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Effect of modified shelter arrangements on growth performance, stress and water usage of commercial broilers in hot and humid climate

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ABSTRACT

The current research was conducted to study the effect of modified shelter arrangements on commercial broiler's performance and water usage in hot and humid climatic regions. Ninety six commercial Vencobb broiler chicks of one week of age were segregated into four groups with three replicates having eight chicks per replicate, viz. TA (asbestos roof as control), TAG (asbestos roof with gunny bags screen), TH (modified asbestos with thatched roof), and THG (modified asbestos with thatched roof with gunny bags as the screen). The overall maximum temperature of the asbestos group's experimental sheds throughout the trial period was substantially greater than that of the thatch group. Significantly, the highest THI was seen in the TAG shed. The cumulative body weight gain was significantly highest in TH shed. The cumulative FCR and performance indices of the thatched group were found to be significantly better than the asbestos group. The net profit/bird and net profit/kg were better in the TH group. According to behavioural studies, the panting rate rose with age in weeks but was much lower in the thatched group. Serum corticosterone levels were considerably lower in the TH and THG groups than in the asbestos roof groups. In hot and humid locations, modified asbestos with a thatched roof may be suitable for commercial broiler poultry.

Keywords: Corticosterone, Gunny bags screen, Heat stress, Humidity index, Shelter modification, Temperature, Thatch roof

India ranks 8th in total meat production (FAOSTAT 2020) and its broiler meat output is anticipated of 4.99 MT which has increased by 4.52% over the previous year (BAHS 2023). Odisha contributes about 2.32% with an annual growth rate of 4.94% in total meat production of India (BAHS 2023). The tropical monsoon climate of Odisha, on India's eastern coast, changes from hot and dry to hot and humid from May to June, with average temperatures of 33°C-38°C and humidity of 68-76% (climate-data.org).

Heat stress occurs when a broiler loses its capacity to manage body heat production and loss. Heat stress is caused by the interplay of high ambient temperature, relative humidity, radiation, and air velocity (Aswathi *et al.* 2019). Pereira *et al.* (2008) stated that broiler breeders have a thermoneutral zone from 21°C to 29°C with a relative humidity of 70%-80%. Broilers have body temperature nearer to upper critical temperature, i.e. 41°C and due to lack of sweat glands, they are more prone to heat stress (Aswathi *et al.* 2019). Furthermore, modern commercial broilers generate significant metabolic heat due to growth potential and less effective heat loss due to plumage cover. Heat stress, caused by broiler stocking density and temperature, causes behavioural, physiological, and neuroendocrine alterations that impact broiler health and performance (Wasti *et al.* 2020) thus, heat stress reduction measures are necessary for sustained intensive broiler production. Although cooling strategies like the provision of exhaust fans, cooling pads, tunnel ventilation, and use of a variety of roof materials have been used efficiently and effectively yet owing to the high initial investment, electricity charges, inadequate and interrupted power supply, and frequent power cuts during peak summers have framed way for alternate micro-environment modifications using a combination of roof modification and passive cooling strategies (Chib *et al.* 2016).

Gunny bags are widely used in Odisha for grain storage, doormats, and more, thus using them as a screen for cooling effect in poultry sheds would benefit farmers. Previous studies utilized simply thatch and other materials for roofing and sprinklers for cooling, but the unusual combination of thatch and gunny bags with water splash was not explored. These redesigned shelter arrangements reduce heat gain and improve heat loss in broiler sheds using natural mechanisms, minimal water, and with least expenditure.

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MATERIALS AND METHODS

Location of experiment: The present experiment was conducted on ninety-six commercial Vencobb broiler chicks from 27th May to 30th June 2021 at Instructional Livestock Farm Complex, College of Veterinary Science and Animal Husbandry, Odisha University of Agriculture and Technology, Odisha, Bhubaneswar. During the whole experiment, the average maximum and minimum temperatures were 33.90°C (range: 29-38.6°C) and 26.44°C (range: 23.8-29.4°C), respectively with 69.30% (range: 52-100%) as mean relative humidity.

