PERFORMANCE OF BROILER CHICKS UNDER DIFFERENT STOCKING DENSITIES IN ENVIRONMENT CONTROLLED VIS-À-VIS OPEN-SIDED HOUSE

Thesis

Submitted to the Guru Angad Dev Veterinary and Animal Sciences University in partial fulfillment of the requirements for the degree of

MASTER OF VETERINARY SCIENCE
in
LIVESTOCK PRODUCTION MANAGEMENT
(Minor Subject: Animal Nutrition)

By

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(L-2014-V-09-M)

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CERTIFICATE I

This is to certify that the thesis entitled, **"Performance of broiler chicks under different stocking densities in environment controlled vis-à-vis open-sided house"** submitted for the degree of **M.V.Sc.** in the subject of **Livestock Production Management** (Minor subject: **Animal Nutrition**) of the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is a bonafide research work carried out by **Manmeet Kaur (L-2014-V-09-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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ABSTRACT

Present study was conducted to assess the resource use efficiency of broilers production, in tunnel ventilated environment control (ECBH) and open sided conventional (OSCBH) house under different stocking densities. Different treatments comprised of T_0 (birds with floor space,1.0/ft^2/ bird in open sided conventional broiler house (OSCBH) as control, while different treatments in tunnel ventilated environment control broiler house (ECBH) were T_1, T_2, T_3, T_4 and T_5 with floor space of 1.0, 0.9, 0.8, 0.7 and 0.6 ft^2 per bird, respectively. The results of shed microclimate indicated that shed temperature and temperature humidity index (THI) at 12:00 and 15: 00 IST and maximum and minimum temperature in OSCBH were significantly ($p \leq 0.05$) higher than ECBH. Litter moisture and pH did no differ significantly and were within permissible limits in both OSCBH and ECBH. Final body weight, body weight gain, feed intake were significantly higher and FCR, PER and EER significantly better in ECBH than OSCBH (T_0) even at 10 % increase in stocking density (T_2). Margin of receipt in T_2 in ECBH from sale of live bird/unit area and Kg live weight per/unit area was maximum which was Rs. 5.08/- and 3.56/- higher than T_0 for OSCBH.

Keywords: Broiler, heat stress, tunnel ventilation, growth performance and economics

Signature of Major Advisor	**Signature of the Student**

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LIST OF ABBREVIATIONS

%	:	Percent
◦C	:	Degree celsius
◦F	:	Degree fahrenheit
µg	:	Microgram
µl	:	Micro litre
µM	:	Micro molar
µM	:	Micro mole
ANOVA	:	Analysis of variance assay
BW	:	Body weight
CAT	:	Catalase
ECBH	:	Environment controlled broiler house
EER	:	Energy efficiency ratio
et al	:	Et alia (and others)
FCR	:	Feed conversion ratio
ft	:	Feet
G6PD	:	Glucose-6-phosphate dehyrogenase
GADVASU	:	Guru angad dev veterinary and animal sciences university
GI	:	Galvanized iron
gm	:	Gram
GPx	:	Glutathione peroxidase
Hb	:	Hemoglobin
hr	:	Hours
IST	:	Indian standard time
Kg	:	Kilogram
LPO	:	Lipid peroxidase
m	:	Meter
M	:	Molar
MD	:	Marek’s disease
MDA	:	Malonldialdehyde
mg	:	Milligram
min	:	Minutes
ml	:	Milli litre
mM	:	Milli mole
OD	:	Optical density
OSCBH	:	Open sided conventional broiler house
PC	:	Protein consumption
PER	:	Protein efficiency ratio
Php	:	Philipine peso
PLC	:	Programmable logical control
SOD	:	Superoxide dismutase
SPSS	:	Software package for social sciences
THI	:	Temperature humidity index

CHAPTER – I

INTRODUCTION

Broiler chicken is one of the cheapest protein source, widely consumed by large section of Indian population across different religion without any social taboo. Economic efficiency of broiler as a cheapest protein source is associated with high genetic potential for faster growth rate, high feed utilization efficiency for conversion of vegetable protein to animal protein and less space and labour requirement than other livestock species domesticated for human food production. These favourable attributes leads to rapid growth of intensive broiler production system in India over last few decades.

India is fourth largest producer of broiler chicken with a highest annual growth of 11.44 %, production of 3.73 million tons and employment generation to 4.29 million people (Sasidhar and Suvedi 2015). India is a tropical country (latitude, 8°.40'- 37^0.60' north and longitude 68^0.70'- 97.25' east) with hot dry to hot humid climate. The average annual temperature in most parts of the country is 25°C or higher (Sirohi and Michaelowa 2007) which is at or above the thermal-neutral zone (18.3°C to 23.9°C) of broiler for optimum production (Sturkie 2000). However, during summer, mean daily temperature ranges from 30-35°C and frequently reaches up to 45°C in harsh summers in the north and north-west regions of the country with a difference of more than 15 °C in daytime maximum and night-time minimum (Attri and Tyagi 2010). Additionally, in the light of widely acknowledged phenomenon of global warming, The globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 (0.65 to 1.06) °C over the period 1880 to 2012, when multiple independently produced datasets exist. Surface temperature is most likely to rise over the 21st century by 2°C with more intense, often and longer heat waves, extreme precipitation events will become more intense and frequent in many regions. (IPCC 2007)

Therefore, development and scientific validation of a number of sustainable adaptation and mitigation strategies as insurance against extreme climatic conditions is a major and challenging area of research. In this series "livestock production in controlled environment" can be an important adaptation strategy, particularly for more susceptible livestock species like broiler.

Broiler is one of the most susceptible livestock species to inclement environmental conditions as much narrow difference between body temperature (41^0C) and lethal temperature (45^0C) (Anonymous 2014).

Additionally, broilers due to thick plumage cover, lack of sweat glands are less equipped for body heat dissipation mechanism. Further, high metabolic heat production associated with high growth rate causes positive heat balance, consequently leads to heat stress to broilers. Heat stress in broiler triggers a series of behavioral and physiological adjustments directed to cope up with negative impact on health and increasing survivability. In attempt to increase evaporative heat loss birds start panting with a rise of 4-6^0C above thermo-neutral zone (Salas *et al* 2013), water consumption increases by 7% with every 1^0C increase in temperature (Fairchild and Ritz 2012). Feed consumption decreases by 1.72% with every 1^0C rise in ambient temperature from 18^0C to 32^0C and this decline is more pronounced when the ambient temperature rises from 32^0C to 38^0C (Rama Rao *et al* 2002). In order to minimize production and economic losses, microenvironment modification to alleviate heat stress is indispensible management strategy in intensive broiler production. Although air temperature represents the major component of the thermal environment, the term 'effective temperature' describes the combined effects of air temperature, air velocity, relative humidity and radiation. The concept of effective temperature recognizes that the broiler regulates heat dissipation and thus maintains homeostasis by integrating all the environmental factors. Effective temperature is particularly useful when the air temperature is below or above the thermal comfort zone (Anonymous 2014). Regulation of shed effective temperature within or close to thermo neutral zone, involves, improving convective heat loss mediating through improving ventilation rate and evaporative heat loss by increasing relative humidity. Earlier a number of studies have been conducted on efficacy of different mechanical cooling systems like fan-pad, fan-foggers and fan nozzles to alleviate heat stress in open sided broiler sheds (Bottcher *et al* 1990, Sartor *et al* 2001, Tao and Xin 2003 and Petek *et al* 2012) but broiler performance in tunnel ventilated-evaporative cooling environment controlled sheds is generally superior to that in naturally ventilated houses (Mayers *et al* 2007, Czajka *et al* 2010, Salas *et al* 2013 and Khajali *et al* 2013). In tunnel ventilation evaporative cooling system, exhaust fans and cooling pads are installed at opposite ends of shed, ensuring unidirectional flow of cool air, creating wind chill effect to birds and reduces dust, moisture and other harmful gases. Depending on humidity, tunnel ventilated evaporative cooling system can reduce shed temperature by 10^0C or more (Salas *et al* 2013).

There is now a shift in trend towards adoption of advanced environment control systems that make possible much closer management of in-house air, temperature and other conditions, thus improvement in feeding efficiency, as birds can use the most of their feed energy for growth and the least energy for maintenance. However, the exact kind and degree of environmental control that is appropriate varies from one place to another depending on the local climate, market or other economic conditions. Tunnel ventilated closed environmental controlled broiler sheds are uncommon in India due to consideration of cost of construction. According to SMFI (2012), broiler operation in climate controlled houses can have a payback period of 4.7 to 6.9 years. But modern poultry houses with good construction insulation, ventilation design, within environmentally conditions control system and automatic equipments inside make possibility of rearing the birds at higher stocking density (Liang *et al* 2013, Farhadi *et al* 2016). Glatz and Bolla (2004) reported that birds in climate controlled systems are provided a minimum of 0.64 ft^2 per bird, thus improving the space use efficiency and long term economy.

Therefore, in the light of availability of scanty literature in Indian conditions, present study was planned to assess the comparative performance, welfare and economics of broiler production with different stocking densities in tunnel ventilated environment controlled and open sided conventional broiler sheds with following objectives.

1. To compare growth performance and carcass quality parameters of broiler chicks under different stocking densities in both the housing systems.
2. To study the impact of different rates of stocking density on welfare indices of broilers.
3. To work out cost-benefit ratio under different stocking densities.

CHAPTER II

REVIEW OF LITERATURE

In broiler production, housing management aims on providing comfortable microenvironment to fully exploit the genetic potential of fast growing modern commercial broiler strains. This is required to maximize economic return over expenditure on feeding and other production inputs. India is a tropical country, so heat stress in a major issue for intensive commercial broiler production during most of months of the year. Therefore, adoption of suitable mechanical cooling strategy for microclimate modification to ensure comfortable microenvironment to fast growing commercial broiler strain is essential management intervention. Therefore, scientific literature on growth, welfare, carcass characteristics and meat quality and space use efficiency and possible economic implications of heat stress and mechanical microclimate modification strategies has been reviewed under following heads.

2.1 Heat stress, housing modifications and growth performance of broilers

2.2. Broiler welfare under different housing modifications and stocking densities.

2.3 Carcass characteristics and meat quality.

2.4. Economic efficiency of broiler production under different housing modifications and stocking densities.

2.1 Heat stress, housing modifications and growth performance of broilers

Mc Geehin *et al* (2001) studied the effect of the potential impacts of climate variability and, change on temperature-related morbidity and mortality and reported that the elevated temperature was associated with excess morbidity and mortality.

Al-Homidan *et al* (2003) reported that heat and cold stresses, wet litter and ammonia emissions are among the extreme conditions adversely affecting the poultry performance.

Ozbey and Ozcelik (2004) conducted a 2 x2 factorial experiment to assess the effect of two temperature regimens (18-24°C and 35°C) and two different weight (heavy; live weight > 27 g and light; live weight < 27 g) on growth, feed efficiency, carcass characteristics and survivability of Japanese quails and reported that the live weight, feed consumption, feed efficiency and survivability were less at 35°C compared with 18-24°C in both heavy and light weight groups.

Aradas *et al* (2005) compared the effect of two different types of mechanical cooling systems on physical environment and growth performance of broiler. They found no difference in the physical environmental profile of broiler open sided broiler shed (G1) and closed (G2, adapted tunnel) broiler shade installed with positive and negative pressure ventilation. Broiler's weight gain was not statistically different in both systems, however as total number of birds was higher in G2 (adapted tunnel based on a combination of with side walls closed with curtains with broilers housed at density of 18 birds/m^2) the final results of meat production was higher in G2 than in G1 (conventional housing system lodging 13 birds/m^2). Better distribution of air flow over the birds in the adapted tunnel ventilation system G2 apparently alleviated the broiler's heat stress.

Yahav (2005) reported that air velocity plays a major role in the broiler's energy balance under high ambient temperatures, also, the optimal air velocity for achieving maximal growth performance differs at different ambient temperature and has a turning point at ambient temperature below 30°C, where chilling affects the broiler.

Dozier *et al* (2006) studied effect of five different stocking densities 25, (75 birds/pen), 30 (90 birds/ pen), 35 (105 birds/pen), and 40 (120 birds/pen) kg of body weight/m^2 and feeding programs on performance and welfare parameters of broilers. The body weight gain, feed consumption and feed conversion were adversely affected with increasing stocking densities by 35 days. Increasing calculated stocking density beyond 35 kg of BW/m^2 (7 lb/ft^2) suppressed final body weight by 6%. Final body weight gain, cumulative feed consumption, and breast fillet weight were decreased 41, 39, and 12 g, respectively, with each 5 kg of BW/m^2 increase of calculated stocking density. Reduction in feed consumption was highly related to the adverse response in final body weight gain due to high stocking density rates.

Yahav *et al* (2008) conducted a study to evaluate the effects of different rates of ventilation on growth performance and surface temperature of young turkeys and concluded that turkeys exposed to 35°C performed optimally at an air velocity (AV) of 2m/s with significantly ($p \leq 0.05$) higher feed intake and significantly ($p \leq 0.05$)

lower body temperature. At 30°C, optimal performance with respect to body weight was reported at air velocity of 1.5 to 2.5 m/s which was lowered significantly ($p \leq 0.05$) at 0.8 m/s. It was further concluded that the combination of 30°C with air velocity from 1.5 to 2.5 m/s was optimal for young turkeys.

Dagtekin *et al* (2009) studied the performance characteristics of pad evaporative coo1ing system in broiler house in mediterranean climate and reported that at 42°C temperature with relative humidity below 50%, the evaporative cooling system can be used effectively to reduce the temperature by 9°C, thus to prevent the negative effect of heat stress on efficiency of feed consumption and mortality.

Al-Aqil *et al* (2009) conducted an experiment to determine the effect of housing birds under window less environmentally controlled chambers (temperature was set at 32°C on day 1 and gradually reduced to 23°C by day 21) or in conventional open-sided houses (OH) with cyclic temperatures (minimum, 24°C; maximum, 34°C) and early age feed restriction on stress, fear reactions and performance of broiler chickens raised in a hot-humid tropical climate. Raising birds in conventional open-sided houses resulted in depressed growth, feed intake and FCR of broiler chickens.

Quinteiro-Filho *et al* (2010) examined the adverse effects of heat stress on performance parameters. Two different heat stressors (31°C±1 and 36°C±1/10 h/ day) applied to broiler chickens from day 35 to 42. It was reported that increasing body temperature from 31°C and 36°C resulted decrease in % body weight gain as well as feed intake and the feed conversion ratio in broiler chickens. Only chickens submitted to 36°C±1, however, presented a decrease in feed conversion and increased mortality.

Petek *et al* (2012) assessed performance of two stage cooling system comprised of passive underground tubes and a box earth couple heat exchange system, followed by a pad cooling system with tunnel ventilation. The control unit had a traditional evaporative cooling system, including pad and fan with tunnel ventilation. They concluded that the air temperature and relative humidity of incoming house and exhausted air in the two stage pad cooling system were found to be significantly lower than those of the traditional system ($P < 0.05$). Body weight gain was also significantly influenced by the cooling system ($P < 0.05$). The results indicated that two stage pad cooling is a more efficient method to alleviate heat stress in broilers during heat stress conditions and to improve growth performance.

Yardimci and Kenar (2008) reported that increasing the stocking density in an environmentally controlled house can have less negative effect on house environment and poultry performance than a conventional house as long as appropriate environmental conditions can be maintained.

Hameed *et al* (2012) carried out a study to investigate the effect of housing system on the production of Arbor acres and Hubbard broiler breeder strains and monitor the differences in production potentials in open and controlled housing on deep litter systems. It was observed that the number of eggs and peak production average was higher at breeder farms under controlled housing system than those managed under open housing system; while feed intake from 0-24 weeks was almost equal under both the housing systems; but relatively higher under controlled housing from 25-64 weeks. There was significant ($P<0.05$) difference between groups for 25-64 weeks production, initial body weight, number of eggs/bird, peak production averages, feed intake 0-24 weeks and 25-64 weeks. Environmentally controlled housing system is recommended to breeder farm owners; despite initial higher cost.

Gupta *et al* (2013) studied the performance of the broiler chicks under different cooling systems during hot-dry summer and concluded that both the cooling systems had significant ($p < 0.05$) effect on the comfort and production efficiency of broiler chicks during hot-dry season. The fan-pad system was found to be more efficient than fan-fogger system.

Purswell *et al* (2012) studied the effect of temperature-humidity index on live performance in broiler chickens grown from 49 to 63 days of age over a range of dry-bulb temperature (15°C, 21°C, and 27°C) and relative humidity (50%, 65%, and 80%) with resulting THI between 60-80°F (14.8 -26.9°C). A series of four studies were completed with broiler chickens housed in environmental chambers. Results showed that as THI exceeds approximately 21°C (70F) bird performance significantly declined and body temperature increased up to 1.7°C above nominal body temperature for broilers (41°C). Regression analysis showed that a quadratic relationship between THI and reduction in performance of broilers.

Tong *et al* (2012) conducted an experiment to on 840 one-day-old male Suqin yellow chickens placed into 4 m^2 cages in groups of 50 (low), 70 (medium), or 90 (high) birds at stocking densities of 25, 35, and 45 birds/m^2 from 1 to 28 days and 12.5, 17.5, and 22.5 birds/m^2 from 29 to 42 days (low, medium, and high, respectively). Final production (live bird mass after fasting) per unit area was 14.46, 19.46, and 24.23 kg/m^2, respectively, at 42 days of age. It was noticed that body weight at 28 and 42 days of age was significantly ($p \leq 0.05$) reduced as the stocking density increased. A depression in daily weight gain was noticed from 1 to 28 days and 1 to 42 days of age, and daily feed intake decreased significantly ($P < 0.05$) in each period as density increased. The feed/gain from 29 to 42 days and from 1 to 42 days of age decreased as density increased. Thus, suggested that increasing the stocking density advantageously affected feed/gain and decreased the final body weight.

Salas *et al* (2013) assessed the comparative performance and profitability of 25,000 broiler birds in shed with climate controlled system and conventional housing. They did not observe significant (P>0.05) difference in live weight from day-old to 5th week (1.63 kg *vs*. 1.65 kg) between conventional and climate controlled system housing, respectively. However, FCR at 3rd and 4th week of age and harvest recovery of the birds under climate controlled system housing was significantly better (P<0.05). Flocks under climate controlled system had more uniformity and cumulative livability than those grown in conventional housing.

Farhadi and Hosseini (2014) found that raising of broilers in the environmentally controlled house at higher stocking density (20 *vs*.16 birds/m^2) than conventional house, had numerically lower mortality rate and greater production efficiency indices. They concluded that environmentally controlled house can be efficiently utilized to improve in production efficiency indices through providing better environmental conditions thus reducing mortality and growth performance at higher stocking density of broiler chickens compared to conventional houses.

Bucklin *et al* (2015) studied the effect of tunnel ventilation system on broiler houses and concluded that a properly designed and operated tunnel ventilation system is an effective option for cooling birds. The combination of high air velocity and evaporative cooling can be used by producers to increase feed consumption, increase growth and reduce mortality when growing heavy birds during hot summer weather.

Benyi *et al* (2015) studied Ross 308 and Cobb Avian 48 broilers raised at stocking densities of 30, 40, and 50 kg BW/m^2 during 49-day production period in winter and summer. Broilers raised at the stocking density of 30 kg BW/m^2 gained more body weight and were heavier at 49 days than those raised at 40 and 50 kg BW/m^2. Thus, concluded that increasing stocking density decreased weight gain of broiler chickens

Farhadi *et al* (2016) conducted an experiment with birds at stocking densities of 16, 18, 20 or 22 birds/ m^2. They concluded that the broiler chicks reared in environmentally controlled house had superior performance, higher livability and lower litter moisture content and foot lesions. Moreover, broiler rearing at the density of 22 birds/m^2 adversely affected growth performance and foot quality, despite the higher live body weight per unit compared to broilers grown at lower densities.

