Balnave, 1988), drop in egg production (Muiruri and Harrison, 1991), egg weight (Balnave and

Muheereza, 1997) and shell quality (Mahmoud *et al.*, 1996). These adverse effects of heat stress on production performance are generally preceded by suppression of feed intake. All these consequences of heat stress may get further aggravated due to global warming effects in future.

Layer house temperature should remain in the thermoneutral range of approximately 18ºC to 29ºC for expression of their normal behavioural patterns such as time spent in resting, walking around, eating, foraging and drinking water naturally.

The extent of heat stress can be expressed as an index value, which is a measurement of combined effects of temperature and humidity on the bird. This stress index can be monitored and controlled using different cooling systems in poultry shelters to increase the comfort and to improve production in poultry birds especially in tropical regions.

MATERIALS AND METHODS

This experiment was conducted in cage system of housing at the Poultry Research Farm, Department of Livestock Production Management, Guru Angad Dev Veterinary and Animal Sciences University Ludhiana. White Leghorn laying pullets (BV-300) procured from Venky's India (Ltd.) at 32 weeks of age having similar body weight range and average group weight (n =144).

In cage system of housing, the size of the pen was 16 × 10 × 10. California cage unit with two rows and two tiers was used for the study. Thus, 4 rows having 12 cages in each row (with a dimension of 1×1×1 feet^3 of individual cage) were placed along the length of shed and following calculations were made.

1 row	= 12 cages
In two row and two tier system	= 4 × 12 = 48 cages
Hence 48 cages	= 48 hens
Air circulation for 1 bird	= 30 cfm
For 48 pullets	= 30 × 48 = 144 feet^3/min

or 40.8 m^3/min or 2448 m^3/hr

A blower fan of size 18 inches with air delivery of 60 m^3/min i.e. 76.8 kg/min was selected with the objective of lowering the ambient temperature of 35 ºC and relative humidity 40% to 30 ºC and 60% respectively, 0.0025 kg moisture/kg dry air was required (standard from psychometric chart).

The rate of moisture addition = total amount of air delivered /min x total moisture /kg dry air = 76.8 × 0.0025 = 0.192 kg water/min or 11.5 kg/hr or 11.5 litres/hr.

Hence, five numbers of foggers each of 0.2 mm diameter with a discharge of 2 litre/hr at a pressure of 30 psi were fitted in front of fan in Fan-fogger cooling system.

In Fan-pad system of cooling, exhaust fan of 18 inches was installed to obtain the desired air velocity.

Design of Fan-fogger cooling system

The fan-fogger system (Fig. 1) consisted of a blower with a copper ring placed in front of it. Fine foggers were placed on the ring, which was connected with a water tank through a high pressure pipe. The water was first filtered and then was pumped into the foggers. The fogger's on and off-time was controlled through a timer. When the fan and foggers both were in on position, a fine mist was created leading to the cooling of the shed. During the off-time of the fogger, the fan was in running condition so that the required temperature and humidity could be maintained. This on/off cycle of the foggers was repeated throughout the day.

Fig. 1: Fan-Fogger system consisted of a blower with a copper ring having fine foggers (5 in no.) connected with a water tank through a high pressure pipe along the width wise of the pen

Design of Fan Pad cooling system

The fan and evaporative pad system (Fig. 2) consisted of cellulose pads which were made up of cellulose paper haised in G.I casing with a water distributor through a P.V.C header. The intricately woven cellulose pads were efficient to provide necessary amount of water to achieve maximum cooling of air coming in contact. The evaporative pads were placed at one end of the shed and exhaust fan of 18 inches dimension at the opposite end. The water was pumped to the pads through a pump and the pad was kept wet. The cross ventilation of air with wind velocity of 0.5-0.7 m/s through the system cooled the shed.