Experimental design: Four gable asbestos-roofed broiler sheds were selected for the present experiment which was modified two weeks before the arrival of chicks. The experimental sheds are depicted in Supplementary Fig. 1 were TA (asbestos roof as control), TAG (asbestos roof with gunny bags screen), TH (asbestos roof covered with 2” thatch (straw)), and THG (asbestos roof covered with 2” thatch (straw) and gunny bags as screen); the gunny bags screens were hung between 10AM - 5PM and lifted from 5PM - 10AM. They were splashed with water at 10.30AM and 12.30PM. Further, each shed was partitioned with a wire net for three replications of each treatment.

The experimental broiler sheds were cleaned, disinfected, and whitewashed, and feeders and waterers were thoroughly washed with the help of potassium permanganate two weeks prior to the arrival of the chicks. The birds were reared in a deep litter system of housing. Further, two-inch-thick litter material (wood shavings) was spread over the floor and two layers of newspaper were spread under the brooder. The brooder was kept at the center for uniform heating and was switched on 24 h before the arrival of chicks and the chick guard was placed around the brooder. The feeder and waterer were kept in place before the arrival of the chicks.

Management of experimental birds: One hundred (four extra) commercial Vencobb chicks procured from Eastern Hatcheries Private Limited, Bhubaneswar were weighed, and wing banded on the first day of the experiment. The chicks each of 40 g were first brooded together up to the 7th day in two replicates under a normal broiler shed. Out of one hundred commercial Vencobb chicks procured four chicks were discarded from the start of the experiment considering the weak condition of the chicks and the remaining ninety-six chicks each weighing approximately 142 g were segregated into each treatment group equally, i.e. twenty-four birds under each treatment with eight birds in each replicate. *Ad lib.* clean drinking water was provided throughout the day. From day old to the second week, an electric bulb was provided in sufficient quantity to maintain the brooding temperature, i.e. 95°F which was gradually reduced by 5°F in the succeeding weeks (Sastry 2012). The feeding schedule was categorized into three phases: The pre-starter phase (1-7 days), the starter phase (8-21 days), and the finisher phase (22-35 days). The birds were fed broiler ration computed by Japha Comfeed India Pvt. Ltd. having ME 2980 Kcal, 3075 Kcal, 3175 Kcal, and CP 21%, 20.5%, 19% for pre-starter, starter, and finisher, respectively. Vaccination of the Commercial Vencobb broilers was done as per the protocol.

Temperature, humidity and THI recording: Temperature and relative humidity were recorded daily at around 6-7AM and at 1.30-2.30PM using an R-tek temperature and humidity meter. The Temperature Humidity Index was evaluated by using the NRC, 1971 formula as given below:

$$\text{Temperature Humidity Index (THI)}=(1.8 *T+32) - ((0.55-0.0055*RH) *(1.8 *T-26))$$

Where, T = Maximum Temperature

Recording of body weight and performance: Individual body weights of the birds were measured by using an electric pan balance at weekly intervals during the period of the experiment. The body weight gain was measured by subtracting the initial body weight from the final body weight. The cumulative feed conversion ratio (FCR) was calculated as follows:

$$\text{Cumulative FCR} = \frac{\text{Cumulative feed consumption (g)}}{\text{Cumulative body weight gain (g)}}$$

Mortality, if any, was recorded during the entire experimental period. The broiler performance efficiency index (BPEI) considered total saleable live weight, number of chicks, and feed conversion ratio and was calculated by using the formula (Murugan and Ragavan 2017).

$$\text{BPEI}= \frac{\text{Total saleable live weight (kg)}}{\text{No.of chicks} \times \text{feed conversion Ratio}} \times 100$$

The broiler farm economy index (BFEI) considered average live weight, feed conversion ratio, liveability, and rearing period in days and was calculated by using the formula (Patil *et al.* 2017).