2.2. Broiler welfare under different housing modifications and stocking densities

Broiler welfare is reflected through a number of behavioral, physical and biochemical changes. These changes have great relevance to growth performance of broilers and economic implications to farmers.

2.4.1 Behaviour

Hall (2001) studied the effect of stocking density on the welfare and behaviour of commercially reared broiler chickens and reported that broiler chickens spent a lot of time lying down when reared at densities varying from 7.5 to 30 chickens/m^2.

Arnould and Faure (2004) studied the use of pen space and activity of broiler chickens reared at two different stocking densities 2 and 15 chickens/m^2, respectively and reported an uneven distribution of broiler chickens on the floor surface. Broiler chickens spontaneously limit their physical efforts at higher stocking densities and tend to stay and rest near drinkers and feeders as much as possible which might lead to deleterious effects on their health and comfort.

Thomas *et al* (2011) conducted a trial to examine the influence of floor density on broiler behavior, reared at four stocking densities 13, 25, 28 and 50 and were coded very low (VL), low (L), medium (M) and high (H), respectively. They reported that the most commonly observed behaviour in all of the densities was resting (lying), ranged from 76.0% to 85.7% of total behaviour. Resting and standing behavior tended to increase in H than L group of all experimental period. Pecking behaviour was not constantly changed by stocking density. Locomotion was not only reduced with increasing age but increase stocking density of all experimental period and all groups. Other behaviours (dust-bathing, preening, eating or drinking) were not influenced ($P > 0.05$) by stocking density.

Guo *et al* (2012) concluded that group size and stocking density in furnished cages have an effect on behavior and performance of hens. The furnished cage system with small group sizes was favourable for hen welfare without markedly affecting performance.

Son (2013) reported that locomotion was not only reduced with increasing age but increase in stocking density of all experimental period and all groups (3 stocking density, ranging from 30 to 44 kg/m^2). The duration of tonic immobility (TI-reaction) decreased at age of 21 than 35 days, but not affected by stocking density. These data indicated that stocking density can influence broiler behaviour and welfare indices.

2.4.2 Body Lesions and Changes

Sorensen *et al* (2000) studied the effects of stocking density on leg weakness in broiler chickens in two trials. In Trial 1, walking ability was assessed at 28, 42, and 49 days of age. Birds were stocked at 833, 625, or 435 cm^2 per bird. In Trial 2, birds were stocked at 625 or 455 cm^2 per bird and assessed for tibial dyschondroplasia (TD) by radiographic examination at 28 day and walking ability at 35 day. The effect of high stocking density on walking ability was apparent even at 4 weeks of age. Thus, concluding that the lower stocking density substantially reduced the prevalence of leg weakness.

Reiter and Bessei (2000) reported significant decrease in locomotor and scratching activity with increased stocking density from about 10 to 35 kg/m^2.

Sanotra *et al* (2002) reported that fast growth rate is generally accompanied by decreased locomotor abilities and extended time spent resting (sitting or lying) behavior.

Dawkins *et al* (2004) observed that out of five stocking densities 30, 34, 38, 42 and 46 kg/ m^2 only fewer birds in two highest target stocking densities 42 and 46 kg/m^2 were with the best gait score 0 but culling rates were not greater, which suggested that at least some aspects of leg health are compromised at or above a stocking density of 42 kg/m^2. They concluded that the effect of stocking density and housing conditions on chicken welfare *per se* is, within limits, less important than other factors in bird's environment.

Dawkins *et al* (2004) evaluated that there has been debate about the importance of stocking density as an influence on bird welfare and locomotion. Within limits, putting as many birds in a house as possible for each rearing cycle will improve profitability. For every 1 kg/m^2 increase in stocking density as measured at the time of the flock assessment, across a range from 15.9 to 44.8 kg/m2, there was a 0.013 deterioration in flock gait score.

Fairchild (2005) stated that at higher stocking densities the birds grew slower, were jostled more and had reduced walking ability.

Dozier *et al* (2006) examined the effects of stocking density on live performance, physiological stress level indicators Stocking density treatments were 25, (75 birds/pen), 30 (90 birds/pen), 35 (105 birds/pen), and 40 (120 birds/pen) kg of BW/m^2. Thus, concluding that litter moisture was higher as stocking density increased, which led to higher footpad lesion scores.

Mtileni *et al* (2007) stated that due to the limited physical access to feeders as well as the competition between birds on feed, high rates of stocking density had been observed to drastically reduce broilers growth rate, feed consumption, feed conversion ratio, and their carcass quality, as well as increase litter moisture and incidences of footpad and thighs lesions.

Knowles *et al* (2008) reported the high prevalence of poor locomotion occurred despite culling policies designed to remove severely lame birds from flocks. They showed that the primary risk factors associated with impaired locomotion and poor leg health are those specifically associated with rate of growth. Factors significantly associated with high gait score included the age of the bird (older birds), visit (second visit to same flock), bird genotype, not feeding whole wheat, a shorter dark period during the day, higher stocking density at the time of assessment, no use of antibiotic, and the use of intact feed pellets.

Buijs *et al* (2009) the welfare of 4 replicates of birds stocked per pen at stocking density of 6, 15, 23, 33, 35, 41, 47, and 56 kg was studied. It was noted that different aspects of welfare were influenced at different densities or group sizes, or both. Thus, evaluating the effects of stocking density on welfare as a whole would require either identification of acceptable levels for each separate indicator or a weighting of the indicators in an integrated welfare score. The lowest 2 densities (6 and 15 kg/m^2) scored better than most middle densities (23, 33, 35, and 47 kg/m^2), whereas all densities scored better than the highest density (56 kg/m^2).

Bilgili *et al* (2009) in 3 successive trials, 8 different bedding sources (pine shavings, pine bark, chipped pine, mortar sand, ground hardwood pallets, chopped straw, ground door filler, and cotton-gin trash) were compared in side-by-side experimental pens by rearing mixed-sex birds. Bedding materials had little influence on the live performance of broilers in 3 successive trials. Prevalence of foot pad dermatitis varied significantly ($P < 0.05$) among the bedding materials. The incidence of foot pad dermatitis paralleled high litter moisture and caking scores, with chipped pine, chopped straw, cotton-gin trash, and pine shavings showing the highest severity scores and mortar sand and ground door filler showing the lowest. From foot pad dermatitis etiology standpoint, the ability of the bedding to absorb (i.e., ground door filler) and quickly release (i.e., mortar sand) moisture may be the most important characteristics.

Buijs *et al* (2009) reported that stocking density did not affect bursa weight, mortality, or concentrations of corticosterone metabolites in droppings but did influence leg health and footpad and hock dermatitis and tended to influence fearfulness (8, 19, 29, 40, 45, 51, 61, and 72 birds per 3.3 m^2).

Skrbic *et al* (2009) determined tendencies of worsening of the condition of litter, increase of the frequency of lower scores for walking ability (gait score), hock burns and foot pad lesions which occur with increase of stocking density, indicate the importance of this rearing factor and need to define limiting stocking densities from the aspect of broiler welfare but also economical efficiency of production.

Bilgili *et al* (2010) reported that wet and caked litter was a primary cause in greater incidence of foot pad dermatitis and hock burns and proper ventilation was a key factor for decreasing wet litter.

Ventura *et al* (2010) studied 2,088 one-day-old broiler chicks were randomly assigned to one of the following barrier and density treatment combinations over 4 replications: simple barrier, complex barrier, or no barrier (control) and low (8 birds/m^2), moderate (13 birds/m^2), or high (18 birds/m^2) density. Broilers at higher densities had more severe footpad ($P < 0.0001$) and hock lesions in conclusion, this study showed a negative effect of high density on broiler footpad health. Although barrier perches did not appear to reduce fearfulness, the improvement in footpad health suggests that simple barriers may provide key welfare benefits to broiler chickens.

Garcia *et al* (2012) reported that carcass lesions (scratches, bruises and footpad lesions) were influenced by the litter material evaluated. It was found that males presented higher incidence of dermatitis and footpad lesions than females. Each litter material presented different compaction degrees, which increased with the experimental period.

Knierim (2013) investigated two stocking densities on similar levels legally regulated (35 kg/m^2 und 40 kg/m^2) and two lower stocking densities (18 kg/m^2 und 25 kg/m^2) were in groups of 18 to 42 Lohmann broiler chickens in three batches with each time one replication of all stocking densities. Walking ability was only different between the lowest and the two higher densities. Altogether results reflect behavioural restriction at the higher stocking densities with increased risks for footpad alterations and lameness.

Lampang (2014) studied the productivity and tonic immobility duration of cross-bred chickens raised at different stocking densities (8, 12 and 16 birds/m^2) and recommended stocking density of 12 birds/m^2 without affecting the productivity and welfare status.

Farhadi *et al* (2016) observed that lower incidence and severity of foot pad dermatitis and hock burns in broiler chickens grown in environmentally controlled house was mainly associated with lower litter moisture content due to better controlling of environmental conditions and proper ventilation than conventional house.

2.4.3 Biochemical Changes

Altan *et al* (2003) conducted an experiment to determine the effect of heat stress on oxidative stress and lipid peroxidation in broiler chicks. They reported that increased rectal temperature, heterophill/lymphocyte ratio, duration of tonic immobility, fearfulness among the birds and decreased haematocrit value. A significant effect of heat stress was also reported on Malondialdehyde (MDA) concentration, Catalase, Superoxide dismutase (SOD) and Glutathione Peroxidase activity in broiler chicks.

Muniz *et al* (2006) reported that stress may cause immunodeficiency by affecting cell and humoral responses, as well as body weight decrease, and foot-pad dermatitis.

Brodacki *et al* (2006) showed a highly significant increase in haematological indices in birds kept under the environment-friendly system compared to the intensively reared group.

Lin *et al* (2010) investigated the effects of acute heat stress on function of hepatic mitochondrial respiration and lipid per oxidation in broiler chickens and reported that the acute heat stress induced a significant production of ROS, function of the mitochondrial respiratory chain, ant oxidative enzymes {superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx)} activity and formation of Malondialdehyde (MDA).

Gupta *et al* (2013) studied the efficacy of two mechanical cooling systems namely fan pad (FP) and fan fogger (FF) to reduce heat stress in broiler chicks. They reported significantly higher lipid per oxidation (LPO) indicated by significantly ($p < 0.05$) higher malondialdehyde (MDA), catalase and GPx in response to high shed temperature in control group than FP and FF groups.

Abudabos *et al* (2013) evaluated that major displacements in broilers' homeothermic status, high stocking density broilers (45.0 kg/m^2) experienced pronounced elevations of their body temperatures as well as head, body and shank surface temperatures over the control stocking density broilers (26.5 kg/m^2).

Wang *et al* (2014) concluded that higher stocking density tended to be associated with reduced weight gain ($P<0.10$), and significantly ($P < 0.001$) increased plasma glutamic-pyruvic transaminase activity. Increased dietary tryptophan significantly ($P<0.01$) reduced the activities of lactic dehydrogenase and glutamic-pyruvic transaminase while increasing total cholesterol in the plasma, reducing drip loss of breast muscle ($P < 0.10$) and improving feed efficiency ($P < 0.10$).

2.3 Carcass characteristics and meat quality

Feddes *et al* (2002) demonstrated that live body and carcass weights were decreased with reduced bird density, however, bird uniformity was better at high densities with no effect on mortality, breast meat yield, carcass grade and incidences of scratches. It was further concluded that high yield/ unit area and good carcass quality could be achieved at the increased stocking density with adequate ventilation rate.

Fairchild (2005) reported that stocking density had no effect on mortality, breast meat yield, carcass grade, incidence of scratches, or carcass quality. It was concluded that high yield per unit area and good carcass quality could be achieved at the increased stocking density when adequate ventilation rates were provided.

Simsek *et al* (2009) studied 5 different stocking densities for birds 22.5, 18.75, 15, 11.25, and 7.5 broilers/m^2 in *ad libitum* and limited- or pair- feeding regimens and reported that lowering of fat deposition could be related to broilers in the lower density group having more movement space. Limited feeding increased the fat ratio of the chicken meat. Lowering the stocking density reduced the fat ratio and increased the protein ratio of the meat in both feeding regimens. The total saturated fatty acid (SFA) ratio was found to be quite high, whereas the total polyunsaturated fatty acid (PUFA) and n-3 fatty acid ratios were found to be low in the limit-fed broilers. Lowering the stocking density had a variable effect on fatty acid composition of the meat; total SFA and monounsaturated fatty acid ratios decreased, whereas total PUFA, n-3, and n-6 ratios increased in the *ad libitum* groups. Total SFA and monounsaturated fatty acid ratios increased and total PUFA, n-3, and n-6 ratios decreased in the pair- feeding groups. Serum total and high-density lipoprotein cholesterol levels were reduced with lower stocking densities in the *ad libitum* groups, but only high-density lipoprotein cholesterol was reduced in the pair- feeding groups.

Tong *et al* (2012) conducted an experiment on 840 one-day-old male Suqin yellow chickens were placed into 4 m^2 cages in groups of 50 (low), 70 (medium), or 90 (high) birds at stocking densities of 25, 35, and 45 birds/m^2 from 1 to 28 days and 12.5, 17.5, and 22.5 birds/m^2 from 29 to 42 days (low, medium, and high, respectively). At 42 day, there was no significant ($P < 0.05$) effect of the stocking density on eviscerated carcass, breast, and abdominal fat yields. The thigh yield of chickens in the medium-density group improved significantly ($P < 0.05$) compared with those of the other 2 groups. Thus, concluded that stocking density did not influence eviscerated carcass yields and abdominal fat yields.

Farhadi *et al* (2016) reported that broiler rearing in the environmentally controlled house led to improvement in the produced meat yield as kg of BW/m^2 compared to conventional house. Moreover, kg of BW/m^2 increased by increasing stocking density. Improved meat yield per floor space in environmentally controlled house was mainly related to better environmental conditions for broiler chickens, so that the greater weight gain and lower mortality rate resulted a greater meat yield as kg BW/m^2 in broilers reared in higher stocking density.

2.4. Economic efficiency of broiler production under different housing modifications and stocking densities.

Feddes *et al* (2002) studied the economics of four stocking densities 23.8, 17.9, 14.3, and 11.9 birds/m^2. They reported that although the treatment with 23.8 birds/m^2 resulted the lowest body weight but the yield of broilers per unit of floor space was highest (46.0 kg/m^2).Stocking density had no effect on mortality, breast yield, carcass grading, incidence of scratches, or carcass quality. It was concluded that high yield per unit area with good carcass quality could be achieved when ventilation rate and air circulation were adequate. Also, that increasing stocking density is an important management practice taken by the growers to reduce the costs of poultry production.

Estevez (2007) reported that stocking density has critical implications for the broiler industry because higher returns can be obtained as the number of birds per unit space increases. The implications of this are that the welfare of broilers can be ensured at a reasonable range of densities, as long as the requirements for environmental quality are fulfilled.

Mayers *et al* (2007) assessed retrospective data from 18 tunnel-ventilated and 41 conventional houses to compare performance indices of the two types of housing during different seasons and reported tunnel-ventilated house was a more profitable venture than the conventional house. The benefit: cost ratios were 1.18 for the tunnel-ventilated house and 1.04 for the conventional house. The net profit margin (15.38 vs. 3.59 %,) net profit per kg, (0.51 vs. 0.12 BDS $ and net profit per m^2 (94.83 vs. 13.13 BDS $) were also higher for the tunnel ventilated house.

Czajka *et al* (2010) indicated the need for further research and observations to show differences in the adaptability of broiler chicks to different production systems. This will make it possible to optimize housing conditions in accordance with the principles of welfare and proper choice of meat type breeds and commercial lines so as to maximize production and economic results while making the birds resistant to production stress.

Salas *et al* (2013) reported that due to better feed conversion efficiency, uniformity of birds and harvest recovery, revenue per bird 14.69 Php for climate controlled system than 11.96 Php for conventional housing, was higher. Moreover, return over expenses 150% for climate controlled system was significantly higher than in conventional housing (84%).

Khajali *et al* (2013) conducted a study to compare the growth performance as well as blood and carcass variables of two broiler strains reared in a conventional broiler house and a modified greenhouse equipped with cooling pads and tunnel ventilation system. The construction cost of a greenhouse was estimated approximately one-third of a conventional house (≈40.00 *vs.*120.00 US$ per square meter). In conclusion, modified greenhouses equipped with cooling pads and tunnel ventilation system is recommended for low-cost rearing of broiler chickens.

CHAPTER – III

MATERIALS AND MEHODS

This study was conducted on 984 commercial Vencobb broiler chicks procured from M/s Venky's India (Ltd.) during April-May 2016 at the Poultry Research Farm of the Department of Livestock Production Management, Guru Angad Dev Veterinary and Animal Science University, Ludhiana (Latitude: 30°54' North Longitude : 75°48' East).

3.1 EXPERIMENT DETAILS

3.1.1 Experimental Broiler Shed

This experiment was conducted in open sided conventional (OSCBH) and environmentally controlled broiler sheds (ECBH). Environment controlled broiler shed was installed with tunnel ventilated-evaporative cooling system, controlled by temperature humidity solenoid sensors attached with programmable logical control (PLC) panel. Evaporative cooling pad was made up of cellulose paper haised in galvanized iron (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 water was pumped to the pads through a pump to keep pads wet. Two evaporative pads having dimensions of 3.1 m x1.98 m x 15.24 cm (length x width x thickness) were fitted at north and south walls of west end of East -West oriented shed. Two, 53" exhaust fans were fixed at eastern wall of shed, ensuring unidirectional flow of air form west to east. Side walls of ECBH were covered with polystyrene curtains.

ECBH shed had area of 16.91 m x 9.05 m (length x width). Flat type concrete roof with height of 3.35 m with 2/3rd of the side walls covered with open-able polystyrene curtains. The shed comprised of ten pens of 1.03 x 4.17 m (4.30 m^2) area each. Five pens in the shed were prepared for the trial. Further each pen with the help of wire net was divided into 3 equal compartments of 1.43 m^2 each, representing replicate of each treatment.

OSCBH shed had dimension of 10.05 m x 7.16 m (length x width) with flat type concrete roof having 3.35 m height and 2/3rd of open side walls were fixed with

Picture 1: Temperature-Humidity Control Panel

Picture 2: Cellulose Cooling Pads

Picture 3: Exhaust Fan

Picture 4: Environment Controlled Broiler House

Picture 5: Open Sided Conventional Broiler House

GI mash and comprising of 12 pens of 1.78 x 1.57 m (2.80 m^2) area each. Three pens in the shed were prepared for the trial for each replicate.

3.1.2 Treatment Details

A total of 984 day old healthy Vencobb broiler chicks were individually sexed and weighed using electronic balance. These sexed chicks were randomly distributed to 6 treatment groups each having 3 replicates of 30, 46, 51, 58, 66 and 77 birds each. The treatment details are as follow:

T_0: Rearing of broiler chicks in open housed shed with 30 birds in each replicate with floor space allowance of $1/ft^2$ per bird.

T_1: Rearing of broiler chicks in environmentally controlled shed with 46 birds in each replicate with floor space allowance of $1/ft^2$ per bird.

T_2: Rearing of broiler chicks in environmentally controlled shed with 51 birds in each replicate with floor space allowance of $0.9/ft^2$ per bird.

T_3: Rearing of broiler chicks in environmentally controlled shed with 58 birds in each replicate with floor space allowance of $0.8/ft^2$ per bird.

T_4: Rearing of broiler chicks in environmentally controlled shed with 66 birds in each replicate with floor space allowance of $0.7/ft^2$ per bird.

T_5: Rearing of broiler chicks in environmentally controlled shed with 77 birds in each replicate with floor space allowance of $0.6/ft^2$ per bird.