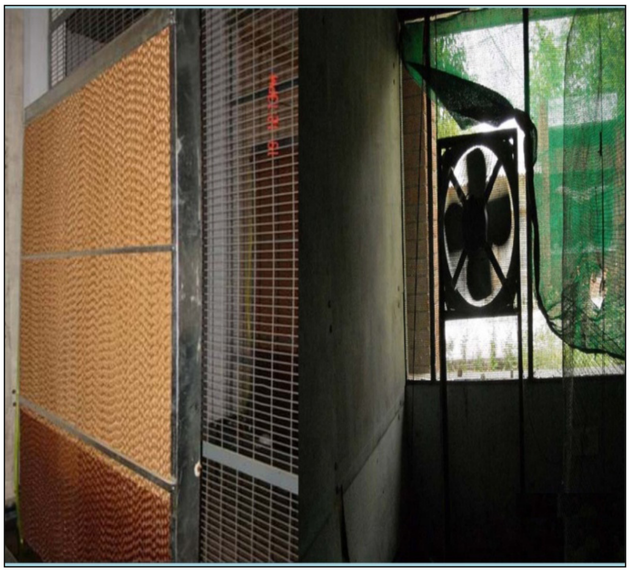

Fig. 2: The fan-pad system consisted of cellulose pads placed along the width-wise of the shed and the exhaust fan of 18” size fitted at the opposite end

Preparation of poultry house

All preparations were made in the poultry house before the arrival of pullets. After removal of all the equipments and old litter, the house was thoroughly cleaned, washed and disinfected. Fan -fogger and Fan-pad systems were installed in the poultry house to cause cooling of different sheds. Two thermo-hygrometers in each pen were fixed to record the temperature and humidity conditions in the shed. This experiment was conducted in cage system of rearing. First week of experiment was considered as acclimatization period. Therefore actual data recording was done from 2nd week onwards till the completion of 10th week from the start of the experiment (April to Mid June).

Experiment details

This experiment was conducted on 144, white Leghorn laying pullets kept in cage system of housing consisted of two treatment groups, Fan-fogger system (FF) and Fan-pad system (FP), which were tested and compared with control group without any cooling system (control). The pullets were randomly allocated to 12 groups each having 12 numbers. The birds used for the experiment were similar in body weight range and average group weight. The pullet ration was computed using various ingredients procured from the local market (Table 1).

Table 1: Ingredient composition of Layer diet

Ingredients	Kg/100Kg feed
Corn	33
Rice polish (de-oiled)	20
Rice polish (oiled)	18
Soybean meal	21
DCP	1.5
Lime stone Powder	3
Lime stone Grits	3
Salt	0.5
Additives*	+
Calculated composition	
Protein, %	17.21
ME, kcal/kg	2526
Lysine, %	0.86
M+C, %	0.73
Calcium, %	1.68
Available phosphorous, %	0.50

*Provided per 100 kg diet; Additives included (per 100 kg).

Liver tonic (SuperliveTM) 0.25g, Vitamin C 20g, Choline chloride 50g, Trace minerals 50g (Ferrous sulphate, 120mg; Cupric sulphate, 12mg; Potassium iodide, 1mg; Manganese sulphate, 90 mg; Zinc sulphate, 60 mg; Salinomycin, 500 mg), Vitamin A, 825000IU; Vitamin D_3, 165000IU; Vitamin E, 500mg; Vitamin B_{12}, 0.015mg; Vitamin K, 100mg; Thiamine, 80mg; Riboflavin, 6mg;

Vitamin B_6, 160 mg; Niacin, 1200mg; Biotin, 0.2mg; Folic acid, 1.0mg; In addition to these supplements, methionine and cystine (M+C) were also added to fulfil the requirements.

Daily feed recording and eggs laid were maintained separately for each group. Feed and water were made available *ad libitum* all the times. The body weight of all the laying pullets was recorded at the start and at the end of the experiment. All the eggs produced in a group were weighted twice in a week. Egg quality parameters were recorded once in two weeks by selecting eight eggs from each treatment group after one month from the start of experiment. Mortality, if any, was also recorded daily. Rectal temperature was noted twice in a week by digital thermometer in the afternoon at 2 pm. Temperature and humidity of the room was recorded from 4 places in shed, three times in a day using Data logger (SIKA Electronics, MH 3350). The blood sample of 5-10ml was collected by cardiac puncture with a sterilized syringe having anticoagulant into it from four birds from each treatment for evaluation of biochemical parameters.