$$\text{BFEI}= \frac{\text{Average live weight (kg)}}{\text{Growing period (days)} \times \text{Feed conversion ratio}} \times \text{Livability}$$

Recording of feed intake and water used: A measured amount of feed was given on daily basis and feed intake was calculated at weekly intervals by deducting the leftover feed at the end of the week from the total feed supplied during that week. Feed intake from 1st week to the desired week was the cumulative feed intake. *Ad lib.* water was provided throughout the day and residual water was not taken into consideration for total water intake. In the morning hours, all the waterers irrespective of the treatments were taken out and the residual water was measured and cleaned with fresh water. The number and the size of the waterer increased with age. The water used for splashing the gunny bags in asbestos with gunny bags as screen (TAG) and modified asbestos with thatched roof with gunny bags as screen (THG) was done manually at 10.30 AM and 12.30 PM and this water was measured by a standard bucket of 15-liter capacity. The daily water used for drinking, splashing of gunny bags, and washing of waterers recorded for all the treatments was summed up and the total water usage per bird was calculated. The water-to-feed ratio up to a particular week was calculated by dividing the cumulative water intake up to that particular week by the cumulative feed intake of that week.

Behavioural parameters recording: The results are depicted in Supplementary Table 5. From the 14th day onwards different thermoregulatory, comfort, and maintenance behavouir were observed manually during the peak of the temperature (at around 1.30PM - 2.30PM) using scan and focal sampling techniques and represented in the percentage of birds showing the behaviour. All the experimental birds under each treatment were observed by scan sampling method for ten min where the comfort behaviour (litter bathing, wing spreading, wing flapping, and preening) and maintenance behavouir (feeding and drinking) were recorded. However, the thermoregulatory behaviour, i.e. panting was recorded by the focal sampling method where a particular bird was focused and observed for panting rate recording. The different behavioural parameters mentioned above have been defined as follows (Hesham *et al.* 2018). Panting- Open mouth breathing with gular fluttering; Panting rate- Number of gular fluttering per min; Wing spreading- Spread wing posture is fluffed-up, the feather with one or both wings held away from the body; Wing flapping- Quick up and down movement of wings or as if in flying; Litter bathing- Cowering close to the ground and vigorously wriggling their bodies and flapping their wings to pour litter over their body; Preening- To groom with beak especially by rearranging the barbs and barbules of the feathers and by distributing oil from the uropygial gland; Feeding- Number of birds visiting the feeder for feeding during peak temperature of the day; Drinking- Number of birds visiting the waterer for drinking during peak temperature of the day.

Blood collection and serum extraction: At the end of the experiment 2 mL of blood was drawn from the wing vein of three birds from each replicate in a sterilized centrifuge tube without adding anticoagulants for blood biochemical estimation. The blood samples after collection were kept in a slanting position for 3 h to obtain serum. Then, the harvested serums were pipetted into 3 ml cryovials and properly packaged and stored at -20°C for further laboratory studies. Serum biochemical parameters, i.e. glucose, total protein, albumin, bilirubin (total, direct, indirect), urea, creatinine, and calcium estimated by using the kit prepared by Nice Chemicals Pvt. Ltd., Kerela, India, using Tabletop centrifuge R 8C plus and Systronics UV-VIS spectrophotometer. The serum indirect bilirubin was estimated by subtracting the serum direct bilirubin value from the serum total bilirubin value. The serum corticosterone was estimated by using the BT LAB Bovine Cortisol ELISA kit and Bio-Rad ELISA Reader.

Economics calculation: The economics of broiler production was calculated by considering the cost of chick, total feed, litter, vaccine, and medicine. The raw materials cost was calculated by taking into consideration that it will be used for five cycles, the number of experimental birds, and the floor space occupied by the experimental birds. The labor cost for splashing water on the gunny bags was calculated by man-hours, i.e. 15 min per day for water splashing for 28 days then divided by the number of experimental birds and floor space occupied by the experimental birds. The labour cost for thatching the roof and hanging gunny bags was divided by the number of experimental birds and the floor space occupied by the experimental birds of that particular treatment. The total labour cost per bird was calculated by summing the labour cost for splashing water on the gunny bags as well as for thatching the roof and hanging of gunny bags. The net profit per bird was calculated by subtracting the cost of production per bird from the market price fetched on a live weight basis.