Control panel in ECBH was adjusted to different temperature-humidity regimen as pre comfortable microenvironment requirement of broiler chicks in relation to their age as depicted in Table 3.1:

Table 3.1: Temperature-humidity regimen in ECBH

Age (weeks)	Temperature (^{0}C)	Relative humidity (%)
1	32	50%
2	30	50%
3	28	50%
4-6	25	50%

3.1.3 Management of Chicks

Broiler chicks were reared on deep litter with a provision of different space allowances per chick from day old to 42 days of age as mentioned in treatment details under standard management conditions. The provision of artificial light during night through incandescent bulbs was made available to ensure round the clock light to broiler chicks. The entire experimental period was divided into 2 phases namely starter-cum-grower (0-4 weeks) and finisher (5-6 weeks). The starter-cum-grower and finisher rations were formulated to contain 22 and 20% crude protein and 2928.95 and 2976.45 Kcal ME/ Kg, respectively (Table 3.2).

Table 3.2: Ingredient and nutrient composition of rations fed to experimental broiler chicks

Ingredient (%)	Starter-cum-Grower (1-4 weeks)	Finisher (5-6 weeks)
Maize yellow	45.7	50.7
Soybean meal	39	34
Rice polish(oiled)	10	10
Oil	2	2
Dicalcium phosphate	1.5	1.5
Limestone powder	1.5	1.5
Common salt	0.3	0.3
Additives	+	+
Methionine	0.220	0.210
Calculated Chemical Composition		
CP %	22	20
ME, kcal/kg	2928.95	2976.45
Lysine %	1.16	0.16
Methionine%	0.41	0.41

Additives (per 100 kg): Trace Mineral 50g,Indomix 20g, Indobee 40g, Auromycin 15g, Coccidiostat 50g, Choline Chlor 50g, Merivite (Vitamin B12) 25g and Vitamin C 5g.

Note: Coccidiostat was added up to 4 weeks of age only.

These similar starter-cum-grower and finisher rations were offered to chicks in all treatment groups. Feed was made available *ad libitum* throughout the experimental period. A weighed quantity of feed was offered two times a day in morning and evening. Waterers were cleaned daily and continuous supply of cool and fresh drinking water was ensured during the experimental period. The chicks were vaccinated against Marek, Ranikhet and Infectious Bursal diseases according to vaccination schedule (Table 3.3). Mortality if any was recorded daily and birds were sent for post-mortem examination to ascertain the reason of death. To prevent cake formation and accumulation of ammonia in shed, the litter was stirred from time to time. The cooling systems were operated from 3 weeks to 6 weeks of age as brooding of chicks was carried out up to first 2 weeks.

Table 3.3: Vaccination schedule followed during the experiment

S. No.	Age	Disease	Type of vaccine	Route
1	Day old	M.D	HVT vaccine	S/C
2	7 days	Ranikhet	F_1 vaccine	I/O
3	14 days	Gumboro	IBD vaccine (Georgia strain)	Drinking water
4	21 days	Ranikhet	Lasota strain	Drinking water

*Pre-vaccinated chicks were received from the hatchery.

3.2 OBSERVATION RECORDED

3.2.1 Shed Microclimate

The microclimate of the shed was assessed with the help of dry and wet bulb mercury thermometer and minimum and maximum alcohol thermometer. These thermometers were installed in broiler shed at around 0.5 feet above the ground level. In order to assess diurnal variation in shed microclimate dry bulb and wet bulb temperature were recorded twice a day at 12:00 and 15:00 IST. The data of dry and wet bulb temperature was used to determine temperature-humidity index (THI) and relative humidity of shed. Temperature-humidity index (THI) in each group was calculated by using the formula as mentioned under (Tao and Xin 2003)

$$\mathbf{THI_{broilers} = 0.85\ T_{db} + 0.15\ T_{wb}}$$

Where,

T_{db}= dry bulb temperature

T_{wb} = wet bulb temperature.

3.2.2 Litter Moisture and pH

The litter moisture and pH were assessed at the end of the experimental trial. Randomly litter samples were collected from the different treatment pens from different locations i.e. from under the drinkers and feeders, along the sides of the house and close to the doorways. Samples were collected in zip lock polythene bags. For moisture estimation, 150 g samples were weighed and oven dried at 100^0C for overnight.

$$\textbf{Litter Moisture Content (\%)} = \frac{\textbf{(Wet Litter Weight – Dry Litter Weight)}}{\textbf{Wet Litter Weight}} \times \textbf{100}$$

For pH estimation, 10 g sample was weighed and dissolved in 50 ml double distilled water, stirred and kept for 30 minutes at room temperature. Then, with the help of calibrated pH meter reading was recorded.

3.2.3 Body Weight

The body weight of individual chicks was recorded at weekly intervals with the help of digital weighing balance. All chicks were weighed early in the morning each week prior to feeding. The average weekly body weight and body weight gain were calculated for each replicate of the entire experimental group.

3.2.4 Feed Consumption

Daily each replicate of all the treatment groups was offered a weighed quantity of feed. At the end of every week, feed consumption was calculated by subtracting the residual feed from total feed offered during different days of the week. The average feed intake for each group was calculated by dividing the total feed intake by the number of birds taking into account mortality/culling, if any, in the particular pen.

3.2.5 Feed Conversion Ratio (FCR)

The feed conversion ratio in each replicate was calculated by dividing the average feed intake by average weight gain for the week.

$$\textbf{FCR} = \frac{\textbf{Feed consumed (g)}}{\textbf{Body weight gain (g)}}$$

3.2.6 Protein Efficiency Ratio (PER)

PER was calculated as grams of body weight gain per g protein consumed.

$$\text{PER} = \frac{\text{Body weight gain (g)}}{\text{Protein consumed (g)}}$$

3.2.7 Energy Efficiency Ratio (EER)

The EER was calculated as Kcal of metabolizable energy consumed per gram of body weight gain.

$$\text{EER} = \frac{\text{Energy consumed (kcal)}}{\text{Body weight gain(g)}}$$

3.2.8 Space Use Efficiency

Space use efficiency was calculated as live body weight gain per unit floor area as per following formula:

$$\text{Live BW/ unit floor space (g/ft}^2\text{)} = \frac{\text{No. of marketable live birds} \times \text{Average body weight of birds}}{\text{Space allowance} \times \text{No. of birds allocated}}$$

3.2.9 Percent Mortality and Culling

Record of mortality (if any) was maintained on daily basis. The necropsy examinations were made for any gross pathological lesions and cause of death of each chick. Total mortality in each treatment was then calculated and expressed on percentage basis.

3.2.10 Broiler Welfare

Broiler chickens' welfare was assessed on the basis of behavioral expression and serum biochemical changes.

3.2.10.1 Broiler behavior

The behavioral status of the birds was recorded using Sony® handy cam video recorder. Instantaneous sampling technique was used for recording the behavior of broiler chicks as continuous recording is not possible, usually because too much behavior occur too frequently. Recording in each replicate of all the treatments was done for 20 minutes between 12:00-14:00 (IST), twice a week from 3rd week onwards. The behavior activities like preening, scratching, wing flapping, feeding, drinking, resting, dust bathing, leg stretching of bird in response to various stocking densities were examined on nominal scale. In nominal scale, data was examined presence or absence of particular behavioral activity at a momentary time frame. Later data of all behavioral were compiled to determine the percent incidence of different behavior shown by birds in different treatments.

3.2.10.2 Rectal temperature

Fifteen birds per treatment were randomly picked up to record the rectal temperature twice a week from 3rd week onwards and temperature was measured with the help of clinical thermometer by inserting the later into the cloaca of the said birds at around 12:00 pm (IST).

3.2.10.3 Incidence of body lesions and changes

Sixty birds from each treatment in 6th week were randomly selected to record the incidence of following body lesions and changes as per European welfare quality assessment protocol for poultry (Butterworth *et al* 2009) (Table 3.4).

Table 3.4: Protocol for assessment of incidence of body lesions and changes

Parameter	Score	Condition	Assessment
	0	Absence	
	1	Minimal	
Foot pad lesion	2	Mild	
	3	Moderate	

Parameter	Score	Condition	Assessment
	4	Severe	
Hock burns	0	Absence	
	1	Minimal	
	2	Mild	
	3	Moderate	
	4	Severe	
Breast blisters	0	Absence	
	1	Evident	

Parameter	Score	Condition	Assessment
Gait score	0	Normal, dexterous and agile	Analysis done from the videography on the basis of the prescribed basis.
	1	Slightly Abnormal but difficult to define	
	2	Definite and identifiable abnormal	
	3	Obvious abnormality, ability to move affected	
	4	Severe abnormality, only takes few steps	
	5	Incapable to move	
General cleanliness	0	Feathers are clean	
	1	Minimal dirt on the feathers	
	2	Feathers are evidently dirty	
	3	Unclean feathers	

3.2.10.4 Biochemical parameters

Four birds from each treatment were randomly picked up to obtain blood samples at 3^{rd} week and 6^{th} week. 3-5ml of blood was drawn intra-cardiacally with a sterilized syringe into a sterilized test tube having anticoagulant. Blood samples were centrifuged at 3000 rpm for 10 minutes thrice to form the hemolysate and it was stored at -20^0C for further biochemical analysis.

a. Lipid peroxidation

Lipid peroxidation in erythrocytes was assayed using the method of Stocks and Dormandy (1971).

Principle: It is based on the principle that malondialdehyde, an end product of lipid peroxidation reacts with thiobarbituric acid to yield a pink coloured trimethine complex exhibiting an absorption maximum at 532 nm wavelength.

Reagents:

- Phosphate buffered saline (0.1 M. pH 7.4)
- 40 mM sodium azide
- 28% Trichloroacetic Acid
- 1% Thiobarbituric acid (TBA) reagent
- 40 mM Hydrogen peroxide

Procedure:

Two test tubes marked as test and control were taken.

Test: To 2ml of 10% RBC/ tissue homogenate, 1 ml of 40 mM H_2O_2 and 0.1 ml of sodium azide were added in the test tube and incubated at 37^0C for 1 hour. After incubation, the total volume was made to ml with PBS in each tube and 2 ml of ice chilled TCA was added to stop the reaction. The tubes were centrifuged at 3000 rpm for 0.1 ml hemolysate (for estimation of erythrocytic lipid peroxidation) or tissue min. to 4 ml of supernatant, 1 ml of TBA was added and the tubes were kept in boiling water bath for 15 min. Finally, the optical density was measured at 532 nm against a blank (no H_2O_2 was added) after cooling the contents of tubes to room temperature.

The values were expressed as nmol MDA produced/g Hb/h using a molar extinction coefficient of pure MDA as 1.56 X10^5(Esterbauer *et al* 1982).

b. Superoxide dismutase (SOD)

The activity of superoxide dismutase in erythrocytes and tissues were measured by the method of Marklund and Marklund (1974).

Reagents:

- 0.6 mM Pyrogallol: 76 mg of pyrogallol in 100 ml of double distilled water, stored in brown bottle, every hour. This solution was prepared fresh.
- 6 mM EDTA: 223 mg EDTA disodium salt in 100 ml double distilled water.
- 100 mM Tris- HCl buffer: 1.21 g Tris in 80 ml of double distilled water. Adjust pH to 8.4 with 10 mM HCl and make volume to 100 ml.

Procedure:

Two cuvettes marked as control and test was taken.

To a cuvette, 1.5 ml of 100 mM Tris-HCl buffer, 0.5 ml of 6 mM EDTA and 1 ml of 0.6 mM pyrogallol solution were added. The rate of auto-oxidation of pyrogallol was taken from the increase in absorbance at 420 nm for 4 minutes at 30 seconds intervalusing ultraviolet visible spectrophotometer (Lambda 25, Perkin Elmer, Germany). For the test, appropriate amount of enzyme was added to inhibit the auto-oxidation of pyrogallol to about 50%.

A unit of enzyme activity is defined as the amount of enzyme causing 50% inhibition of the auto-oxidation of pyrogallol observed in blank.

c. Glutathione peroxidase (GPx)

The activity of erythrocytic as well as tissue glutathione peroxidase was measured by the method given by Hafeman *et al* (1974), a modification of Mill's procedure.

Principle: The assay is based on the principle that glutathione peroxidase catalyzes the reaction between hydrogen peroxide (H_2O_2) and reduced glutathione (GSH) to form oxidized glutathione (GSSG) and water (H_2O). The rate of oxidation of GSH by H_2O_2 is used as a measure of glutathione peroxidase activity.

Reagents:

- 2.0 mM reduced glutathione (GSH): 61.46 mg of reduced glutathione is dissolved in double distilled water and volume was made up to 100 ml with double distilled water.
- 0.4 M sodium phosphate buffer (pH - 7.0), containing 0.0004 M ethylene di amine tetra acetic acid (EDTA): 5.67 gram of disodium hydrogen phosphate, 4.79 gram of sodium dihydrogen phosphate and 0.011 gram of EDTA were accurately weighed and dissolved in double distilled water and the volume was made up to 100 ml with double distilled water after adjusting the pH to 7.0.
- 0.01 M sodium azide: 65.01 mg of sodium azide was dissolved in double distilled water and the volume was made up to 100 ml with double distilled water.
- 1.25 mM hydrogen peroxide (H_2O_2): Taken 150 micro liter of 30% hydrogen peroxide in a measuring cylinder and the volume was made up to one liter with double distilled water.
- 0.4 M disodium hydrogen phosphate (Na_2HPO_4): 5.67 gram of disodium hydrogen phosphate was dissolved in double distilled water and the volume was made up to 100 ml with double distilled water.
- Meta phosphoric acid precipitation solution: Dissolved 1.67 gram glacial m-phosphoric acid, 0.2 gram EDTA and 30 gram sodium chloride in double distilled water and volume was made up to 100 ml with double distilled water.
- DTNB reagent: Dissolved 40 mg 5,5-dithiobis (2-nitro benzoic acid) in 1% trisodium citrate solution and volume was made up to 100 ml with an aqueous 1% trisodium citrate solution.

Procedure:

Three separate glass stoppered centrifuge tubes marked as test, control and blank were taken. 0.2 ml reduced glutathione was taken in all the three test tubes followed by addition of 0.2 ml sodium phosphate buffer and 0.1 ml sodium azide to all the tubes. Then 0.1 ml hemolysate or tissue homogenate (for assay of tissue GPx activity) [diluted 1:200 times with double distilled water] was added to test and control tubes. Added 0.1 ml distilled water to blank instead of hemolysate or tissue homogenate. Then 0.2 ml distilled water was added to all the tubes. All the tubes were incubated for five minutes followed by addition of 0.2 ml pre warmed hydrogen peroxide (at 37^{o}C) to test and blank tubes and 0.2 ml distilled water to control tube. After three minutes interval added 4 ml m- phosphoric acid precipitation solution to all the tubes. All the tubes were then centrifuged (2500 rpm for 10 minutes) and 2 ml filtrate was pipetted out from all the tubes followed by addition of 2 ml 0.4 M disodium hydrogen phosphate solution and 0.1 ml of DTNB reagent to all the tubes containing the filtrate and mixed thoroughly. Then the absorbance of test (*At*) and control (*Ac*) tubes were read against the blank at 420 nm using ultraviolet visible spectrophotometer (Lambda 25, Perkin Elmer, Germany).

Calculation:

Erythrocytic glutathione peroxidase activity (U/g Hb) or

tissue glutathione peroxidase activity (U/mg protein) = $10 \times \frac{(Log Ac - Log At)}{Y} \times 200$

Where, *Ac* is absorbance of control

At is absorbance of test

'*Y'* is Hb concentration in gram/0.1 ml hemolysate

(for erythrocytic GPx activity)

or protein in milligram/0.1 ml tissue homogenate (for tissue GPx activity).

d. Catalase (CAT)

Procedure: The activity of Catalase in erythrocyte lysate was determined according to the method described by Aebi (1983).

Reagents

Hydrogen peroxide, mM: 0.34 ml of 30% H_2O_2 was diluted with buffer. The optical density of diluted H_2O_2 at 240 nm should be around 1.5. Buffered H_2O_2 solution was prepared fresh every time.

Test procedure: Take 2 ml of phosphate buffer in quartz cuvette, add 20 µl of erythrocyte lysate/tissue homogenate and mixed well. The reaction was started by the addition of 1ml of 30 mM H_2O_2 and the decrease in absorbance was recorded at every 10 sec interval for 1 min at 240 nm in a U.V. spectrophotometer.

The results were expressed as µmol H_2O_2 decomposed per min per mg Hb using 36 as molar extinction coefficient of H_2O_2.

e. Glucose-6-phosphate dehydrogenase (G-6-PD)

The erythrocytic and tissue glucose-6-phosphate dehydrogenase was assayed by the method given by Deutsch (1978).

Principle: The method is based upon the ability of enzyme to catalyze the conversion of glucose-6-phosphate and NADP to 6-phosphogluconolactone and reduced nicotinamide adenine dinucleotide phosphate (NADPH). During the reaction the rate of increase in absorbance at 340 nm was used as a measure of glucose-6-phosphate dehydrogenase activity.

Reagents:

- 3.8 nM NADP: 59.84 mg of $NADP^+$ was dissolved in doubled distilled water and the volume was made up to 20 ml with doubled distilled water.
- 0.5 M Tris buffer (pH - 7.5): Dissolved 7.88 g of TRIS in doubled distilled water and volume was made up to 100 ml with double distilled water after adjusting the pH to 7.5.
- 0.63 M $MgCl_2$: 12.807 g of anhydrous magnesium chloride was dissolved in double distilled water and volume was made up to 100 ml with double distilled water.
- 33 mM glucose-6-phosphate: Dissolved 1.003 gram of glucose-6-phosphate in double distilled water and volume was made up to 100 ml with double distilled water.

Procedure:

A cuvette was taken and 1.7 ml distilled water, 0.3 ml $NADP^+$, 0.3 ml TRIS buffer, 0.3 ml magnesium chloride and 0.3 ml glucose-6-phosphate solution was added to it.

Reaction was initiated by adding 0.1 ml diluted hemolysate or tissue homogenate (1:10 v/v) for assaying G6PD activity in erythrocytes and tissues respectively and increase in absorbance was recorded for four minutes at 340 nm wavelength using ultraviolet visible spectrophotometer (Lambda 25, Perkin Elmer, Germany).

Calculation:

Erythrocytic glucose-6-phosphate dehydrogenase activity (U/g Hb) or tissue glucose-6-phosphate dehydrogenase activity (U/g protein) = 8095 x Change in absorbance per unit time x dilution factor.

3.2.11 Carcass Characteristics

Four birds from each treatment were randomly sacrificed at 6^{th} week of age. They were completely bled, scalded at 53°C for 75 seconds and de-feathered by hand picking. The head was removed by cutting through the joint between head and first vertebra avoiding bone. Then shanks were removed by making a cut through the hock joint starting on the inside joint surface. The oil glands were removed, cutting drop into the tail vertebra and following the motion. After that, abdomen was cut up open and the viscera were removed. The dressed carcass was cut into different cut up parts viz., wings, neck, breast, back, thigh and drumsticks. The weight of inedible parts, i.e. blood, feather and offal was removed. The giblet weight (heart, liver and gizzard) and eviscerated yield were recorded. The data were expressed on percent of total meat yield basis for comparison of various treatments.

3.2.12 Economics of Broiler Production: The effect of different stocking densities under different housing conditions on economic gain in broiler production was expressed as cost benefit ratio per bird. The cost components were calculated as total working expenditure on purchase of chicks, feeding cost and operating cost of ECBH. However, labour cost was not included because care and management of broiler were performed by own. Net income was determined by subtracting working cost from gross income obtained from sale of live bird on the basis of per bird, per Kg live weight and per unit floor area, briefly described as follow.

a. ***Feeding cost:*** Feeding cost per bird during different growth phase was calculated separately by multiplying per unit feed price with average feed consumption per bird. Total feeding cost in different treatment was determined by summing up feeding cost in different phases.