Observations recorded

The observations which were recorded in this experiment include body weight, temperature - humidity index, feed intake, Hen day egg production (HDEP), Egg weight and rectal temperature. The egg quality parameters include Specific gravity (SG), yolk Index, yolk colour, Shell Thickness, Bird Behaviour and Welfare and mortality percent.

Determination of antioxidant enzymes

The activity of Lipid peroxidation, superoxide dismutase (SOD) and catalase in erythrocytes was assayed by method of Stocks and Dormandy (1971), Marklund andMarklund (1974) and by Aebi (1983) respectively. The activity of glutathione peroxidase in erythrocyte lysate was assayed by the method of Hafeman *et al.* (1974) and Glucose-6-phosphate dehydrogenase (G6PD) activity was assayed by the method of Deutsch (1978)

Statistical analysis

The collected data was subjected to statistical analysis using Software Package for Social Sciences (SPSS Version 16.0) available in the Central library, Guru Angad Dev Veterinary and Animal Sciences, Ludhiana. The recorded data were subjected to one-way analysis of variance (Snedecor and Cochran 1989) and comparison among means was made by Duncan's multiple range test with significance level of $P \leq 0.05$("Duncan 1955").

RESULTS AND DISCUSSION

Microclimatic conditions

The data for microclimatic conditions in the shed, THI, rectal temperature and survivability rate under this experiment have been given in Table 2.

Table 2: Effect of different treatments on micro climate and physiological parameters of laying pullets

Parameters	Treatment		
	Control	**Fan Fogger (FF)**	**Fan Pad (FP)**
Temperature, °C	$33.54^a \pm 0.06$	$32.26^b \pm 0.06$	$31.40^c \pm 0.04$
Relative Humidity, %	$43.27^c \pm 0.05$	$47.64^b \pm 0.08$	$49.51^a \pm 0.06$
THI	$81.58^a \pm 0.09$	$80.75^b \pm 0.09$	$79.99^c \pm 0.07$
Rectal temperature, °F	$106.59^a \pm 0.01$	$106.56^{ab} \pm 0.01$	$106.53^b \pm 0.01$
Survivability, %	83.33 ± 0.00	85.44 ± 3.98	87.50 ± 1.49

Mean values bearing different superscripts in a row differ significantly ($p<0.05$).

The temperature of the pens in FP and FF groups during the experimental period was 31.40°C and 32.26°C, respectively. This was, respectively, 2.14 and 1.28°C lower than that in the control (33.54°C) group. This difference in mean shed temperature was highly significant among all the groups. The relative humidity data recorded under different treatment groups was 49.51, 47.64 and 43.27%, respectively in FP, FF and the control group which differed significantly because of moisture addition in the air, by both the cooling systems. The data for THI under different treatments indicated that THI value was significantly lowered in FP group because of evaporative pad cooling. Similarly, FF group had significantly lower THI than the control group, though it was not as effectively lowered as was in FP group. Thus, the THI value differed statistically in both the treatment and the control group.

The rectal temperature recorded under various treatments indicated that the difference in the values for the rectal temperature of birds under all the groups was statistically significant.

The survivability rate, however, was highest (87.50%) in FP followed closely in FF (85.41%) compared to the lowest (83.33%) in the control group. The difference among treatments for survivability percent was not significant.

Production performance

The data for production performance has been given in Table 3. The FP and FF groups had significantly higher egg production than the control group throughout the experiment. The overall, hen-day egg production ranged between 84.62% to 90.10% among both the treatments and the control. The FP group had 5.5% and 0.73% ($P<0.05$) more egg production than the control and FF groups, respectively.