Statistical analysis: The data was analyzed by using the ANOVA model of the analysis tool pack of Microsoft Excel 2019.

RESULTS AND DISCUSSION

Microclimate of the experimental shed: The overall maximum temperature of the experimental sheds during the trial period of TA and TAG is significantly higher than TH and THG (Table 1). This might be attributed to the higher radiation emission property of asbestos roofs which correspondingly increases the ambient temperature of the surrounding shed microclimate (Yazdani and Gupta 2000, Gawali *et al.* 2004, Nagpal *et al.* 2005, Kamal *et al.* 2013). Thatched roof with bamboo matting was found to be superior due to their lower thermal conductivity (Yazdani and Gupta 2000 and Gawali *et al.* 2004). Nagpal *et al.* (2005) suggested that modification of asbestos roofs with bamboo matting, creepers, straw, or dung cakes improved its heat insulation property with a better microclimate.

The relative humidity (%) in sheds where gunny bags were sprinkled with water, i.e. TAG and THG group increased significantly ($P<0.05$) than the non-gunny bags groups, i.e. TA and TH (Table 1) which may be due to spraying of water in both the groups for two times a day. Water sprinkling on the gunny bags screen has aided in the evaporative cooling technique which correspondingly has increased the microenvironment relative humidity level as it was a closed room. Machado (2008) has also opined that evaporate cooling reduced the shed temperature by 1.9°C and relative humidity increased by 4.0 %.

There is a significantly higher THI value observed in the TAG group than TA, TH, and THG groups (Table 1). The TAG group had an asbestos roof which has higher radiation emissivity resulting in an increase in temperature and wet gunny bags increased the relative humidity making the microenvironment more stressful. TH and THG had a thatched roof which is an insulator and doesn't allow heat from outside to penetrate inside keeping the microenvironment cool. Similar, observations were observed by Jat *et al.* (2005) who found that lower THI

Table 1. Microclimate of the experimental shed

Week	Treatment				P-value
	TA	TAG	TH	THG	
Ambient temperature					
Week 2	37.53^{bA}±0.74	37.20^{bA}±0.69	35.84^{aA}±0.60	34.77^{aA}±0.77	<0.05
Week 3	38.10^{bA}±0.45	37.81^{bA}±0.45	36.96^{aA}±0.32	36.41^{aB}±0.29	<0.05
Week 4	38.29^{A}±1.57	38.04^{A}±1.59	37.60^{B}±1.47	36.96^{B}±1.20	0.923
Week 5	40.19^{bB}±0.31	39.69^{bB}±0.28	38.87^{aB}±0.27	38.31^{aC}±0.31	<0.01
Overall	38.39^{b}±0.47	38.06^{b}±0.47	37.26^{a}±0.44	36.55^{a}±0.43	<0.05
Relative humidity					
Week 2	51.86^{aA}±1.18	55.43^{aA}±1.36	52.57^{aA}±1.17	57.00^{bA}±1.38	<0.01
Week 3	62.57^{B}±2.05	68.71^{B}±1.97	64.57^{B}±2.14	69.14^{B}±1.98	0.085
Week 4	51.43^{aA}±1.02	57.29^{bA}±1.39	52.29^{aA}±1.21	57.14^{bA}±1.30	<0.01
Week 5	54.14^{aA}±1.99	63.86^{bB}±2.06	55.14^{aA}±1.96	62.14^{bA}±1.90	<0.01
Overall	55.00^{a}±1.16	61.32^{b}±1.30	56.14^{a}±1.24	61.36^{b}±1.23	<0.01
Temperature humidity index					
Week 2	88.72^{bA}±0.82	89.08^{bA}±0.78	86.66^{aA}±0.72	86.10^{aA}±0.97	<0.05
Week 3	91.93^{bB}±0.31	92.92^{cB}±0.43	90.75^{aC}±0.23	90.94^{aC}±0.24	<0.01
Week 4	89.59^{A}±1.88	90.58^{A}±1.90	88.86^{B}±1.70	89.10^{B}±1.46	0.902
Week 5	92.17^{aB}±1.22	93.85^{bB}±1.17	91.04^{aC}±0.99	91.85^{aC}±1.03	<0.05
Overall	90.60^{a}±0.63	91.61^{b}±0.67	89.33^{a}±0.60	89.50^{a}±0.64	<0.05