Feeding cost = Feed price per Kg X Average feed consumed per bird (Kg)

b. ***Operating cost*****:** Operating cost of cooling system was calculated as total expenditure on electricity consumption for running the ECBH.

c. ***Working expenditure*****:** Total working expenditure for OSCBH and ECBH was calculated by summing up the feeding cost, operating cost and chick cost per treatment.

Working expenditure= Feeding cost + Operating cost + Chick cost

d. ***Margin of receipt:*** Margin of receipt was calculated by subtracting total income from total expenditure.

Margin of receipt= Total income – Total Expenditure

e. ***Margin of receipt per unit area*****:** Margin of receipt per unit area was calculated by dividing margin of receipt per bird by floor allowance per bird.

$$\textbf{Margin of receipt per unit area} = \frac{\textbf{Margin of receipt per bird}}{\textbf{Floor space per bird}}$$

f. Cost benefit ratio:

Cost benefit ratio was determined as a ratio of gross income to the working expenditure.

$$\textbf{Cost benefit ratio} = \frac{\textbf{Gross Income}}{\textbf{Working expenditure}}$$

Statistical analysis

To assess the effect of different stocking densities under different housing conditions on production performance of broiler, experimental data were analyzed for one way analysis of variance (ANOVA), using SPSS 22 software. The means were compared for statistical significance difference at 5% level by Tukey’s pair wise comparison.

CHAPTER – IV

RESULTS AND DISCUSSION

4.1 Microclimate in Open Sided Conventional (OSCBH) and Environment Controlled Tunnel Ventilated (ECBH) broiler sheds

4.1.1 Ambient temperature

The data on ambient temperature in OSCBH and ECBH recorded at 12:00 IST and 15:00 IST from 3rd to 6th week have been presented in Table 4.1 and graphically represented in Figure 1 and 2. The results indicate that average weekly temperature during different weeks in OSCBH at 15:00 IST was numerically higher than temperature recorded at 12:00 IST. Whereas, ambient shed temperature in ECBH recorded at 12:00 and 15:00 IST did not differ significantly ($p \leq 0.05$). However, during entire observation period shed temperature recorded at 12:00 and15:00 IST was significantly ($p \leq 0.05$) lower in ECBH than OSCBH. The shed temperature in OSCBH during experimental period ranged from 38.57^{0}C to 44.14^{0}C whereas in ECBH shed temperature varied from 28.33^{0}C to 29.59 ^{0}C. These results indicated that shed temperature in ECBH group was much closer to thermo-neutral zone 18.3^{0}C to 23.9^{0}C of broiler (Sturkie 2000) than OSCBH**.** In comparison to OSCBH, tunnel ventilation cooling system in ECBH effectively reduced shed temperature during peak heat stress from 26.54% to 32.96%. Similar to these findings Li *et al* 1992, also reported that tunnel ventilation with evaporative pad cooling system is effective to keep shed temperature below 28 to 30^{0}C even at 10 to 20% higher stocking density of broiler chicks.

4.1.2 Temperature-humidity index (THI)

The data on THI in OSCBH and ECBH recorded at 12:00.00 IST and 15:00 IST from 3rd to 6th week has been presented in Table 4.1 and graphically represented in Figure 3 and 4. The results indicate that THI in ECBH at 12:00 IST and 15:00 IST during different weeks was significantly ($p \leq 0.05$) lower than OSCBH group. THI in OSCBH group during entire experimental period between 12:00-15:00 IST ranged from 96.45 to 104.98 whereas, in ECBH THI, ranged from 81.10 to 82.94. THI in ECBH during experimental period was more invariable than OSCBH. THI in ECBH group during peak heat period was of the level of moderate heat stress while in

Table 4.1: Temperature and temperature-humidity index (THI) in OSCBH and ECBH shed.

Weeks	Housing Type	Time					
		12:00 IST			15:00 IST		
		Shed temperature (^{o}C)	Wet Temperature (^{o}C)	THI	Shed temperature (^{o}C)	Wet Temperature (^{o}C)	THI
3	OSCBH	$38.57^{a}\pm0.30$	20.14±0.51	$96.45^{a}\pm0.48$	$40.00^{a}\pm0.31$	20.71±0.42	$98.79^{a}\pm0.56$
	ECBH	$29.11^{b}\pm0.21$	20.80±0.38	$82.16^{b}\pm0.41$	$29.59^{b}\pm0.16$	21.01±0.31	$82.94^{b}\pm0.31$
4	OSCBH	$41.86^{a}\pm1.06$	20.71±0.42	$101.63^{a}\pm1.70$	$43.57^{a}\pm1.72$	20.71±0.42	$104.26^{a}\pm2.59$
	ECBH	$28.33^{b}\pm0.28$	19.37±0.14	$80.57^{b}\pm0.45$	$28.99^{b}\pm0.32$	19.94±0.25	$81.73^{b}\pm0.54$
5	OSCBH	$41.14^{a}\pm0.74$	19.86±0.40	$100.31^{a}\pm1.16$	$44.14^{a}\pm1.55$	20.14±0.51	$104.98^{a}\pm2.37$
	ECBH	$28.56^{b}\pm0.38$	20.03±0.18	$81.10^{b}\pm0.61$	$28.80^{b}\pm0.40$	20.11±0.11	$81.49^{b}\pm0.61$
6	OSCBH	$38.43^{a}\pm0.37$	22.71±1.08	$96.93^{a}\pm0.59$	$39.71^{a}\pm0.29$	21.86±0.96	$98.66^{a}\pm0.46$
	ECBH	$29.33^{b}\pm0.34$	20.66±0.34	$82.45^{b}\pm0.60$	$29.39^{b}\pm0.39$	20.97±0.42	$82.62^{b}\pm0.66$

Means bearing different superscripts for OSCBH and ECBH for different weeks in column differ significantly ($P \leq 0.05$).

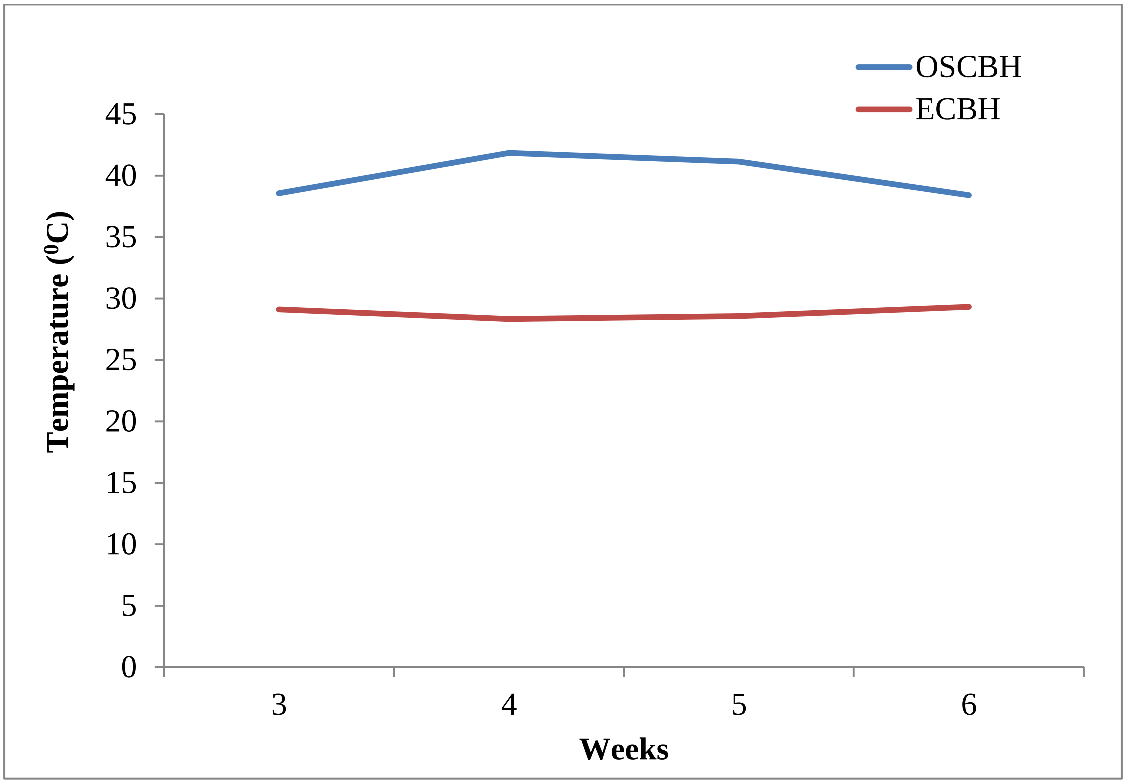

Figure 1 : Shed Temperature at 12:00 (IST)

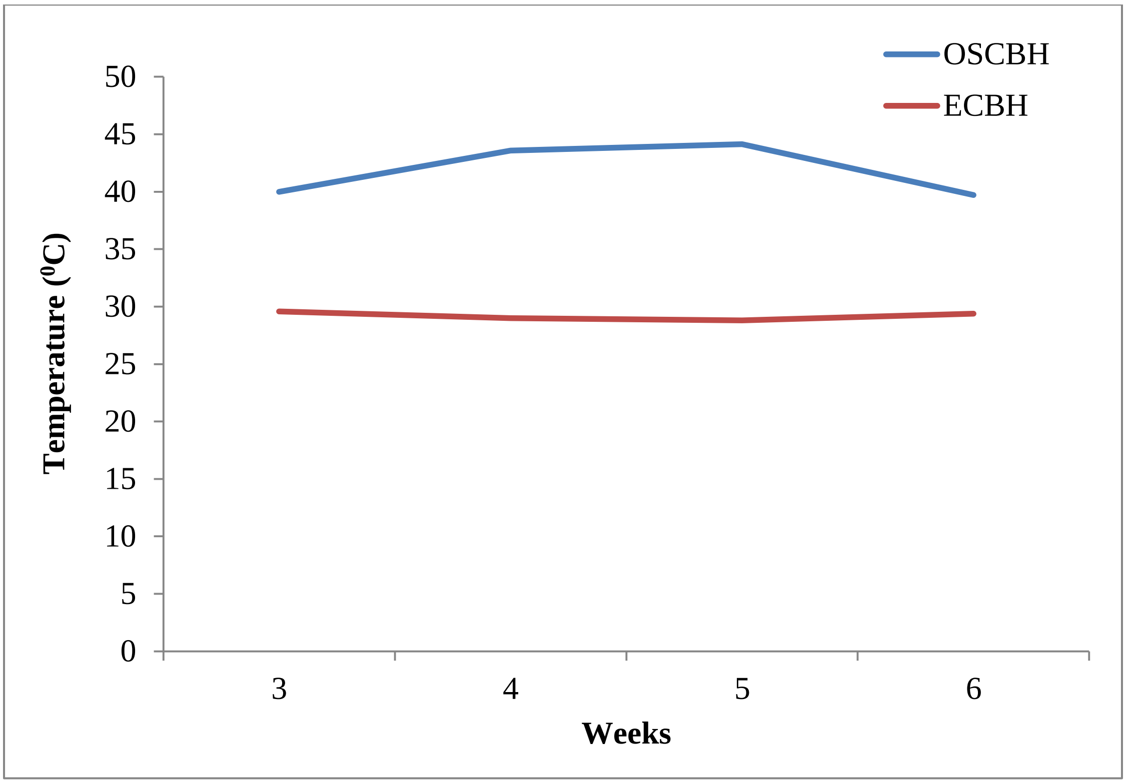

Figure 2 : Shed Temperature at 15:00 (IST)

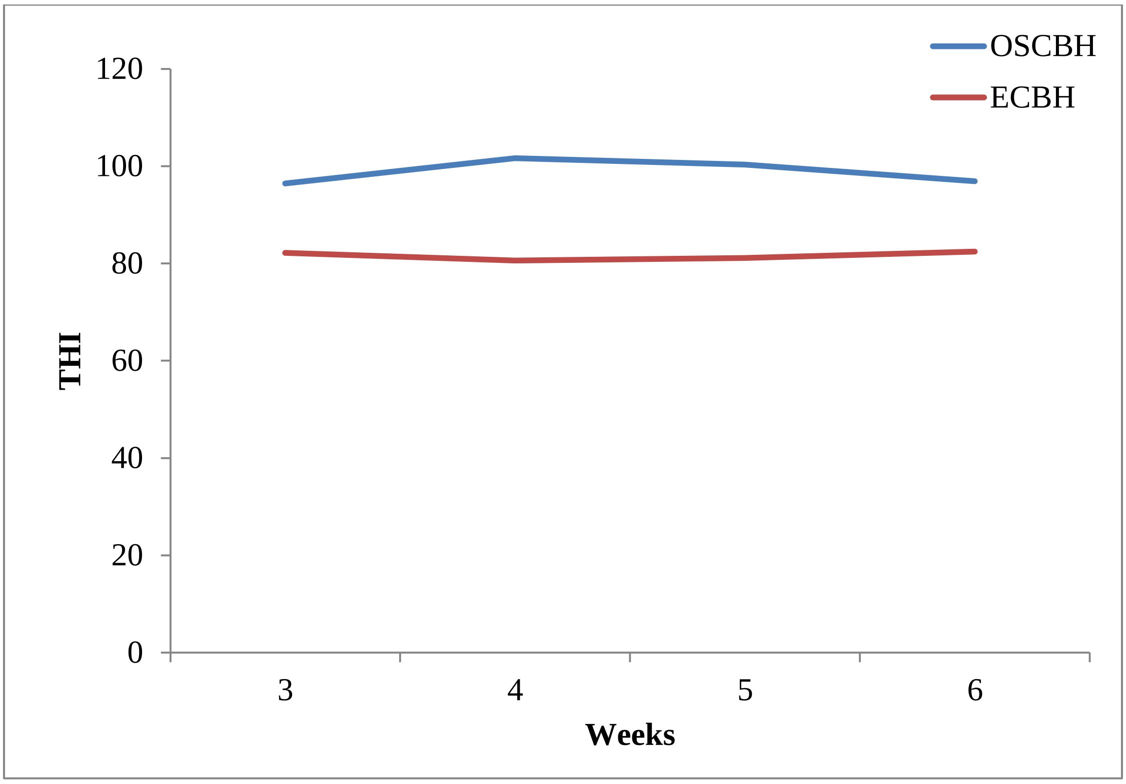

Figure 3 : Shed THI at 12:00 (IST)

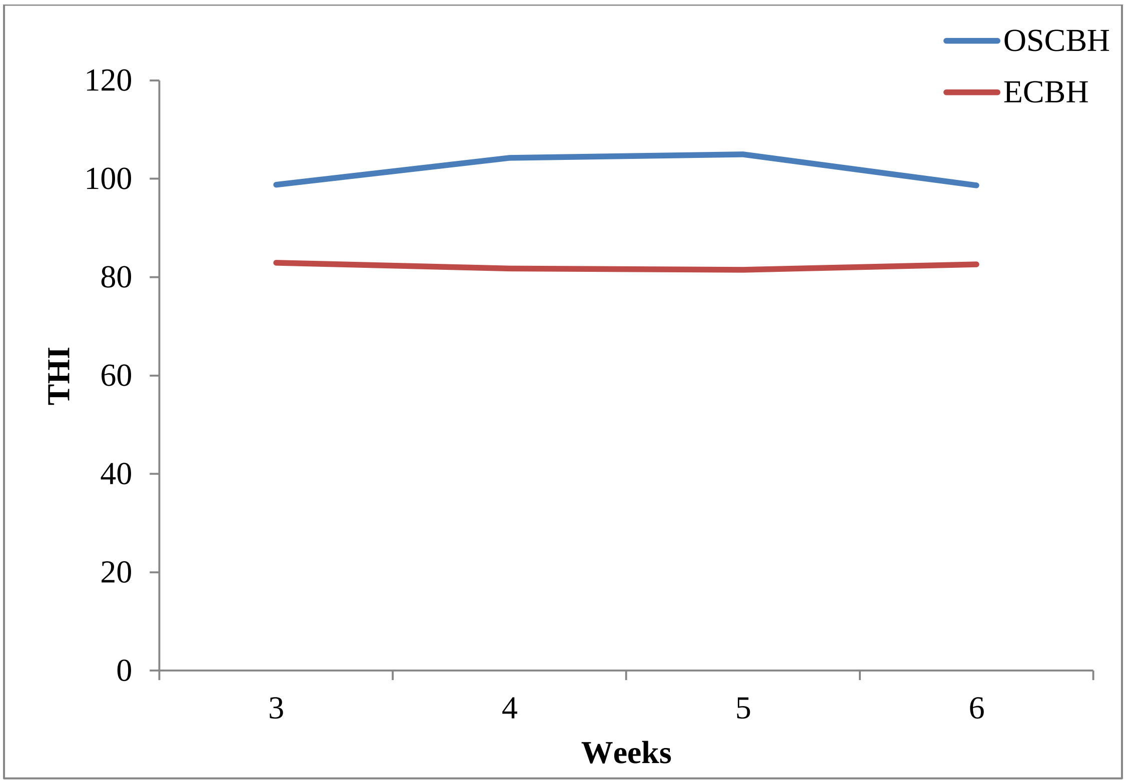

Figure 4 : Shed THI at 15:00 (IST)

OSCBH there was severe heat stress to broilers (Anonymous 2012). Therefore, broiler chicks in OSCBH also exposed to severe heat stress while birds in ECBH experienced maximally moderate heat stress. Thus, the results of lower THI in ECBH group could be attributed to lower shed temperature and higher relative humidity, indicated by less difference in dry bulb and wet bulb temperature, in ECBH than OSCBH.

4.1.3 Minimum-maximum temperature in broiler sheds

The data on maximum and minimum temperature indicates extremes of shed microclimate in OSCBH and ECBH, have been presented in Table 4.2 and graphically represented in Figure 5 and 6. The results indicate that maximum temperature in OSCBH and ECBH ranged from 40.10^0C to 45.40^0C and 28.82^0C to 29.60^0C, respectively. However, minimum temperature in ECBH and OSCBH groups ranged from 20.13^0C to 23.14^0C and 24.27^0C to 28.10^0C, respectively. Minimum shed temperature in ECBH group was with in thermo-neutral zone (18.3^0C to 23.9^0C) of broiler (Sturkie 2000), whereas in OSCBH minimum temperature during entire experimental period was much higher than thermo-neutral zone. Therefore, birds in OSCBH group experienced heat stress during entire experimental period from 3 to 6 weeks of age. However, minimum temperature in ECBH within the range of thermo-neutral zone revealed that duration and severity of heat stress in broiler chicks in ECBH was much lower than OSCBH.

Table 4.2: Maximum and minimum temperature in OSCBH and ECBH shed

Week	**Temperature (^{o}C)**	**Treatment**	
		OSCBH	**ECBH**
3	Maximum	$41.30^a \pm 0.51$	$29.60^b \pm 0.18$
	Minimum	24.27±0.67	23.14±0.15
4	Maximum	$44.90^a \pm 0.46$	$29.00^b \pm 0.28$
	Minimum	$25.61^a \pm 0.92$	$20.13^b \pm 0.17$
5	Maximum	$45.40^a \pm 0.38$	$28.82^b \pm 0.38$
	Minimum	$25.79^a \pm 0.55$	$20.47^b \pm 0.14$
6	Maximum	$40.12^a \pm 0.98$	$29.42^b \pm 0.35$
	Minimum	$28.10^a \pm 1.20$	$20.47^b \pm 0.21$

Means bearing different superscripts for OSCBH and ECBH for different weeks in row differ significantly (P ≤0.05).