The daily feed consumption data indicated that the feed intake increased in all the groups, irrespective of the treatment effect, throughout the experimental period and ranged between 98.70 g to 102.95 g per bird per day. The feed intake was statistically similar between the treatment groups and was significantly higher than control group by 3.86 g & 4.25 g in case of FP and FF groups respectively. ($P < 0.05$).

The average egg size increased slightly with the advancement in the age of laying pullets in all the treatment groups. During the entire experiment, both the treatment and the control groups had similar values for egg size. The difference for egg size in all the treatment groups was non-significant.

Birds under FP, FF groups produced 49.24g, 48.96g egg mass which is numerically higher than those in the control (46.50g) group but statistically non significant during the experiment period.

Overall, the laying pullets in FP and FF treatment groups performed better, with slightly lower values of FCR than those in the control group. However, the difference for FCR among all the treatment groups was non-significant. The same trend was followed for protein conversion and energy efficiency ratios among all the treatment groups. The data indicated that the FP and FF groups had lower PCR and EER values lower than those in control group with non-significant difference during first eight weeks of study. However, this trend was maintained by both the treatment groups with significant difference when compared to the control group during the last two weeks i.e., 42^{nd} week of age. The pooled data for PCR and EER indicated that FP and FF groups had slightly lower values compared to control group with non-significant difference.

Table 3: Effect of different treatments on production and egg quality parameters in laying pullets

Parameters	Treatment		
	Control	Fan Fogger (FF)	Fan Pad (FP)
	Production performance		
Average body weight, g (34 weeks)	1427 ±3.65	1424±2.68	1426 ±4.38
Average body weight, g (42 weeks)	$1356^a \pm 8.9$	$1346^a \pm 5.25$	$1318^b \pm 3.20$
Hen day egg production, %	$84.62^b \pm 0.33$	$89.37^a \pm 1.81$	$90.10^a \pm 0.32$
Feed intake/bird/day, g	98.70 ± 0.57	102.95 ± 2.56	102.56 ± 1.00
Average egg weight, g	54.95 ± 0.80	54.79 ± 0.57	54.64 ± 0.47
Daily egg mass/hen/day, g	46.50 ± 0.76	48.96 ± 1.07	49.24 ± 1.10
FCR, kg feed/kg egg mass	2.12 ± 0.03	2.10 ± 0.02	2.08 ± 0.03
Protein conversion ratio, PCR	0.36 ± 0.00	0.36 ± 0.00	0.35 ± 0.00
Energy efficiency ratio, EER	5.36 ± 0.10	5.31 ± 0.06	5.26 ± 0.07
	Egg quality		
Shell thickness, mm	0.35 ± 0.00	0.35 ± 0.00	0.35 ± 0.00
Specific gravity	1.083 ± 0.00	1.084 ± 0.00	1.084 ± 0.00
Haugh unit	$82.37^b \pm 1.91$	$85.90^{ab} \pm 1.09$	$87.33^a \pm 0.28$
Yolk Index	$0.49^b \pm 0.00$	$0.49^b \pm 0.00$	$0.52^a \pm 0.00$
Yolk colour score	6.71 ± 0.25	6.56 ± 0.15	7.09 ± 0.07

Mean values bearing different superscripts in a row differ significantly ($p<0.05$).

Egg quality

The data on egg quality parameters (Table 3) indicated that the egg shell thickness decreased in general with the advancement of age, irrespective of the treatments. The egg shell thickness was not influenced significantly by treatments during first eight weeks of experiment while it was significantly higher in FP group as compared to both FF and control groups. However, the cumulative data indicated almost same shell thickness values in all the treatment groups. Similarly, the difference for specific gravity among all the treatment groups was non-significant. The eggs in FP and FF had significantly higher H.U values than the control group indicating better albumin quality in both the treatment groups. The H.U values were statistically similar in both the cooling groups. However, the eggs in FP group had statistically higher value for yolk index as compared to both FF and control group. The yolk index values for FF and control were statistically similar. The yolk colour score ranged between 6.56 in FF to 7.09 in FP against the control, with yolk colour score of 6.71 however, the difference for yolk colour score was non-significant among all the treatment groups.