^{abc} Means with different superscripts in a row differ significantly (P<0.01). ^{ABC} Means with different superscripts in a column differ significantly (P<0.01).

value and better micro-environment in thatched and mud roof houses than in asbestos sheets.

Effect on growth and water use: The cumulative body weight gain (g) of TH and THG is higher than TA and TAG groups and shows a negative correlation with THI (r=-0.88) (Table 2). The birds of the TH groups overall showed higher body weight gain than the THG groups which is also significantly higher than TA and TAG groups. Temperatures combined with humidity are a worse condition for broiler performance than high temperatures. The evaporative heat loss increased with the rise in temperature but reduced with an increase in humidity (Lin *et al.* 2006). Sohail *et al.* (2012) found that the THI value above the critical levels decreased body weight. Body weight gain in the modified asbestos with thatched roof group (TH) where THI value was comparatively lower than other groups, performs better than an asbestos roof with gunny bags as screen group (TAG) which collaborates with the findings of Aswathi *et al.* (2019) and Sohail *et al.* (2012).

The cumulative feed intake during the experimental period was around 3 kg per bird in all the groups which did not vary significantly among the groups as the variation of temperature (36.55°C - 38.39°C) and THI (89.33 - 91.61) was minimal (Aswathi *et al.* 2019 and Sohail *et al.* 2012).

Relatively better FCR was found in TH and THG than the other two groups. Similarly, the performance efficiency index and farm economy index were better in TH and THG than in TA and TAG. This current result showed a correlation with THI as r=0.86, -0.88, and -0.87 for FCR, BPEI, and BFEI respectively which agrees with the findings of Lin *et al.* (2006) and Sohail *et al.* (2012) who suggested that higher THI value results in higher FCR. Sohail *et al.* (2012) reported that the THI value above the critical threshold level increased the FCR by 25.6% at 42 days of age. Similarly, Lin *et al.* (2006) have reported that high temperature combined with high humidity reduces broiler performance. Purswell *et al.* (2012) have reported that higher THI in heavy broiler birds decreases the broiler performance.

The total water intake of different groups was around 6.5 L from day old to the end of the experiment and no variation was observed among the groups. Similarly, the water-to-feed ratio was around 2 to 2.25 in the groups and there is no variation among the groups. The total water usage of TA and TH was around 8 and 12 L for THG and TAG. According to NRC (1994) for each 1°C rise in temperature above 21°C, the water intake of the birds increases by about 7%, and thus at high ambient temperatures, the broiler's water-to-feed ratio increases. The feed and water intake were found to be highly influenced by ambient temperature, with high temperatures reducing feed consumption while increasing water intake (Balogun *et al.* 2013). The ratio of water to feed nearly doubled for the birds reared at 32 °C birds as compared to the birds raised at 22°C, i.e. 3.0 vs 1.6 g: g (Bonnet *et al.* 1997). In the present experiment, there is no variation in water intake and the water-to-feed ratio of different groups as the variation of temperature (36.55°C-38.39°C) and THI (89.33-91.61) was minimal. The total water usage was due to water sprinkled on gunny bags in THG and TAG which agrees with Liang *et al.* (2020) who found that water required for cooling the shed was around 0.1-0.2 L per day per bird. Our findings which have a correlation of 0.5 of water intake, water to-