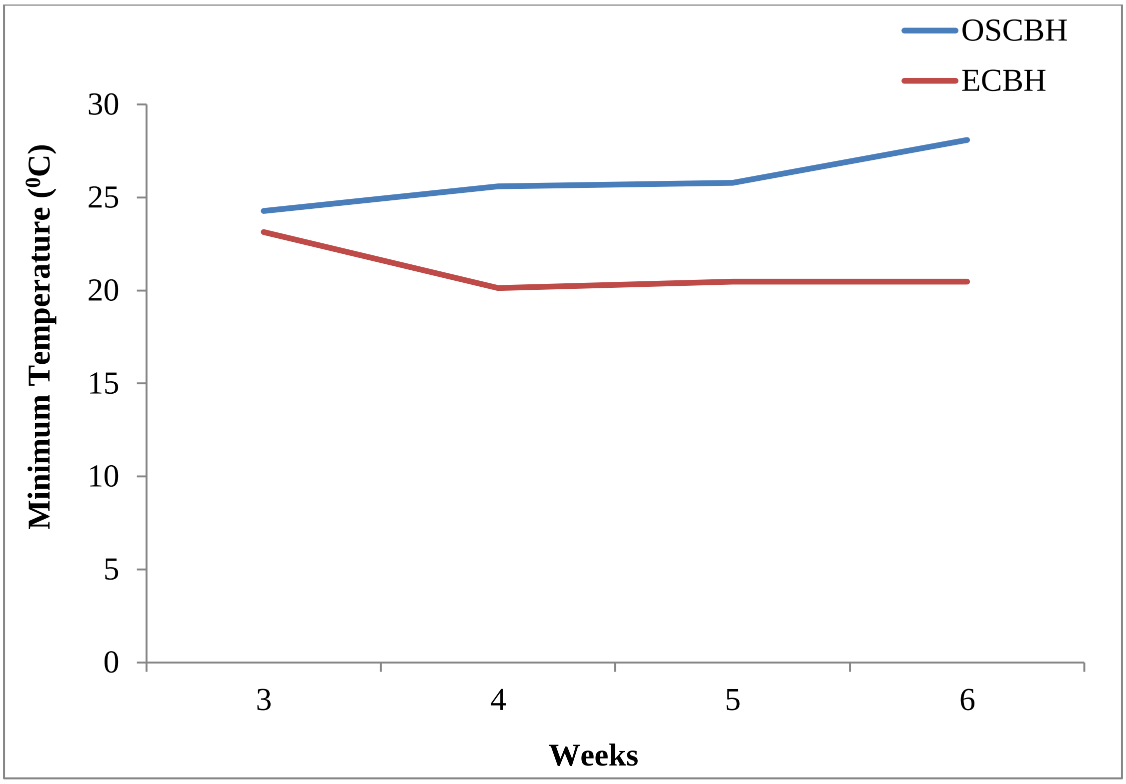

Figure 5: Minimum temperature (^{0}C) during different weeks

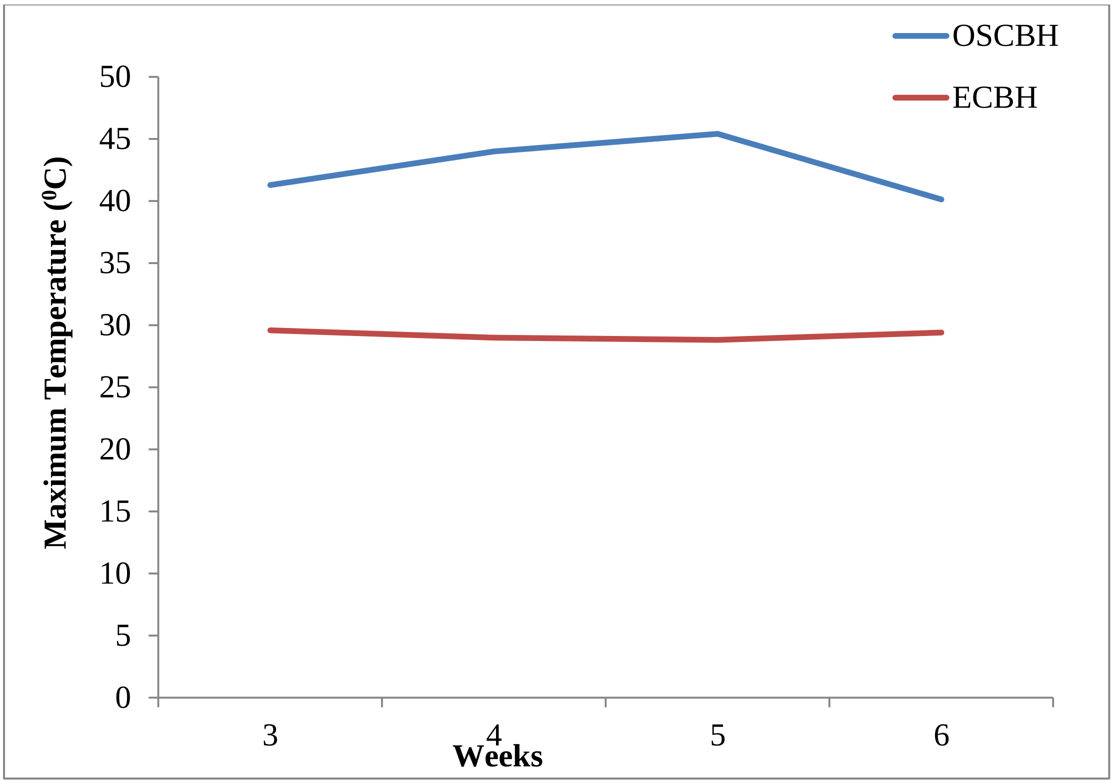

Figure 6: Maximum temperature (^{0}C) during different weeks

4.1.4 Litter moisture and pH

The data on moisture and pH of litter under different stocking density in OSCBH and ECBH have been presented in Table 4.3 and graphically represented in Figure 7 and 8. No specific trend was observed in the litter moisture content of different treatment groups. There was no significant difference in the moisture levels of various treatment groups. Litter pH of various treatments ranged from 7.21 to 7.73. Highest litter pH was in T_5 followed by T_4, T_2, T_3, T_1 and T_0. However, there was no significant ($p \leq 0.05$) difference among T_0, T_1, T_2, T_3 and T_4.

Table 4.3: Litter moisture and pH in different treatments

Shed	Treatment	Moisture %	pH
OSCBH	T_0	23.00±1.26	7.25^{ab}±0.04
ECBH	T_1	22.00±1.39	7.21^{a}±0.06
	T_2	24.44±0.80	7.30^{ab}±0.06
	T_3	23.67±1.26	7.23^{ab}±0.05
	T_4	26.00±1.26	7.45^{b}±0.02
	T_5	26.44±0.78	7.73^{c}±0.04

Means with different superscripts in a column differ significantly (P≤0.05)

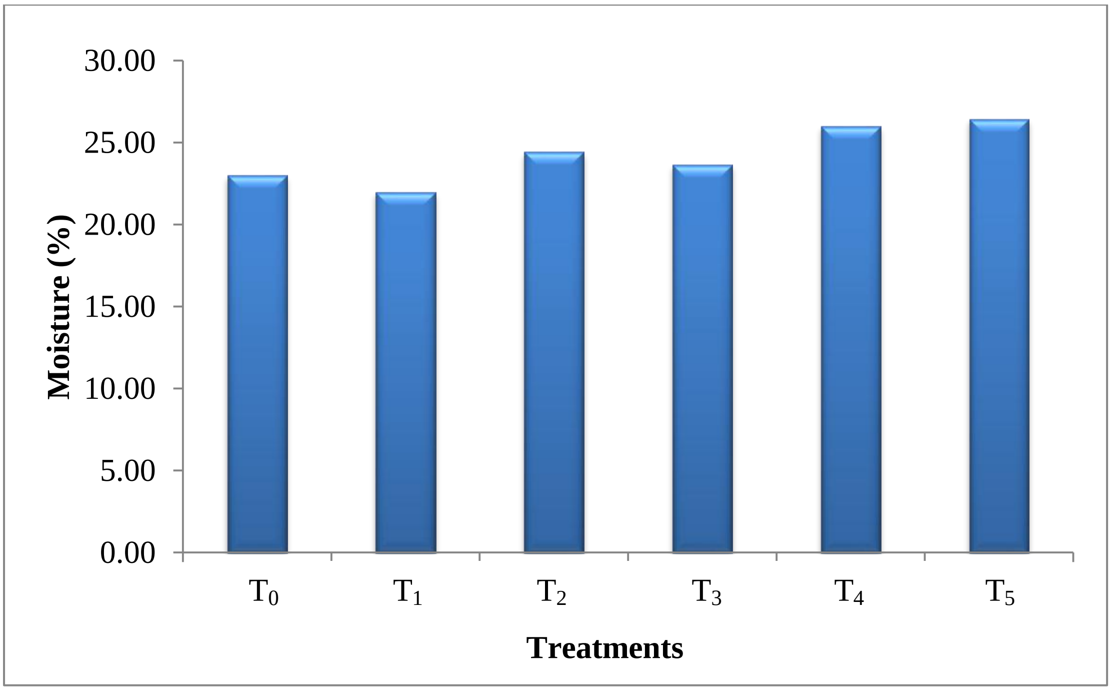

Figure 7: Litter Moisture% in different treatments

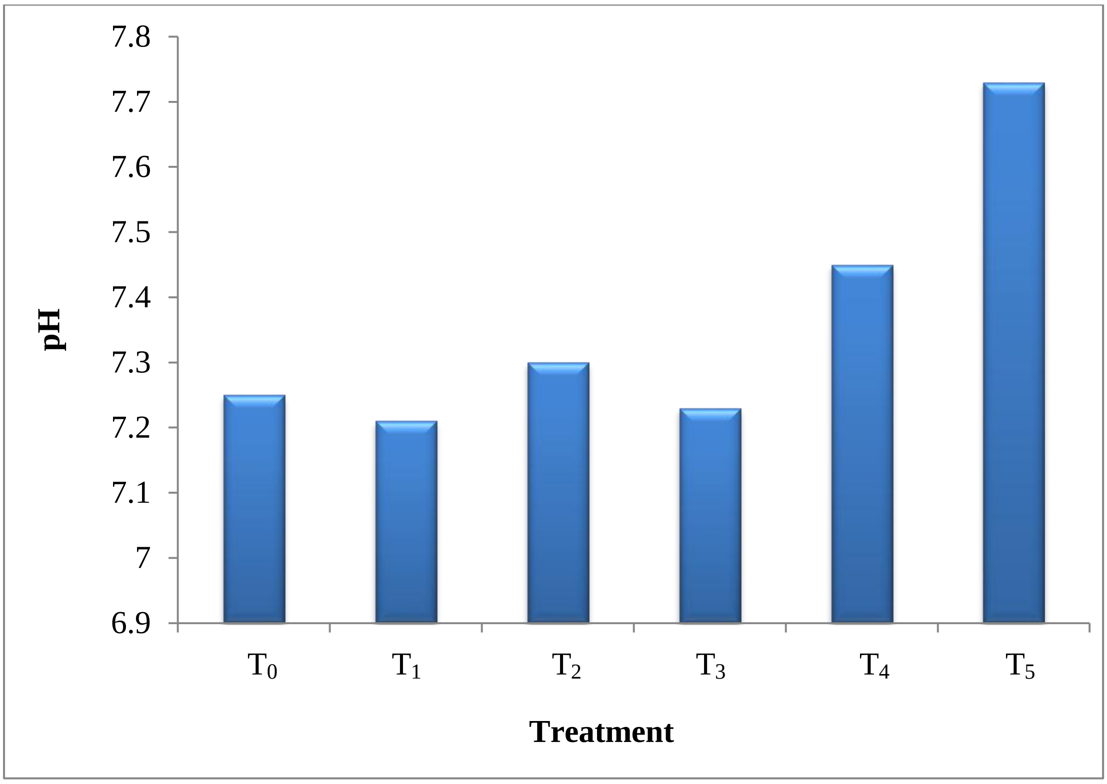

Figure 8: Litter pH in different treatments

Al-Homidan *et al* (2003) reported that wet litter is one of the extreme condition adversely affecting the poultry performance. According to Terzich (1997), litter pH has decisive role in ammonia volatilization, and the main ureolytic bacterium (*Bacillus pasteurii*) cannot grow in neutral pH, but thrives in pH higher than 8.5. Benito (1991) mentioned that ammonia production may be minimal when litter moisture and pH are maintained below 30% and 7.5, respectively. These results in current study indicated that litter moisture and pH were within the acceptable range in all treatment groups in both the types of sheds, thus did not possess any welfare implications even at 40% (T_5) increase in stocking density of broiler chicks in ECBH.

4.2 Growth Performance of Broilers

4.2.1 Body weight

The data on effect of different housing system and stocking density on growth performance of broiler chicks have been presented in Table 4.4 and graphically represented in Figure 9.

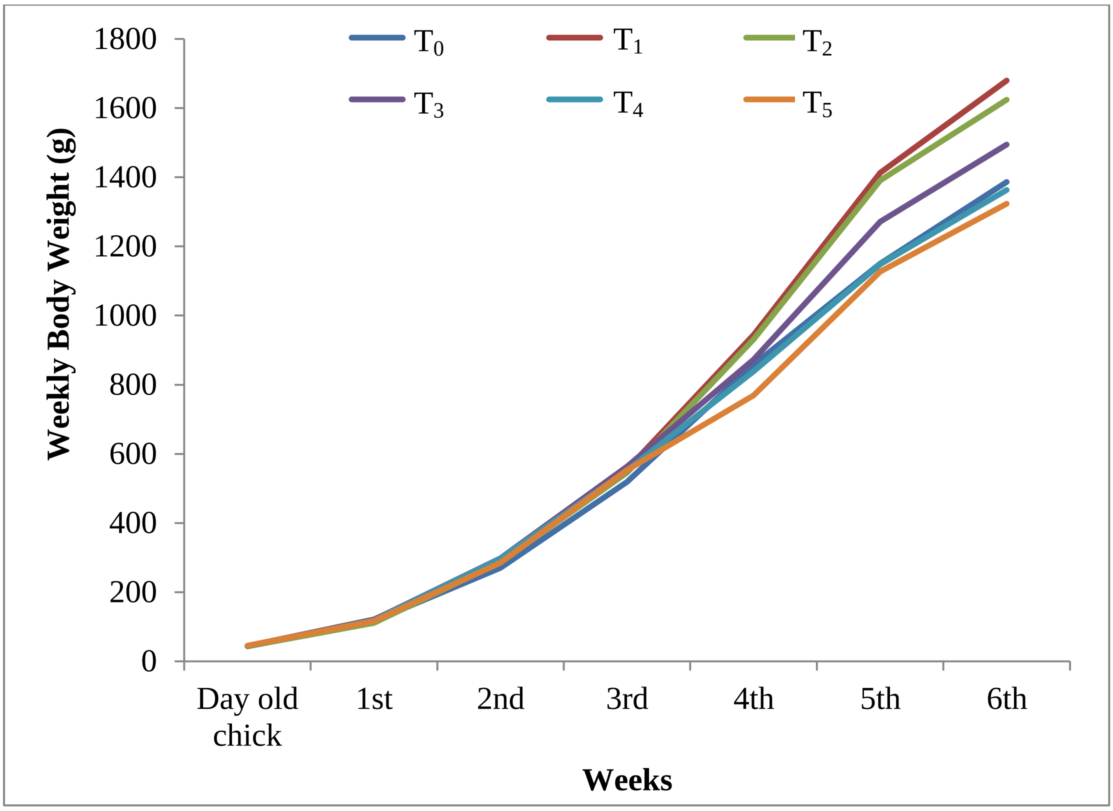

Figure 9: Weekly body weight in different treatments

The data on weekly body weight indicate that body weight of broiler chicks in all treatment groups increased with increase in age. Among different treatment groups, during first week body weight did not vary significantly ($p \leq 0.05$). However, during 2nd and 3rd week body weight of broiler chicks in OSCBH (T_0) was significantly ($p \leq 0.05$) lower than ECBH (T_1, T_2, T_3, T_4 and T_5). However, body weight broiler chicks in ECBH group did not show any significant variation ($p \leq 0.05$) with increase in stocking density. From 4th week onwards body weight of broiler chicks in T_1 was significantly ($p \leq 0.05$) higher than T_0, T_2, T_3, T_4 and T_5. However, there was no significant ($p \leq 0.05$) difference in body weight of broiler chicks between in T_1 and T_2.

Table 4.4: Weekly body weight of broiler chicks in different treatments

Week	Weekly Body Weight (g)					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
Day old	43.33±0.09	44.52±0.31	43.68±0.34	44.58±0.24	44.38±0.37	45.44±1.21
1^{st}	116.55^{ab}±2.55	121.00^{b}±1.12	110.57^{a}±0.68	120.43^{b}±1.65	118.13^{ab}±1.62	116.71^{ab}±1.33
2^{nd}	270.03^{a}±3.84	285.71^{bc}±2.81	286.49^{bcd}±1.13	297.95^{d}±2.57	296.77^{cd}±2.13	284.45^{b}±0.35
3^{rd}	519.29^{a}±1.66	555.35^{b}±4.04	546.00^{b}±6.72	563.76^{b}±7.00	552.51^{b}±2.17	553.16^{b}±1.47
4^{th}	858.21^{b}±13.95	943.99^{d}±11.11	931.00^{cd}±14.70	872.74^{bc}±16.33	838.78^{b}±11.60	769.04^{a}±10.45
5^{th}	1150.59^{a}±3.42	1412.84^{c}±10.64	1390.86^{c}±10.26	1271.52^{b}±8.46	1148.06^{a}±15.35	1127.36^{a}±11.73
6^{th}	1386.01^{b}±5.42	1679.70^{e}±2.25	1624.19^{d}±7.22	1495.10^{c}±17.07	1362.90^{ab}±12.19	1323.60^{a}±4.89

Means bearing different superscripts in a row differ significantly ($P \leq 0.05$).

4.2.2 Body weight gain

The data on average weekly body weight gain have been presented in Table 4.5 and graphically represented in Figure 10. The data indicate that the rate of body weight gain of broiler chicks increased with increase in age up to 4th week in OSCBH (T_0) and subsequently, growth rate decreased during 5th and 6th weeks of age. However, in ECBH (T_1, T_2, T_3, T_4 and T_5) group average weekly body weight gain of broiler chicks increased with age up to 5th week of age. However, body weight gain during 6th week in all ECBH treatment groups decreased. During 1st week average body weight gain in OSCBH (T_0) and ECBH (T_1, T_2, T_3, T_4 and T_5) did not differ significantly ($p\leq 0.05$) but during 2nd and 3rd week, body weight gain in OSCBH (T_0) was significantly ($p\leq 0.05$) lower than all ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups. During 5th week in comparison to OSCBH (T_0) body weight gain only in ECBH (T_1, T_2 and T_3) was significantly ($p\leq 0.05$) higher, however, body weight gain in T_4 and T_5 did not vary significantly ($p\leq 0.05$). During 6th week body weight gain only in ECBH (T_1) was significantly ($p\leq 0.05$) higher than OSCBH (T_0) but body weight gain among T_0, T_2, T_3, T_4 and T_5 did not vary significantly ($p\leq 0.05$). Among different treatments in ECBH (T1, T2, T3, T4 and T5), body weight gain during 2nd week, in T3 was significantly ($p\leq 0.05$) higher than T_1 and T_5 but there was no significant ($p\leq 0.05$) difference between T_2, T_3 and T_4 and T_1, T_2 and T_5. However, during 3rd week there was no significant ($p\leq 0.05$) difference between average body weight gains. During 4th week average body weight gain was highest in T_1 followed by T_2, T_3, T_4 and T_5. But no significant ($p\leq 0.05$) difference was observed between T_1 and T_2, between T_2 and T_0 and between T_3 and T_4.