Antioxidant enzymes

The data for antioxidant enzymes in laying pullets is given in Table 4. In the blood samples of birds, G_6PD level differed significantly in all the treatment groups. Control group had highest G_6PD level followed by FF and FP groups.

Table 4: Effect of different treatments on antioxidant enzyme activities (Mean ± SE) of laying pullets

Parameters	Treatments		
	Control	Fan Fogger (FF)	Fan Pad (FP)
GPx, EU/mg Hb	$1.17^{a} \pm 0.03$	$1.07^{ab} \pm 0.00$	$0.99^{b} \pm 0.07$
LPO, nmol MDA produced /g Hb/hou	3.23 ± 0.19	2.98 ± 0.08	2.90 ± 0.12
SOD, EU/mg H	7.76 ± 0.25	7.53 ± 0.10	7.46 ± 0.32
Catalase, µmol H_2O_2 decomposed/min/g H	$5684.24^{a} \pm 4.15$	$5505.40^{b} \pm 4.73$	$5497.03^{b} \pm 3.87$
G_6PD, µmol NADPH/ min/g Hb	$983.77^{a} \pm 3.54$	$948.75^{b} \pm 4.48$	$932.02^{c} \pm 6.12$

Mean values bearing different superscripts in a row differ significantly (p<0.05).

The level of catalase enzyme in the blood sample of FF and FP group birds was found significantly lower when compared with the control group. The FF and FP group however, had statistically similar values for level of catalase enzyme. The GPx level was highest ($P<0.05$) in control group and lowest in FP group, however FF group had statistically similar values for GPx level, to both control and FP group. The LPO and SOD enzyme level in the blood samples were numerically higher in the control group birds followed by those in FF and FP. However, the numerical difference of LPO and SOD among all the groups was non-significant.

Bird behaviour and welfare

Behavioural response of laying pullets under different treatment groups have been represented as (Table 5) average percentage of the observation period.

Agonistic behaviour

The data recorded for agonistic behaviour in laying pullets under both the cooling treatments indicated less frequency of agonistic behavioural expression like pecking as compared to those of control group. Both the FP and FF groups had comparatively lower pecking percentage than the control group. However, the variation among all the treatment groups was non-significant. This variation in agonistic behaviour of laying pullets attributed to strong influence of cooling treatments in relieving the birds from heat stress compared to control group birds reared without any cooling.

Non-agonistic behaviour

Data for non-agonistic behaviour (Table 5) indicated that the percentage of lying, sitting and standing had significant difference with cooling treatments. Birds of FP and FF groups spent more time in leg stretching, body preening, wing flapping, preening to wing or uropygial gland and eating against the control group. Though, head scratching, body preening activities were higher significantly in both cooling treatments when compared with the control. Significantly, more number of birds were lying in the control group, as an attempt to reduce the movement presumably to minimize the heat production. The birds under control group were drinking more water and were eating less compared to both the treatment groups. The birds in a standing position under both the treatment groups out numbered ($P < 0.05$) the control group. Panting was also higher ($P < 0.05$) in the control group than both FP and FF groups. However, FF group had statistically similar percentage of panting to both FP and control groups.

Table 5: Agonistic and non-agonistic behaviour of laying pullets under different treatments

Parameters		Treatments		
		Control		Fan Pad (FP)
		Activities (% of time)		
Agonistic behaviour	Pecking	4.93 ± 1.29	3.02 ± 0.48	2.56 ± 0.10
Non-agonistic behaviour	Head scratching	4.27[b] ± 0.88	7.42[ab] ± 1.99	8.59[a] ± 0.30
	Body preening	6.87[b] ± 0.44	8.37[ab] ± 1.09	10.61[a] ± 0.30
	Wing preening	2.58 ± 0.98	4.53± 1.61	5.43 ± 1.19
	Wing flapping	9.58 ± 0.58	9.63 ± 0.46	10.98 ± 0.72
	Leg stretching	5.59 ± 1.52	7.67 ± 0.73	9.18 ± 1.64
	Preening to uropygial gland	1.20 ± 0.05	1.50 ± 0.33	1.72 ± 0.31
	Lying	26.47[a] ± 2.90	13.50[b]± 1.35	10.66[b] ± 1.56
	Sitting	9.76[a] ± 1.15	8.04[ab] ± 1.01	5.82[b] ± 0.98
	Eating	4.50 ± 2.33	8.77 ± 1.13	9.47 ± 1.34
	Drinking	4.56 ± 1.46	3.61 ± 0.88	2.98 ± 0.70
	Standing	6.98[b] ± 1.56	12.10[a] ± 1.38	13.41[a] ± 1.42
Other	Panting	12.64[a] ± 0.61	11.77[a] ± 1.47	8.51[b] ± 0.70