Table 2. Growth, performance, and water usage of the experimental broiler birds

	Treatment				P-value
	TA	TAG	TH	THG	
Body weight gain (g/bird)					
Starter (0-21 day)	773.82^{a}±8.51	786.60^{a}±1.98	842.31^{b}±7.15	815.83^{b}±14.83	<0.05
Finisher (22-35 day)	1018.32^{b}±11.19	971.32^{a}±12.09	1051.38^{b}±4.63	1025.34^{b}±1.89	<0.05
Overall (0-35 day)	1792.14^{a}±3.39	1757.92^{a}±14.08	1893.69^{c}±11.77	1841.18^{b}±6.41	<0.01
Feed intake (g/bird)					
Starter (0-21 day)	1122.44±13.81	1143.42±31.71	1162.09±34.46	1157.38±38.75	0.808
Finisher (22-35 day)	1901.08±21.18	1885.33±18.50	1915.02±7.40	1910.26±6.57	0.568
Overall (0-35 day)	3023.52±34.99	3028.75±50.21	3077.11±41.86	3067.64±45.32	0.768
Feed conversion ratio					
Starter (0-21 day)	1.45±0.02	1.46±0.04	1.38±0.05	1.42±0.02	0.470
Finisher (22-35day)	1.87±0.04	1.94±0.01	1.82±0.02	1.86±0.02	0.111
Overall (0-35 day)	1.69^{b}±0.02	1.72^{b}±0.01	1.62^{a}±0.01	1.67^{a}±0.02	<0.05
Broiler performance efficiency index (BPEI)					
Overall (0-35day)	108.61^{a}±1.25	104.37^{a}±0.08	119.03^{c}±1.60	112.93^{b}±0.90	<0.01
Broiler farm economy index (BFEI)					
Overall (0-35day)	3.10^{a}±0.03	3.01^{a}±0.03	3.38^{c}±0.02	3.24^{b}±0.04	<0.01
Water intake (mL/bird)					
Starter (0-21day)	2516.22±77.16	2552.54±110.01	2497.48±19.19	2392.69±40.77	0.501
Finisher (22-35 day)	4361.99±119.68	4195.67±241.83	4157.31±92.69	3985.77±6.54	0.425
Overall (0-35 day)	6878.21±196.84	6748.21±351.84	6654.79±111.88	6378.46±47.31	0.474
Total water used for drinking, washing, splashing (L/bird)					
Overall (0-35 day)	8.30^{a}±0.20	12.49^{b}±0.35	8.07^{a}±0.11	12.12^{b}±0.05	<0.01
Water: Feed					
Starter (0-21 day)	2.24±0.04	2.23±0.03	2.15±0.05	2.07±0.03	0.101
Finisher (22-35days)	2.29±0.04	2.22±0.11	2.17±0.04	2.09±0.01	0.238
Overall (0-35days)	2.27±0.04	2.23±0.08	2.16±0.01	2.08±0.02	0.127

[abc]Means with different superscripts in a row differ significantly (P<0.05).

feed ratio, and total water usage with THI collaborate with Aswathi *et al.* (2019), Bonnet *et al.* (1997), and Balogun *et al.* (2013) who observed higher water consumption in heat-stressed birds.

Stress behaviour: The percentage of birds panting was 100% irrespective of the treatments in the 3rd, 4th, and 5th weeks. However, the panting rate (per min) varied significantly with TH and THG recording minimum followed by TAG and then by TA (Fig. 1). The percentage of birds showing various comfort behavovir like litter bathing, wing flapping, wing spreading, and preening as well as maintenance behaviors like feeding and drinking