The results of cumulative body weight gain presented in Table 4.6 showed similar trends in cumulative body weight gain up to 5th week of age. However, results of total body weight gain showed significantly ($p\leq 0.05$) higher body weight gain in T_1, T_2 and T_3 ECBH treatment groups than T_0 (OSCBH) treatment group. However, there was no significant ($p\leq 0.05$) difference between T_0 and T_4, but total body weight gain in T_5 was significantly ($p\leq 0.05$) lower than T_0.

Table 4.5: Weekly body weight gain of broiler chicks in different treatments

Week	Weekly Body Weight Gain (g)					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1^{st}	$73.22^{ab}\pm2.51$	$76.48^{b}\pm1.37$	$66.89^{a}\pm0.47$	$75.85^{b}\pm1.45$	$73.76^{ab}\pm1.71$	$71.28^{ab}\pm2.50$
2^{nd}	$153.48^{a}\pm1.87$	$164.72^{bc}\pm3.88$	$175.92^{bcd}\pm0.62$	$177.52^{d}\pm2.04$	$178.64^{cd}\pm2.58$	$167.73^{b}\pm1.02$
3^{rd}	$249.26^{a}\pm3.49$	$269.63^{b}\pm2.46$	$259.50^{b}\pm5.60$	$265.82^{b}\pm4.68$	$255.74^{b}\pm1.13$	$268.72^{b}\pm1.81$
4^{th}	$338.92^{cd}\pm13.04$	$388.64^{e}\pm8.12$	$385.01^{de}\pm9.07$	$308.97^{bc}\pm9.77$	$286.27^{b}\pm10.21$	$215.87^{a}\pm11.76$
5^{th}	$292.38^{a}\pm16.66$	$468.85^{c}\pm6.31$	$459.86^{c}\pm9.46$	$398.78^{b}\pm17.30$	$309.28^{a}\pm25.13$	$373.65^{a}\pm6.25$
6th	$235.43^{ab}\pm7.80$	$266.86^{b}\pm10.66$	$233.33^{ab}\pm8.74$	$223.58^{ab}\pm16.81$	$214.85^{a}\pm4.29$	$196.25^{a}\pm6.94$

Means bearing different superscripts in a row differ significantly ($P \le 0.05$).

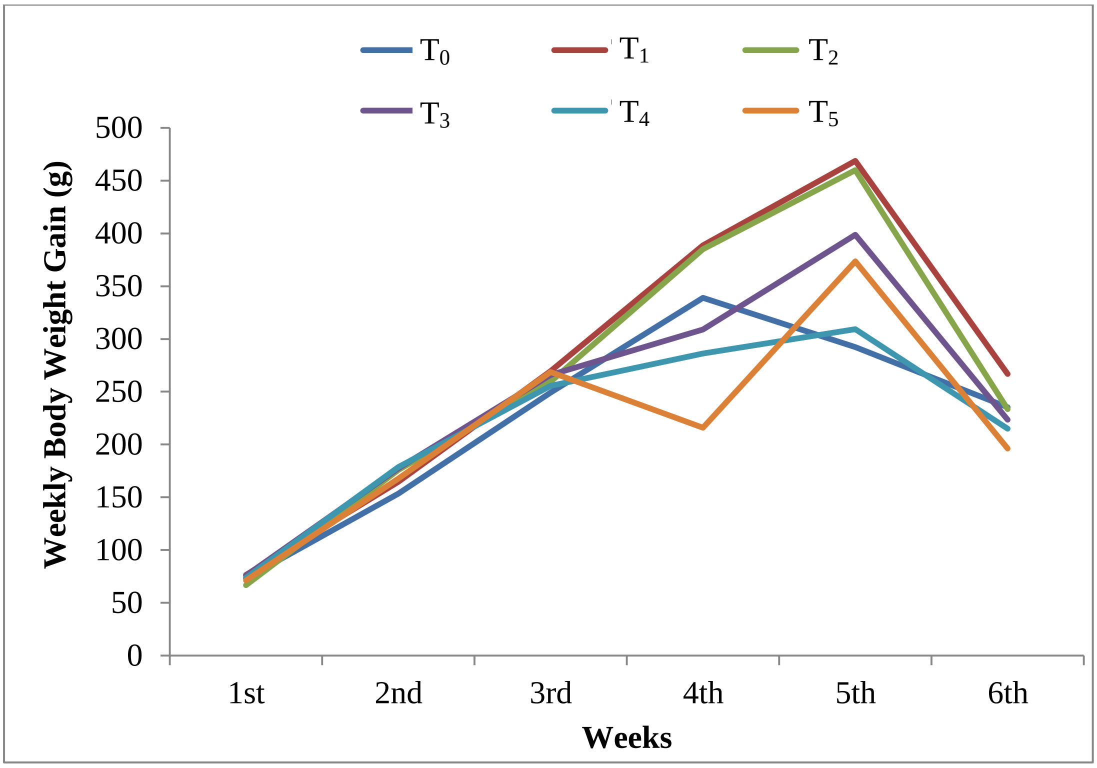

Figure 10: Weekly body weight gain in different treatments

These results showed comparatively more depression in body weight gain in OSCBH (T_0) than broiler chicks in ECBH (T_1, T_2, T_3, T_4 and T_5) with increase in age of birds. However, within ECBH (T_1, T_2, T_3, T_4 and T_5) body weight gain also depressed with increasing stocking density and this decrease was more pronounced over 3 weeks of age, indicated increased growth depression with increase in age of birds. This higher rate of growth depression with age of birds in OSCBH (T_0) can be attributed to that susceptibility to heat stress of birds increased with increase in age and body weight (Cooper and Washburn 1998). During first 2 weeks temperature in OSCBH (T_0) was within the temperature profile requirement of birds but with progression of age, birds experienced more heat stress due to much higher shed temperature and THI than required for optimum growth performance (Tables 4.1, 4.2 and 4.3). Within ECBH (T_1, T_2, T_3, T_4 and T_5) again depression in weekly body weight gain with increasing stocking densities over the age of birds might be due to high litter moisture, more competition for feeding and watering space and limited muscular development due to limited floor space.

Table 4.6: Cumulative body weight gain of broiler chicks in different treatments

week	Cumulative Body Weight Gain (g)					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1^{st}	$73.22^{ab}\pm2.51$	$76.48^{b}\pm1.37$	$66.89^{a}\pm0.47$	$75.85^{b}\pm1.45$	$73.76^{ab}\pm1.71$	$71.28^{ab}\pm2.50$
2^{nd}	$226.70^{a}\pm3.76$	$241.20^{bc}\pm2.52$	$242.81^{bcd}\pm1.04$	$253.37^{d}\pm2.55$	$252.39^{cd}\pm1.76$	$239.01^{b}\pm1.48$
3^{rd}	$475.95^{a}\pm1.59$	$510.83^{b}\pm3.88$	$502.32^{b}\pm6.63$	$519.18^{b}\pm6.89$	$508.13^{b}\pm1.82$	$507.73^{b}\pm0.69$
4^{th}	$814.87^{b}\pm13.87$	$899.47^{d}\pm10.83$	$887.32^{cd}\pm14.75$	$828.16^{bc}\pm16.27$	$794.41^{b}\pm11.44$	$723.60^{a}\pm11.66$
5^{th}	$1107.25^{a}\pm3.47$	$1368.32^{c}\pm10.34$	$1347.18^{c}\pm10.51$	$1226.94^{b}\pm8.21$	$1103.69^{a}\pm15.69$	$1081.92^{a}\pm12.36$
6^{th}	$1342.68^{b}\pm5.33$	$1635.18^{e}\pm2.18$	$1580.51^{d}\pm7.54$	$1450.52^{c}\pm17.03$	$1318.53^{ab}\pm12.56$	$1278.17^{a}\pm5.72$

Means bearing different superscripts in a row differ significantly ($P \leq 0.05$).

These results were in agreement of Farhadi *et al* (2016) and Benyi *et al* (2015) who also reported decrease in body weight gain with increase in stocking density. Salas *et al* (2013) observed no significant ($p \leq 0.05$) difference in live body weight of broiler chicks up to 5th week of age reared in conventional and climate controlled shed. However, in present study, on similar stocking density (T_0 and T_1) significant ($p \leq 0.05$) depression in growth was observed from 2nd week onwards. These differences in results could be due to degree of variation in environmental profile of location of study.

4.2.3 Live body weight per unit floor area

The data on average live body weight per unit floor area of broiler chicks have been presented in Table 4.7.

The body weight per unit floor allowance (g/ft^2) ranged minimum 1386.01g for T_0 to maximum 3485.60 g for T_5. The results showed significant ($p \leq 0.05$) difference between all the treatment groups (T_0, T_1, T_2, T_3, T_4 and T_5). Highest live body weight per unit floor area was observed in T_5, followed by T_4, T_3, T_1 and T_0 with floor area allowance of 0.6, 0.7, 0.8, 0.9 and 1.0 square feet per bird, respectively. In ECBH groups, body weight per unit floor area increased with increasing stocking density, which can be attributed to relative less depression in body weight with unit decrease in floor allowance in ECBH installed with tunnel ventilated evaporative cooling system. Similar to these findings, Farhadi *et al* (2016) also reported higher live body weight per unit in broilers, reared at 22 birds/m^2 than lower densities 16, 18 and 20, birds/m^2. Benyi *et al* (2015) observed better space use efficiency for production of up to 30 Kg BW/m^2 (3000 g/ft^2).

Table 4.7: Average live body weight per unit area of broiler chicks in different treatments

Treatment	Live Body Weight per Unit Area (g/ft^2)
T_0	1386.01^a±5.42
T_1	2423.54^b±25.67
T_2	2724.91c±13.09
T_3	2821.34^c±15.29
T_4	2925.90^d±16.32
T_5	3485.60^e±33.56

Means bearing different superscripts for different treatments in a column differ significantly (P ≤0.05).

4.2.4 Feed consumption

The data on average weekly feed intake of broiler chicks have been presented in Table 4.8 and graphically represented in Figure 11.

The results showed no significant ($p \leq 0.05$) difference in feed intake of broiler chicks among different treatment groups of OSCBH and ECBH up to 2nd week of age. However, 3rd week onwards feed intake of broiler chicks in OSCBH (T_0) group was significantly ($p \leq 0.05$) lower than ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups. From 2nd week onwards among different ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups, feed consumption showed a decreasing trend with increase in stocking density of broiler chicks. This trend showed more significant ($p \leq 0.05$) difference after 4th week of age and gradually increased with increase in age of birds.

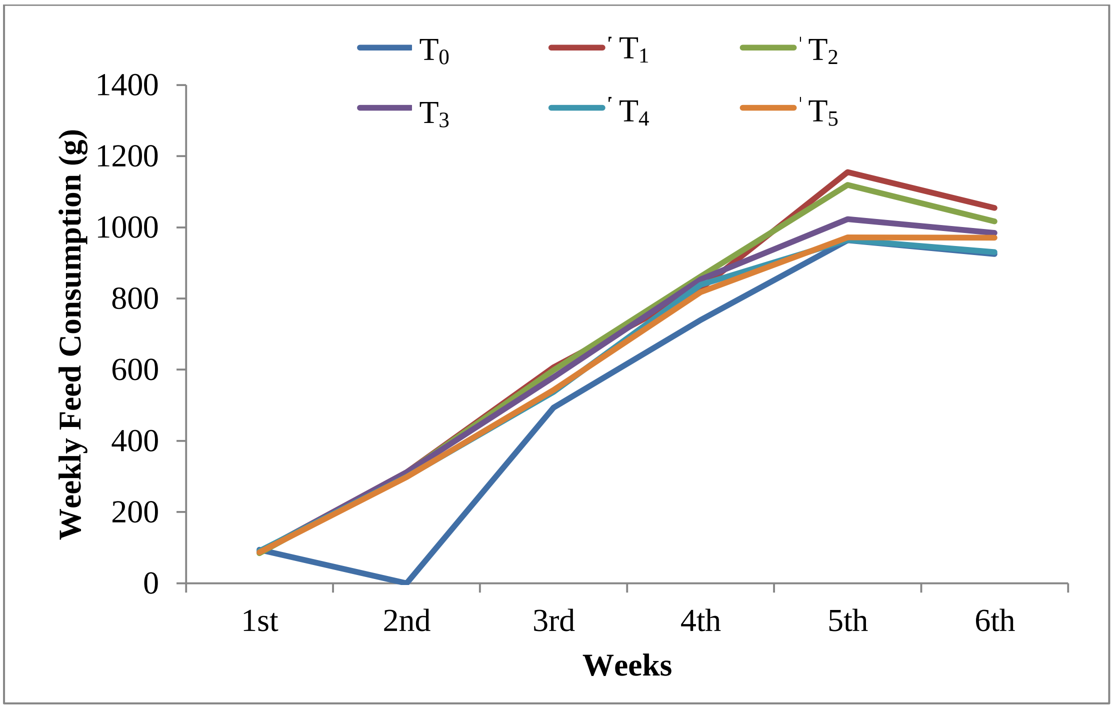

Figure 11: Weekly feed consumption in different treatments

The data presented on cumulative feed intake in Table 4.9 over different weeks also showed similar trends. Overall intake in T_0 (OSCBH) group was significantly ($p \leq$ 0.05) lower than all ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups. Overall feed intake was significantly ($p \leq 0.05$) higher in T_1 followed by T_2, T_3, T_5, T_4 and T_0 but there was no significant ($p \leq 0.05$) difference between T_1 and T_2 and T_4 and T_5.

Significantly ($p \leq 0.05$) better feed intake in all ECBH (T_1, T_2, T_3, T_4 and T_5) groups could be due to that, birds in ECBH group experienced less heat stress than broiler chicks in OSCBH(T_0).

Table 4.8: Weekly feed consumption of broiler chicks in different treatments

Week	Average Weekly Feed Consumption (g)					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	94.53±2.85	87.72±1.26	83.88±2.78	88.11±4.64	90.91±2.63	87.08±2.22
2nd	293.33±0.00	312.03±5.87	310.94±1.16	311.69±1.92	298.98±0.38	298.33±3.01
3rd	$492.97^{a}\pm2.90$	$607.09^{d}\pm4.53$	$598.96^{cd}\pm7.89$	$579.15^{c}\pm4.43$	$537.54^{b}\pm3.42$	$543.16^{b}\pm3.47$
4th	$740.10^{a}\pm0.79$	$828.17^{bc}\pm8.55$	$862.38^{c}\pm3.29$	$854.32^{bc}\pm10.36$	$838.60^{bc}\pm10.14$	$818.18^{b}\pm5.35$
5th	$963.36^{a}\pm5.35$	$1154.84^{c}\pm4.40$	$1118.94^{c}\pm4.15$	$1022.92^{b}\pm3.92$	$964.12^{a}\pm22.88$	$971.83^{a}\pm3.75$
6th	$924.53^{a}\pm1.46$	$1054.07^{d}\pm4.99$	$1016.53^{c}\pm3.62$	$983.89^{b}\pm4.44$	$930.78^{a}\pm3.78$	$970.50^{b}\pm2.30$

Means bearing different superscripts in a row differ significantly ($P \leq 0.05$).

Table 4.9: Cumulative feed consumption of broiler chicks in different treatments

Week	Cumulative Feed Consumption (g)					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	94.53±2.85	87.72±1.26	83.88±2.78	88.11±4.64	90.91±2.63	87.08±2.22
2nd	387.86±2.85	399.75±7.08	394.82±3.92	399.80±3.70	389.89±2.96	385.41±1.62
3rd	$880.83^{a}\pm3.97$	$1006.84^{d}\pm4.12$	$993.78^{d}\pm7.33$	$978.96^{c}\pm2.89$	$927.42^{b}\pm4.89$	$928.56^{b}\pm4.80$
4th	$1620.93^{a}\pm3.76$	$1835.01^{c}\pm7.17$	$1856.15^{c}\pm7.06$	$1833.28^{c}\pm9.43$	$1766.02^{b}\pm13.05$	$1746.74^{b}\pm6.72$
5th	$2584.29^{a}\pm7.98$	$2989.85^{d}\pm8.03$	$2856.20^{c}\pm12.34$	$2829.20^{c}\pm39.32$	$2730.14^{b}\pm12.15$	$2718.57^{b}\pm7.03$
6th	$3508.82^{a}\pm9.38$	$4043.92^{d}\pm10.46$	$3840.09^{c}\pm16.72$	$3813.09^{c}\pm43.65$	$3660.92^{b}\pm10.74$	$3689.08^{b}\pm9.27$

Means bearing different superscripts in a row differ significantly (P ≤0.05).

Similar to these results, earlier several workers also reported significant ($p \leq 0.05$) depression in feed intake with increase in heat stress (Tabiri *et al* 2002 and Quinteiro-Filho *et al* 2010). The results of decrease in feed intake with increase in stocking density in ECBH group were in agreement of Dozier *et al* (2006). They also reported decrease in feed intake with increase in stocking density from 25 to 40 kg of BW/m^2 by 35 days of age.

4.2.4 Feed conversion ratio (FCR)

The data on average weekly FCR have been presented in Table 4.10 and graphically represented in Figure 12. These results of FCR showed no significant ($p \leq 0.05$) difference among different treatment groups during 1^{st} week of age. However, during 2^{nd} week, FCR in T_2, T_3, T_4 and T_5 was significantly ($p \leq 0.05$) better than T_1 and T_0. However, there was no significant ($p \leq 0.05$) difference between T_0 and T_1 and T_1 and T_2. During 2^{nd} week FCR improved with increase in stocking density. Poor FCR in low broiler density might be due to energy expenditure in walking activities resulting more feed consumption in lower stocking density groups (T_0, T_1 and T_2). During 3^{rd} week FCR in T_0, T_4 and T_5 was significantly ($p \leq 0.05$) better than T_1, T_2 and T_3, however, there was no significant ($p \leq 0.05$) difference between T_3 and T_4. Comparatively, poor FCR in T_1, T_2 and T_3 in ECBH group can be due to more energy expenditure in physical activities resulting more feed intake without heat stress to birds. However, better FCR in T_0, T_4 and T_5 might be due to decreased feed consumption in T_0 (OSCBH) group due to heat stress while in T_4 and T_5, less energy expenditure due to limited walking activity due to limited space allowance at higher stocking density. During 4^{th} week, FCR in T_0 (OSCBH) was significantly ($p \leq 0.05$) better than T_3, T_4 and T_5 ECBH group. However, there was no significant ($p \leq 0.05$) difference between T_0, T_1 and T_2 and T_3, T_4 and T_5. During 5^{th} week, FCR in T_0 was significantly ($p \leq 0.05$) poor than T_1, T_2, T_3 and T_5 but there was no significant ($p \leq 0.05$) difference between T_0 and T_4 and T_1, T_2, T_3 and T_5. During 6^{th} week, FCR in T_5 was widest followed by T_3, T_2, T_4, T_1 and T_0.

The results of FCR showed that FCR became poor in all treatment groups with increase in age of birds which might be due to increased heat stress with increase of age along with decrease in genetic potential of growth rate (Ozbey and Ozcelik 2004 and Sohail *et al* 2012). However, up to 4^{th} week of age better FCR in T_0 (OSCBH) could be attributed to relatively more feed intake depression than various ECBH treatment groups.

Table 4.10: Weekly feed conversion ratio of broiler chicks in different treatments

Week	Weekly Feed Conversion Ratio					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	1.29±0.04	1.15±0.03	1.25±0.04	1.16±0.08	1.23±0.04	1.23±0.08
2nd	$1.91^{b}\pm0.02$	$1.90^{b}\pm0.03$	$1.77^{a}\pm0.00$	$1.76^{a}\pm0.03$	$1.67^{a}\pm0.03$	$1.78^{ab}\pm0.03$
3rd	$1.98^{a}\pm0.04$	$2.25^{cd}\pm0.01$	$2.31^{d}\pm0.08$	$2.18^{bcd}\pm0.02$	$2.10^{abc}\pm0.00$	$2.02^{b}\pm0.02$
4th	$2.19^{a}\pm0.09$	$2.13^{a}\pm0.06$	$2.24^{ab}\pm0.06$	$2.76^{b}\pm0.09$	$2.93^{b}\pm0.07$	$3.81^{c}\pm0.19$
5th	$3.32^{c}\pm0.20$	$2.46^{a}\pm0.04$	$2.44^{a}\pm0.04$	$2.58^{ab}\pm0.12$	$3.15^{bc}\pm0.18$	$2.71^{ab}\pm0.08$
6th	$3.94^{a}\pm0.13$	$3.96^{a}\pm0.17$	$4.37^{b}\pm0.15$	$4.45^{ab}\pm0.20$	$4.33^{ab}\pm0.08$	$4.96^{b}\pm0.16$

Means bearing different superscripts in a row differ significantly (P ≤0.05).