Mean values bearing different superscripts in a row differ significantly ($p<0.05$).

However, from the overall comparison of the performance of data recorded in this experiment, it was evident that FP and FF were equally effective for egg production. The difference in the performance of birds due to cooling provided through various cooling systems in present study has also been documented in earlier studies. Dagtekin (2009b) reported effectiveness of evaporative cooling systems to lower the temperature of poultry house, thus improving efficiency of feed conversion, weight gain and mortality in broiler chicks. The poor performance of control group compared to cooling treatments in the present study confirms the findings of Kirunda *et al.* (2001) who reported that egg production in White Leghorn birds decreased when exposed to high environmental temperature. Furthermore, birds exposed to high temperature have been reported to have reduced egg weight, poor shell thickness and lower specific gravity. These results also agree with the findings reported by Mashaly *et al.* (2004) about adverse effects of high temperature on production performance and egg quality parameters in laying hens.

On the other hand, Sharma and Gangwar (1985) compared various cooling systems on the basis of performance of broiler chicks and adjudged air coolers or foggers to be effective to improve growth performance of broiler chicks.

Ugurlu and Kara (2003) also reported 4.28% higher egg production by hens under evaporative cooling system than in natural ventilated house. In the present study also, both the cooling systems (FP and FF) were able to increase hen-day egg production to the tune of 5.5% and 0.73% in comparison to the control without any cooling during the entire experiment.

The data on biochemical analysis indicated that both the treatments were able to provide necessary cooling and in turn comfort, led to the maintenance of the enzyme levels responsible for lipid peroxidation, which are the strong indicators of heat stress in poultry birds. These results confirm the findings of the previous study of Altan *et al*. (2000), in which higher MDA concentration was reported in the broiler chicks as a response to heat stress. Similar findings were reported by Azad *et al*. (2010) with respect to MDA, GPx activity in the broiler chicks. Similarly, Lin *et al*. (2010) and Tan *et al.* (2010) also reported significantly higher production of antioxidative enzymes like SOD, catalase, GPx along with formation of MDA induced by acute heat stress.

The results pertaining to behavioural response by birds with or without cooling under various treatments agree with the findings of Estevez *et al*. (2003) who reported an increase in normal behaviour in the form of locomotory activities with decrease in temperature. On the other hand, there was significant increase in behaviour of lying down or prostration due to increase in environmental temperature was noticed. Moreover, locomotory activities in the present study were also decreased due to exposure to high temperature in the control group than both the cooling groups confirms the findings reported by Maria *et al.* (2004).

The results of this study indicated that Fan-Pad system of cooling could effectively lowered the temperature of pen by 2.14ºC with increase in relative humidity by 6.24% while, Fan-Fogger was able to lower the temperature by 1.28ºC with increase in relative humidity by 4.37%, in cage system of housing. Fan-Pad and Fan-Fogger had significant impact in increasing egg production by 5.48% and 4.75% during this experiment. The Fan-Pad and Fan-Fogger had significant impact in lowering the antioxidant enzyme activities in blood as compared to control group. Cooling systems contributed towards the bird welfare by altering the behavioural expressions from agonistic to non-agonistic activities. Fan-Pad system could have better application in improving egg production and bird welfare in laying pullets during summer season.

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