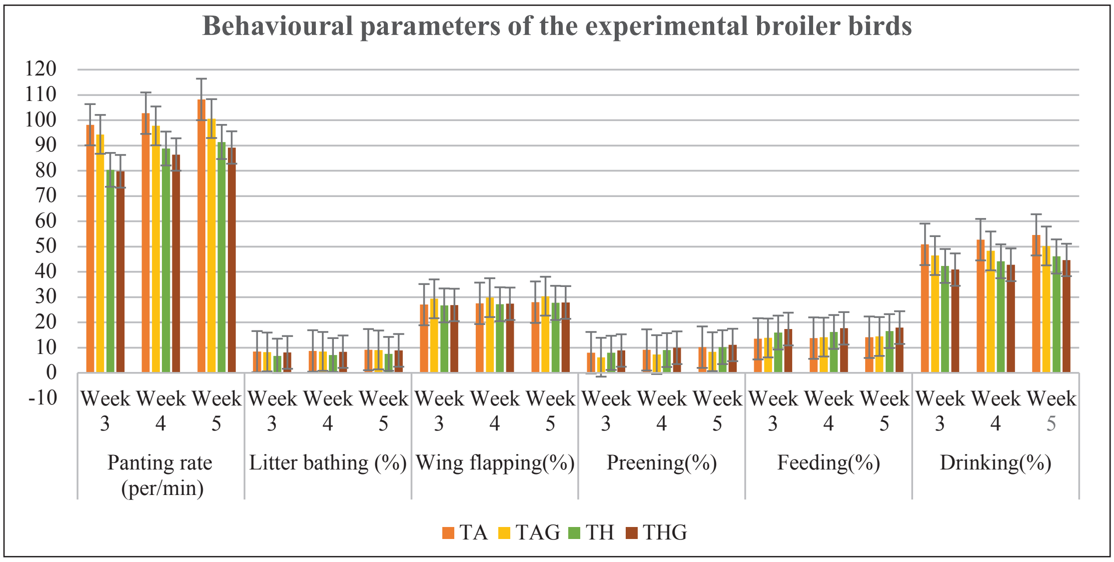

Fig. 1. Behavioural parameters of the experimental broiler birds.

Table 3. Serum biochemical profile of experimental birds

Parameter	Treatment				P-value
	TA	TAG	TH	THG	
Glucose (mg/dL)	211.22±2.41	199.78±8.55	208.82±0.48	210.98±0.96	0.354
Total protein (g/dL)	5.12±0.12	4.80±0.15	4.44±0.15	4.77±0.07	0.314
Albumin (g/dL)	2.63±0.09	2.36±0.34	1.94±0.27	1.67±0.05	0.119
Total bilirubin (mg/dL)	0.31±0.07	0.34±0.16	0.34±0.22	0.55±0.31	0.837
Direct bilirubin (mg/dL)	0.07±0.01	0.04±0.02	0.03±0.01	0.09±0.03	0.253
Indirect bilirubin (mg/dL)	0.24±0.08	0.30±0.14	0.31±0.21	0.46±0.28	0.867
Creatinine (mg/dL)	2.59±0.02	2.48±0.05	2.45±0.09	2.50±0.05	0.551
Calcium (mg/dL)	8.98±1.43	11.29±2.33	9.83±0.58	7.71±1.65	0.532
Corticosterone (ng/mL)	33.57^{b}±1.41	31.27^{b}±1.53	29.63^{a}±1.38	26.51^{a}±1.99	<0.01

^{ab} Means with different superscripts in a row differ significantly (P<0.05).

from 3rd to 5th week did not vary significantly among the treatments. As the present microenvironment has crossed the comfortable THI level hence all experimental birds have experienced panting irrespective of treatment. However, the panting rate followed the trend of TA, TAG, TH, and THG which follows the ambient temperature trend. Since, the birds lack sweat glands they lose heat via evaporation in the form of panting, conduction, and convection by changing the position of wings and squatting lower to the litter. Further, panting enhances the evaporative heat loss when the ambient temperature is high.