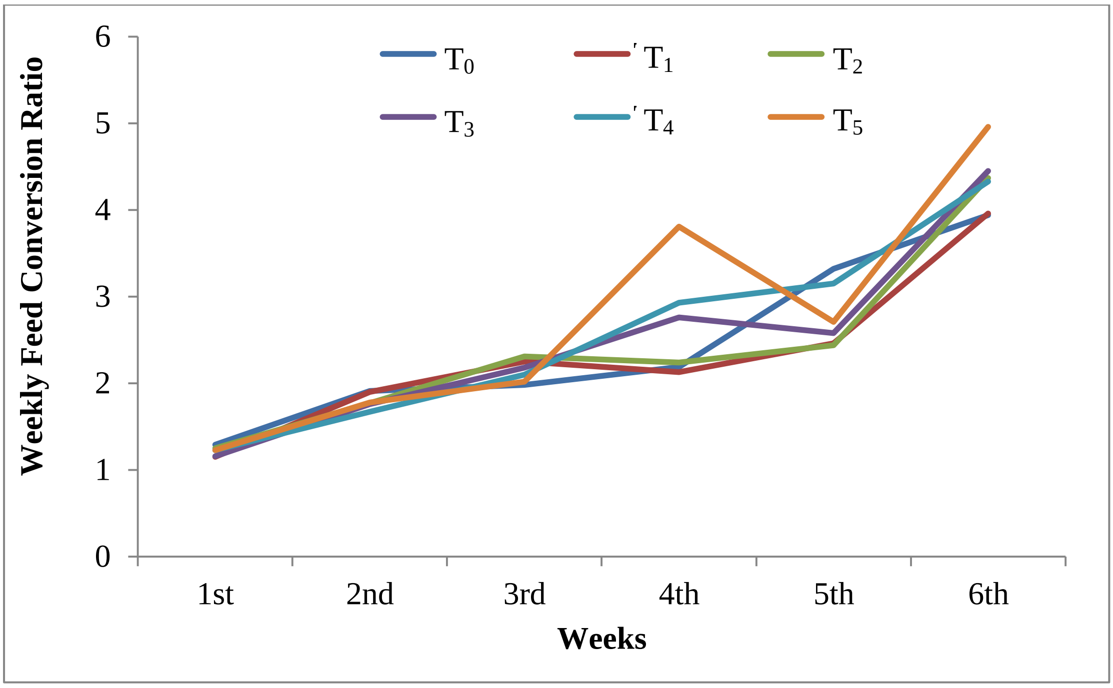

Figure 12: Weekly feed conversion ratio in different treatments

Among different ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups poor FCR in low stocking density groups up to 3rd week of age can be explained due to higher energy expenditure in walking activities due to more space allowance resulting in to more feed intake leading to poor FCR in low stocking density treatment groups. However, over 4th week of age increase in FCR with increase in stocking density in ECBH group could be due to relatively more decrease in body weight gain with increase in stocking density than depression in feed intake (Tong *et al* 2012). Overall, the data of cumulative FCR presented in Table 4.11 revealed that overall FCR in T_1 was significantly ($p\leq$ 0.05) better than T_0 (OSCBH), however, there was no significant ($p\leq$ 0.05) difference between T_0, T_2 and T_3. Overall FCR in T_4 and T_5 ECBH groups were significantly ($p\leq$ 0.05) poor than T_0.

4.2.5 Protein consumption

The data on average weekly protein consumption of broiler chicks have been presented in Table 4.12 and graphically represented in Figure 13.

The results showed no significant ($p\leq$ 0.05) difference in protein consumption of broiler chicks among different treatment groups of OSCBH and ECBH during first week of age. During 2nd week, protein consumption of broiler chicks in OSCBH (T_0)

Table 4.11: Cumulative feed conversion ratio of broiler chicks in different treatments

Week	Cumulative Feed Conversion Ratio					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	1.29±0.04	1.15±0.03	1.25±0.04	1.16±0.08	1.23±0.04	1.23±0.08
2nd	$1.71^{c}\pm0.02$	$1.66^{bc}\pm0.02$	$1.63^{abc}\pm0.01$	$1.58^{ab}\pm0.03$	$1.55^{a}\pm0.02$	$1.61^{ab}\pm0.01$
3rd	$1.85^{a}\pm0.01$	$1.97^{b}\pm0.01$	$1.98^{b}\pm0.04$	$1.89^{ab}\pm0.03$	$1.83^{a}\pm0.01$	$1.83^{a}\pm0.01$
4th	$1.99^{a}\pm0.03$	$2.04^{a}\pm0.03$	$2.09^{ab}\pm0.04$	$2.21^{b}\pm0.03$	$2.22^{b}\pm0.02$	$2.42^{c}\pm0.04$
5th	$2.33^{b}\pm0.01$	$2.19^{a}\pm0.02$	$2.21^{a}\pm0.02$	$2.33^{b}\pm0.01$	$2.47^{c}\pm0.02$	$2.51^{c}\pm0.03$
6th	$2.61^{bc}\pm0.00$	$2.55^{a}\pm0.03$	$2.53^{ab}\pm0.01$	$2.65^{c}\pm0.04$	$2.76^{d}\pm0.02$	$2.89^{e}\pm0.02$

Means bearing different superscripts in a row differ significantly ($p \leq 0.05$).

Table 4.12: Weekly protein consumption of broiler chicks in different treatments

Week	Weekly protein consumption					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	20.80±0.63	19.30±0.28	18.45±0.61	19.38±1.02	20.00±0.58	19.16±0.49
2nd	64.53^{a}±0.00	68.65^{c}±1.29	68.41^{bc}±0.26	68.57^{bc}±0.42	65.77^{abc}±0.08	65.63^{ab}±0.66
3rd	108.45^{a}±0.64	133.56^{d}±1.00	131.77^{cd}±1.74	127.41^{c}±0.97	118.26^{b}±0.75	119.49^{b}±0.76
4th	162.82^{a}±0.17	182.20^{bc}±1.88	189.72^{c}±0.72	187.95^{c}±2.28	184.49^{bc}±2.23	180.00^{b}±1.18
5th	192.67^{a}±1.07	230.97^{c}±0.83	223.79^{c}±0.83	204.58^{b}±0.78	192.82^{a}±4.58	194.37^{a}±0.75
6th	184.91^{a}±0.29	210.81^{d}±1.00	203.31^{c}±0.72	196.78^{b}±0.89	186.16^{a}±0.76	194.10^{b}±0.46

Means bearing different superscripts in a row differ significantly ($P \leq 0.05$).

group was significantly ($p \leq 0.05$) lower than ECBH (T_1, T_2 and T_3) treatment groups but no significant difference was observed between T_0, T_4 and T_5. During 3rd and 4th weeks of age protein consumption of broiler chicks in OSCBH (T_0) group was significantly($p \leq 0.05$) lower than all ECBH groups, however, again during 5th and 6th weeks protein consumption in T_0, T_4 and T_5 was similar. These results showed decreasing trend of protein consumption with increasing stocking density of broiler chicks and depression in protein consumption more significantly ($p \leq 0.05$) apparent after 4th week of age and gradually increased with increase in age of birds.

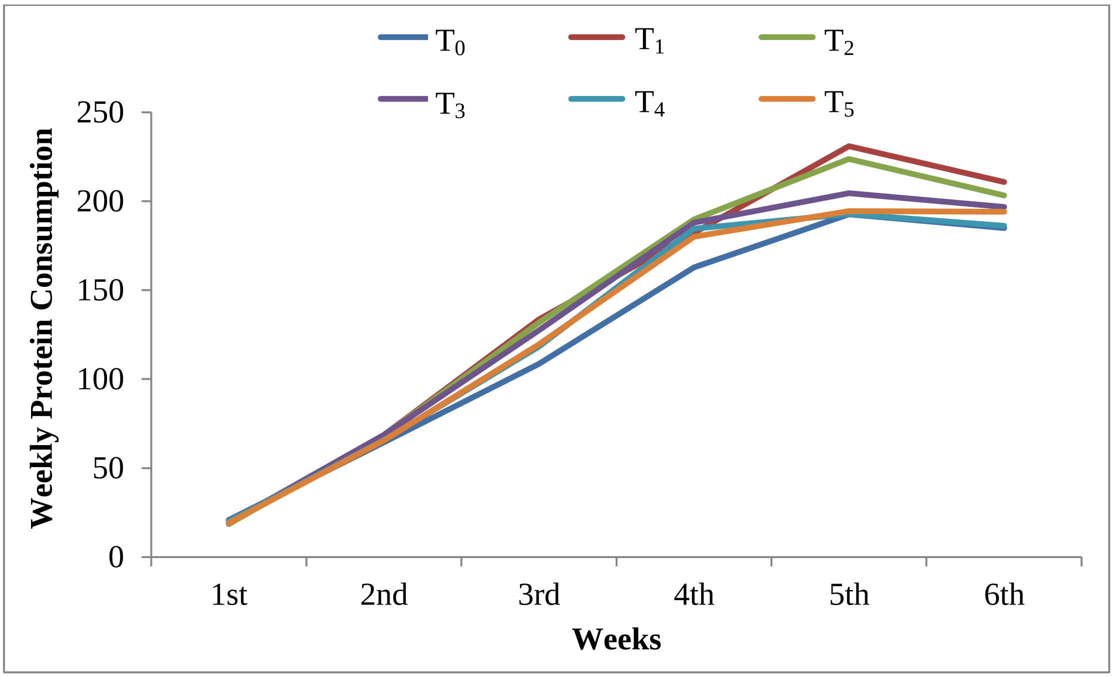

Figure 13: Weekly protein consumption in different treatments

The data presented on cumulative protein consumption in Table 4.13 over different weeks also showed similar trends. Overall protein intake in T_0 (OSCBH) group was significantly ($p \leq 0.05$) lower than all ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups. Overall protein consumption was significantly ($p \leq 0.05$) higher in T_1 followed by T_2, T_3, T_5, T_4 and T_0 but there was no significant ($p \leq 0.05$) difference between T_1 and T_2 and T_4 and T_5.

In comparison to T_0 (OSCBH) significantly ($p \leq 0.05$) higher protein intake of birds in all ECBH (T_1, T_2, T_3, T_4 and T_5) groups could be due to that, birds in ECBH group consumed more feed as shown in Table 4.8 and 4.9 due to less heat stress than broiler chicks as evident from lower THI and maximum-minimum temperature.

Table 4.13: Cumulative protein consumption of broiler chicks in different treatments

Week	Cumulative Protein Consumption					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	20.80±0.63	19.30±0.28	18.45±0.61	19.38±1.02	20.00±0.58	19.16±0.49
2nd	85.33±0.63	87.95±1.56	86.86±0.86	87.96±0.81	85.78±0.65	84.79±0.36
3rd	193.78^{a}±0.87	221.51^{d}±0.91	218.63^{cd}±1.61	215.37^{c}±0.64	204.03^{b}±1.08	204.28^{b}±1.06
4th	356.60^{a}±0.83	403.70^{c}±1.58	408.35^{c}±1.55	403.32^{c}±2.07	388.53^{b}±2.87	384.28^{b}±1.48
5th	549.28^{a}±1.66	634.67^{d}±1.73	632.14^{d}±2.19	607.90^{c}±2.65	581.35^{b}±2.27	578.65^{b}±1.52
6th	734.18^{a}±1.94	845.48^{d}±2.17	835.45^{d}±2.88	804.68^{c}±3.52	767.50^{b}±1.93	772.75^{b}±1.96

Means bearing different superscripts in a row differ significantly ($P \leq 0.05$).

4.2.6 Protein efficiency ratio (PER)

The data on average weekly PER of broiler chicks have been presented in Table 4.14 and graphically represented in Figure 14.

During 1st week of age no significant ($p\leq 0.05$) difference in PER was observed among different treatment groups. However, during 2nd and 3rd weeks results of PER were inconsistent. But, during 4th week of age, PER in T_0, T_1 and T_2 was significantly ($p\leq 0.05$) higher than T_3, T_4 and T_5, however, no significant difference was observed between T_0, T_1 and T_2 and T_3, T_4 and T_5. Again, during 5th week, PER in T_0, T_4 and T_5 was significantly ($p\leq 0.05$) lower than T_1, T_2 and but during 6th week of age there was no significant ($p\leq 0.05$) difference between PER among different OSCBH (T_0) and ECBH (T_1, T_2, T_3, T_4 and T_5) groups. Overall, PER in T_1 had significantly ($p\leq 0.05$) higher than T_0, T_3, T_4 and T_5, but there was no significant ($p\leq 0.05$) difference between T_1 and T_2 and T_4 and T_5 (Table 4.15).

These results indicated depression in PER among different treatment groups with increase in age of birds and increase in stocking density in ECBH group. Arantes de Souza *et al* (2016) reported significant ($p\leq 0.05$) depression in nutrient digestibility (protein), performance and energy and nitrogen balances of broiler chicken on continuous heat stress exposure. This depression in PER can be attributed to poor body weight gain indicated in Table 4.2 and depression in protein digestibility due to chronic heat stress.

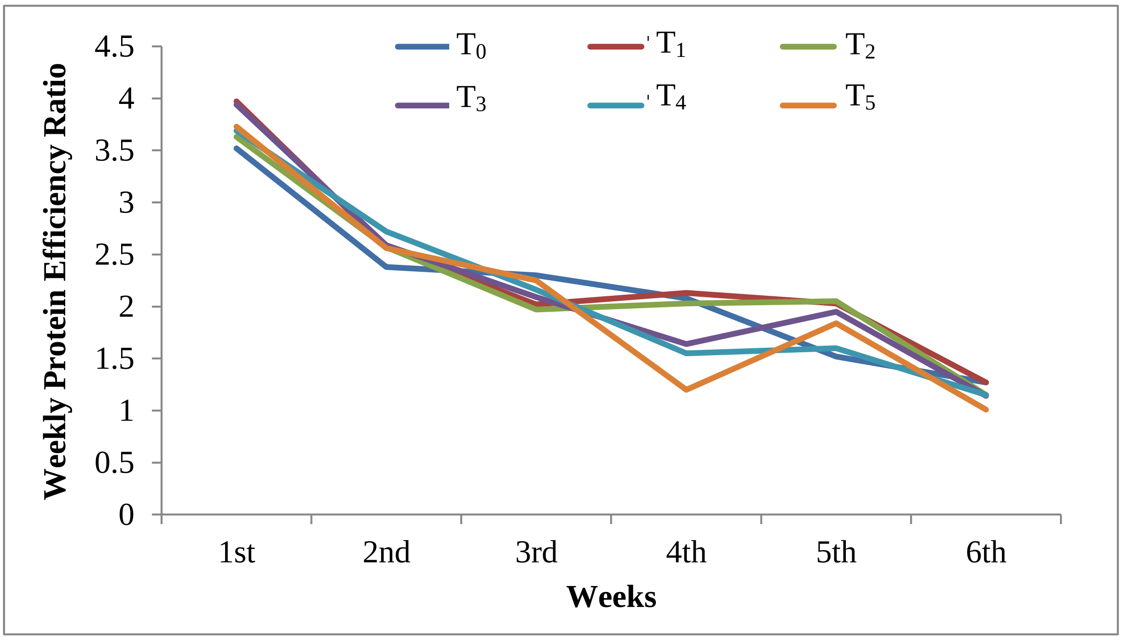

Figure 14: Weekly protein efficiency ratio in different treatments

Table 4.14: Weekly protein efficiency ratio of broiler chicks in different treatments

Week	Weekly Protein Efficiency Ratio					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	3.52±0.10	3.97±0.11	3.63±0.11	3.94±0.27	3.69±0.12	3.73±0.22
2nd	2.38^{a}±0.03	2.57^{ab}±0.04	2.57^{c}±0.00	2.59^{c}±0.09	2.72^{c}±0.04	2.56^{bc}±0.04
3rd	2.30^{d}±0.04	2.02^{ab}±0.01	1.97^{a}±0.07	2.09^{abc}±0.02	2.16^{bcd}±0.00	2.25^{cd}±0.02
4th	2.08^{c}±0.08	2.13^{c}±0.06	2.03^{c}±0.06	1.64^{b}±0.03	1.55^{b}±0.04	1.20^{a}±0.06
5th	1.52^{a}±0.09	2.03^{b}±0.03	2.05^{b}±0.04	1.95^{b}±0.09	1.60^{a}±0.09	1.84^{ab}±0.06
6th	1.27^{b}±0.04	1.27^{b}±0.05	1.15^{ab}±0.04	1.14^{ab}±0.09	1.15^{ab}±0.02	1.01^{a}±0.03

Means bearing different superscripts in row differ significantly ($P \leq 0.05$).

Table 4.15: Cumulative protein efficiency ratio of broiler chicks in different treatments

Week	Cumulative Protein Efficiency Ratio					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	3.66±0.12	3.80±0.24	3.80±0.18	3.85±0.09	3.62±0.25	2.54±1.27
2nd	2.66^{a}±0.03	2.74^{ab}±0.03	2.80^{abc}±0.02	2.88^{bc}±0.05	2.94^{c}±0.04	2.82^{abc}±0.02
3rd	2.46^{b}±0.01	2.31^{a}±0.01	2.30^{a}±0.04	2.41^{ab}±0.03	2.49^{b}±0.02	2.49^{b}±0.02
4th	2.28^{c}±0.03	2.23^{c}±0.03	2.17^{bc}±0.04	2.05^{b}±0.03	2.04^{b}±0.02	1.88^{a}±0.03
5th	2.02^{b}±0.01	2.16^{a}±0.02	2.13^{a}±0.02	2.02^{b}±0.01	1.90^{a}±0.02	1.87^{a}±0.03
6th	1.83^{b}±0.00	1.93^{c}±0.00	1.89^{c}±0.01	1.80^{b}±0.03	1.72^{a}±0.01	1.65^{a}±0.01

Means bearing different superscripts in row differ significantly ($P \leq 0.05$).

4.2.7 Energy efficiency ratio (EER)

The data of weekly EER of broiler chicks have been presented in Table 4.16 and graphically represented in Figure 15. The results of EER showed no significant ($p \leq 0.05$) difference among different treatment groups during 1st week of age. However, on similar stocking density EER from 2nd to 5th week of age was significantly ($p \leq 0.05$) better in T_1 in ECBH than T_0 in OSCBH but again there was no significant ($p \leq 0.05$) variation during 6th week among different ECBH groups (T_1, T_2, T_3, T_4 and T_5), except during 4th week, EER did not depress significantly ($p \leq 0.05$) at highest stocking density (T_5). Better EER up to 30% increase in stocking density could be attributed to better nutrient utilization efficiency and better body weight gain due to less heat stress to broilers. The data of overall EER presented in Table 4.17 revealed that overall EER in T_1 was significantly ($p \leq 0.05$) better than T_0 (OSCBH). However there was no significant ($p \leq 0.05$) difference between T_0, T_2, T_4 and T_5 (Table 4.17).