Present findings collaborated with the findings of Fitra *et al.* (2017). According to their results, the panting rate of broilers reared from day 0 up to 5 weeks of age was 90-110 breaths/min. Kang *et al.* (2020) also found that 70-week layers showed panting that exceeded 200 counts/min at THI above the temperature of 30°C and at 34°C panting rates were elevated to 250 counts/min. Wiernusz and Teeter (1996) reported that increased frequency of breathing enhances the evaporative heat loss when the ambient temperature is high. Nardone *et al.* (2010), Dayyani and Bakhtiari (2013) in their experiment reported that heat-stressed poultry birds showed signs of panting with open beaks, spreading of wings, squatting nearer to cooler areas, droopy, resting, slow and lethargic with closed eyes. Mack *et al.* (2013) from his experiment found that heat-stressed poultry birds spent less time on feeding and walking and more time on panting, resting, and drinking.

The panting rate (per min) varied significantly (P<0.01) with TH and THG recording minimum followed by TAG and then by TA. The percentage of birds showing various comfort behaviors like litter bathing, wing flapping, wing spreading, and preening as well as maintenance behaviors like feeding and drinking from 3rd to 5th week did not vary significantly (P>0.01) among the treatments.

Effect on biochemical parameters: The blood biochemical parameters like glucose (mg/dL), total protein (g/dL), albumin (g/dL), total bilirubin (mg/dL), direct bilirubin (mg/dL), indirect bilirubin (mg/dL), creatinine (mg/dL), calcium (mg/dL) did not vary significantly among the treatments (Table 3). Current results were consistent with Kang *et al.* (2020) who observed no significant changes in glucose, total protein, or other parameters. There was a significantly higher (P<0.01) corticosterone level in TA and TAG than in TH and THG which might be attributed to the fact that heat stress activates the hypothalamus-pituitary-adrenal axis which increases the secretion of stress hormones thereby increasing blood corticosterone levels. The above findings collaborated with Quinteiro Filho *et al.* (2012) and Olfati *et al.* (2018).

Economics: The economics was calculated by taking the cost of feed, raw materials, labor, and miscellaneous

Table 4. Economics of the experimental broiler birds

Particular	Treatment				P-value
	TA	TAG	TH	THG	
Cost of day-old chick (₹)	25.00	25.00	25.00	25.00	-
The total cost of feed consumed per bird (₹)	118.39±3.90	119.01±4.66	120.30±4.45	120.56±4.71	0.981
Raw materials*	-	1.18	3.50	4.68	-
Labour*	-	1.86	0.50	2.36	-
Miscellaneous cost* (₹)	30.00	30.00	30.00	30.00	-
The total cost of production	173.39±3.90	177.05±4.66	179.30±4.45	182.60±4.71	0.573
Average live weight (g)	1832.32^{a}±27.64	1797.52^{a}±33.95	1934.28^{b}±27.24	1881.00^{b}±27.72	<0.01
Return obtained @ ₹120 per kg live weight	219.86^{a}±0.41	215.77^{a}±1.69	232.05^{c}±1.39	225.75^{b}±0.75	<0.01
Net profit/bird (₹)	46.46±4.31	38.71±2.97	52.75±5.85	43.14±3.96	0.285
Net profit/ kg (₹)	25.35±2.30	21.54±1.82	27.26±2.86	22.94±2.18	0.418

^{abc}Means with different superscripts in a row differ significantly (P<0.01).

(litter, vaccine and medicine, etc.) cost into consideration as depicted in Table 4. Despite the higher total cost of production, the modified asbestos with thatched roof group (TH) showed better net profit than other groups.

The total straw bundles cost was ₹3500, and the gunny bags cost was ₹1175; labor cost for thatching was ₹100, for gunny bags hanging was Rs 100 and for splashing of water on gunny bags was ₹311 per 8 h (man-h); miscellaneous cost included litter, vaccine, medicine, etc.

The micro-environment, FCR, corticosterone level, and panting rate were all lower in the thatch group compared to the other groups. Furthermore, it was discovered that the TH group had better overall body weight gain, broiler performance efficiency, farm economy index, and return obtained per kg live weight than the THG group and the asbestos group. This suggests that a modified asbestos roof with thatched roof (TH) might be better for commercial broiler birds than an asbestos roof in hot and humid climatic regions.

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