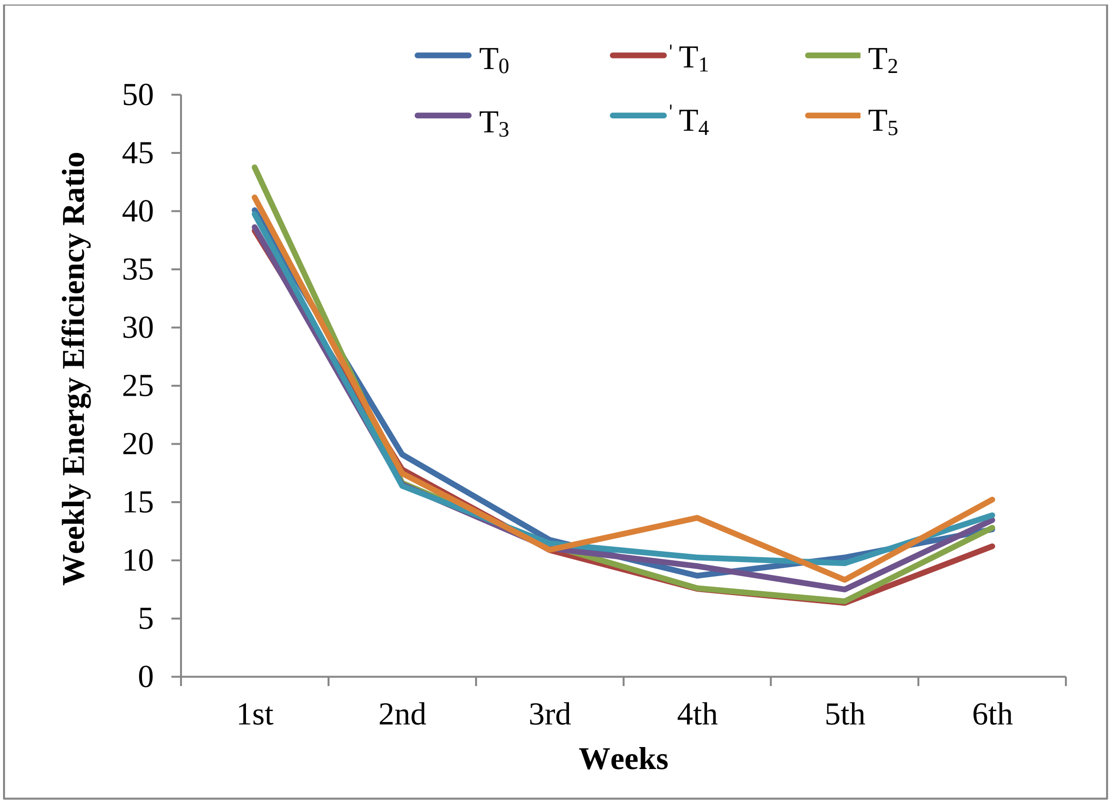

Figure 15: Weekly energy efficiency ratio in different treatments

Table 4.16: Weekly energy efficiency ratio of broiler chicks in different treatments

Week	Weekly Energy Efficiency Ratio					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	$40.09^{ab}\pm1.40$	$38.31^{a}\pm0.69$	$43.77^{b}\pm0.30$	$38.63^{a}\pm0.73$	$39.74^{ab}\pm0.91$	$41.18^{ab}\pm1.50$
2nd	$19.08^{c}\pm0.23$	$17.80^{b}\pm0.42$	$16.64^{a}\pm0.06$	$16.50^{a}\pm0.19$	$16.40^{a}\pm0.24$	$17.46^{ab}\pm0.11$
3rd	$11.75^{b}\pm0.16$	$10.86^{a}\pm0.10$	$11.29^{ab}\pm0.24$	$11.03^{a}\pm0.20$	$11.45^{ab}\pm0.05$	$10.90^{a}\pm0.07$
4th	$8.67^{ab}\pm0.34$	$7.54^{a}\pm0.15$	$7.61^{a}\pm0.18$	$9.50^{ab}\pm0.31$	$10.25^{b}\pm0.37$	$13.65^{c}\pm0.79$
5th	$10.24^{b}\pm0.56$	$6.35^{a}\pm0.08$	$6.48^{a}\pm0.14$	$7.49^{a}\pm0.33$	$9.74^{b}\pm0.75$	$8.32^{ab}\pm0.27$
6th	$12.67^{ab}\pm0.43$	$11.19^{a}\pm0.45$	$12.79^{ab}\pm0.48$	$13.45^{ab}\pm0.94$	$13.86^{b}\pm0.28$	$15.20^{b}\pm0.55$

Means bearing different superscripts in a row differ significantly ($P \leq 0.05$).

Table 4.17: Cumulative energy efficiency ratio of broiler chicks in different treatments

Week	Cumulative Energy Efficiency Ratio					
	OSCBH	ECBH				
	T_0	T_1	T_2	T_3	T_4	T_5
1st	$40.09^{ab}\pm1.40$	$38.31^{a}\pm0.69$	$43.77^{b}\pm0.30$	$38.63^{a}\pm0.73$	$39.74^{ab}\pm0.91$	$41.18^{ab}\pm1.50$
2nd	$59.17^{ab}\pm1.53$	$56.10^{ab}\pm0.27$	$60.42^{b}\pm0.35$	$55.13^{a}\pm0.77$	$56.14^{ab}\pm0.75$	$58.64^{ab}\pm1.39$
3rd	$70.92^{bc}\pm1.37$	$66.97^{ab}\pm0.25$	$71.71^{c}\pm0.59$	$66.15^{a}\pm0.96$	$67.59^{abc}\pm0.70$	$69.54^{abc}\pm1.33$
4th	$79.59^{ab}\pm1.69$	$74.51^{a}\pm0.10$	$79.33^{ab}\pm0.73$	$75.65^{a}\pm1.22$	$77.84^{ab}\pm0.34$	$83.19^{b}\pm2.11$
5th	$89.83^{cd}\pm1.18$	$80.86^{a}\pm0.15$	$85.80^{abc}\pm0.62$	$83.14^{ab}\pm1.04$	$87.59^{bcd}\pm0.97$	$91.58^{d}\pm1.98$
6th	$102.20^{cd}\pm1.58$	$92.04^{a}\pm0.50$	$98.59^{bc}\pm0.14$	$96.59^{ab}\pm0.50$	$101.04^{bc}\pm1.05$	$106.71^{d}\pm1.83$

Means bearing different superscripts in a row differ significantly ($P \leq 0.05$).

4.3 Broiler Welfare

4.3.1 Broiler rectal temperature

The data on rectal temperature have been presented in Table 4.18 and graphically represented in Figure 16. The results revealed that during different weeks the rectal temperature in OSCBH (T_0) was significantly ($p \leq 0.05$) higher than all the ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups. However, in ECBH treatment groups, rectal temperature increased as the stocking density increased. Except 4^{th} week of age highest rectal temperature in broiler chicks was recorded in T_5 group followed by T_4, T_2, T_3 and T_1 during all other weeks, however, there was no significant ($p \leq 0.05$) difference between T_1, T_2 and T_3 and T_4 and T_5.

Table 4.18: Average rectal temperature of broiler chicks in different treatments

Shed	Treatment	Weeks			
		3	4	5	6
OSCBH	**T_0**	$107.03^{d}\pm0.09$	$106.69^{c}\pm0.07$	$107.50^{d}\pm0.06$	$107.71^{c}\pm0.04$
ECBH	**T_1**	$105.44^{a}\pm0.06$	$105.82^{a}\pm0.09$	$105.66^{a}\pm0.09$	$106.17^{a}\pm0.09$
	T_2	$105.81^{ab}\pm0.09$	$105.82^{a}\pm0.10$	$106.12^{b}\pm0.08$	$106.23^{ab}\pm0.07$
	T_3	$105.77^{ab}\pm0.10$	$106.14^{ab}\pm0.09$	$106.09^{b}\pm0.11$	$106.02^{a}\pm0.10$
	T_4	$106.04^{bc}\pm0.11$	$106.44^{bc}\pm0.08$	$106.42^{bc}\pm0.12$	$106.57^{b}\pm0.10$
	T_5	$106.20^{c}\pm0.12$	$105.95^{a}\pm0.10$	$106.58^{c}\pm0.13$	$106.60^{b}\pm0.13$

Means bearing different superscripts for different treatments for different weeks in column differ significantly ($P \leq 0.05$).

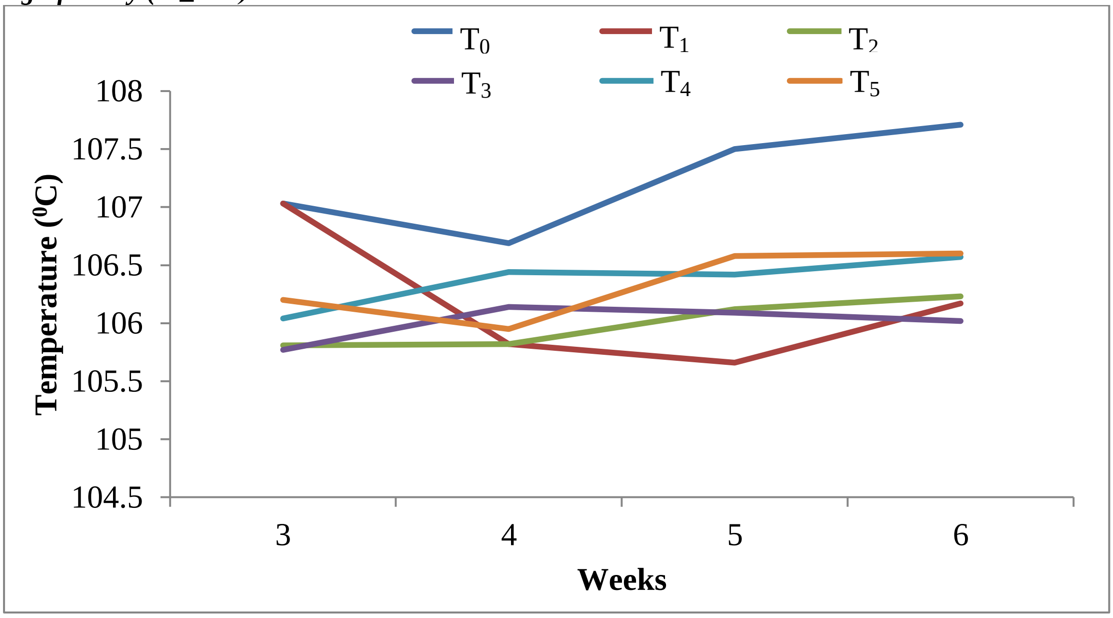

Figure 16: Average rectal temperature in different treatments

Similar to these results, Cooper and Washburn (1998) and Altan *et al* (2000) also reported significant increase in rectal temperature of birds due to heat stress. But results of increased rectal temperature with increase in density were different from reported by Nogueira *et al* (2013), who found no significant increase in rectal temperature of broiler birds with increase in stocking density. These differences in findings were due to seasonal variation in time of experiment.

4.3.2 Broiler behaviour

The data on incidence of behaviour activity of broiler birds have been presented in Table 4.19.

a) ***Feeding behaviour***: The percent incidence of feeding of birds during entire experimental period in OSCBH (T_0) was significantly ($p \leq 0.05$) lower than ECBH (T_1, T_2, T_3, T_4 and T_5) groups. This depression in the feeding incidence of birds in OSCBH (T_0) is able evident from results of depressed feed intake (Table 4.9 and 4.10). These findings were in agreement of workers Mashaly *et al* 2004, Azad *et al* 2010, Quinteiro-Filho *et al* 2010 and Mack *et al* 2013, who also reported decrease in feed intake of broilers to decrease in metabolic heat production to alleviate heat stress.

b) ***Resting behaviour****:* Percent incidence of resting during entire experimental period in OSCBH (T_0) was significantly lower than ECBH (T_1, T_2, T_3, T_4 and T_5) groups. Resting time over the different weeks of recording showed that resting behaviour during 3^{rd} week was significantly ($p \leq 0.05$) higher than resting incidence in 4^{th}, 5^{th} and 6^{th} weeks of age. Resting is normal welfare behavior of birds, resting time of bird decreases with increase in temperature. Therefore, decrease in resting incidence over the time might be due to increased heat stress with age.

c) ***Drinking behaviour*****:** The results of percent incidence of drinking amount different treatment groups throughout the experimental period did not differ significantly ($p \leq 0.05$) among different treatment groups. This non-significant ($p \leq 0.05$) difference among different treatment groups might be due non-recording of drinking activity due to shorter sampling time as relatively lesser time is spent in drinking water in ethogram of broiler.

d) ***Panting behaviour*****:** The results of percent incidence of panting, indicating attempt of birds to increase evaporating cooling to alleviate heat stress showed that significantly ($p \leq 0.05$) higher panting behavior was observed in OSCBH (T_0)

Table 4.19: Percent incidence of different behavioral activities shown by broiler birds under different treatments

Week	Treatment	Parameters							
		Feeding	**Drinking**	**Resting (without panting)**	**Panting**	**Preening**	**Dust bathing**	**Scratching**	**Wing Flapping**
3	T_0	$21.08^{cd}\pm2.31$	3.19 ± 0.68	$55.19^{a}\pm2.73$	$12.08^{b}\pm1.66$	3.07 ± 0.35	$0.80^{b}\pm0.24$	$4.58^{c}\pm0.77$	$1.94^{bc}\pm0.44$
	T_1	$19.83^{cd}\pm1.31$	2.54 ± 0.62	$70.98^{bc}\pm1.61$	$0.00^{a}\pm0.00$	1.74 ± 0.30	$0.00^{a}\pm0.00$	$1.74^{a}\pm0.35$	$1.12^{abc}\pm0.37$
	T_2	$22.30^{d}\pm1.15$	3.22 ± 0.51	$66.69^{b}\pm1.51$	$0.00^{a}\pm0.00$	2.26 ± 0.33	$0.14^{ab}\pm0.14$	$2.06^{ab}\pm0.34$	$1.85^{ab}\pm0.37$
	T_3	$16.34^{bc}\pm1.04$	1.71 ± 0.40	$76.93^{cd}\pm1.48$	$0.00^{a}\pm0.00$	2.61 ± 0.63	$0.23^{ab}\pm0.16$	$2.12^{ab}\pm0.44$	$1.28^{abc}\pm0.28$
	T_4	$11.72^{ab}\pm0.79$	1.57 ± 0.29	$81.78^{de}\pm0.99$	$0.31^{a}\pm0.21$	2.95 ± 1.04	$0.42^{ab}\pm0.15$	$3.38^{abc}\pm0.59$	$0.70^{ab}\pm0.21$
	T_5	$10.33^{a}\pm1.07$	1.28 ± 0.28	$83.89^{e}\pm1.32$	$0.67^{a}\pm0.31$	3.01 ± 0.51	$0.60^{ab}\pm0.19$	$3.90^{bc}\pm0.46$	$0.57^{a}\pm0.20$
4	T_0	$14.44^{a}\pm1.15$	3.33 ± 0.68	$59.36^{a}\pm2.33$	$15.00^{d}\pm1.46$	1.89 ± 0.51	0.23 ± 0.16	3.75 ± 0.81	1.81 ± 0.40
	T_1	$21.06^{c}\pm1.25$	2.14 ± 0.30	$69.06^{bc}\pm1.35$	$0.00^{a}\pm0.00$	1.86 ± 0.43	0.14 ± 0.14	2.15 ± 0.34	0.97 ± 0.21
	T_2	$23.32^{c}\pm0.91$	2.39 ± 0.36	$60.66^{a}\pm1.51$	$8.40^{bc}\pm0.71$	1.77 ± 0.45	0.10 ± 0.10	2.82 ± 0.36	1.01 ± 0.23
	T_3	$19.95^{bc}\pm1.07$	2.58 ± 0.46	$62.78^{ab}\pm1.91$	$5.17^{b}\pm0.83$	1.10 ± 0.32	0.11 ± 0.11	3.23 ± 0.54	1.16 ± 0.26
	T_4	$20.05^{bc}\pm0.73$	2.76 ± 0.57	$62.59^{ab}\pm1.55$	$8.34^{bc}\pm0.96$	2.51 ± 0.37	0.34 ± 0.16	3.18 ± 0.57	1.50 ± 0.31
	T_5	$16.53^{ab}\pm0.91$	3.07 ± 0.65	$71.29^{c}\pm1.73$	$9.32^{c}\pm0.61$	1.46 ± 0.28	0.37 ± 0.20	1.73 ± 0.34	1.87 ± 0.43
5	T_0	8.89 ± 1.52	1.07 ± 0.32	$57.96^{a}\pm3.71$	$25.56^{c}\pm2.23$	3.33 ± 1.67	$0.92^{b}\pm0.28$	1.39 ± 0.44	$1.81^{b}\pm0.49$
	T_1	15.66 ± 2.02	1.96 ± 0.50	$77.47^{b}\pm2.99$	$1.22^{a}\pm0.58$	0.62 ± 0.31	$0.12^{a}\pm0.12$	0.17 ± 0.17	$0.53^{a}\pm0.25$
	T_2	12.37 ± 2.51	2.05 ± 0.45	$80.13^{b}\pm2.47$	$1.90^{a}\pm0.53$	1.85 ± 0.52	$0.22^{ab}\pm0.15$	0.78 ± 0.33	$0.58^{a}\pm0.19$
	T_3	20.35 ± 0.74	2.19 ± 0.42	$66.45^{a}\pm1.28$	$1.98^{a}\pm0.50$	1.31 ± 0.35	$0.14^{ab}\pm0.14$	0.74 ± 0.23	$0.67^{ab}\pm0.27$
	T_4	12.37 ± 0.80	1.70 ± 0.34	$78.85^{b}\pm0.91$	$3.67^{ab}\pm0.69$	1.49 ± 0.34	$0.36^{ab}\pm0.15$	1.03 ± 0.39	$0.77^{ab}\pm0.19$
	T_5	23.14 ± 8.59	1.33 ± 0.23	$78.42^{b}\pm0.93$	$6.59^{b}\pm0.95$	1.78 ± 0.30	$0.88^{ab}\pm0.24$	1.40 ± 0.34	$1.16^{ab}\pm0.27$
6	T_0	$10.83^{a}\pm1.56$	2.35 ± 0.42	$66.25^{a}\pm1.60$	$18.06^{C}\pm0.90$	1.11 ± 0.33	$0.00^{a}\pm0.00$	$2.36^{b}\pm0.51$	0.69 ± 0.28
	T_1	$12.80^{a}\pm1.99$	1.11 ± 0.38	$78.89^{c}\pm2.41$	$0.00^{a}\pm0.00$	0.90 ± 0.33	$0.14^{ab}\pm0.14$	$0.74^{a}\pm0.23$	1.17 ± 0.35
	T_2	$15.42^{ab}\pm1.01$	1.16 ± 0.31	$77.27^{b}\pm1.59$	$1.88^{ab}\pm0.48$	1.20 ± 0.31	$0.21^{ab}\pm0.15$	$1.09^{ab}\pm0.31$	0.89 ± 0.27
	T_3	$19.74^{b}\pm1.35$	1.33 ± 0.41	$70.36^{ab}\pm1.85$	$2.40^{ab}\pm0.60$	1.05 ± 0.31	$0.35^{ab}\pm0.14$	$1.47^{ab}\pm0.37$	1.01 ± 0.25
	T_4	$12.26^{a}\pm0.93$	1.73 ± 0.34	$79.07^{c}\pm0.92$	$3.31^{b}\pm0.66$	1.32 ± 0.30	$0.58^{ab}\pm0.21$	$1.78^{ab}\pm0.40$	0.60 ± 0.20
	T_5	$13.74^{a}\pm0.81$	1.90 ± 0.33	$79.24^{c}\pm1.19$	$3.46^{b}\pm0.66$	1.33 ± 0.29	$0.83^{b}\pm0.25$	$1.73^{ab}\pm0.39$	0.70 ± 0.17

Means with different superscripts differ significantly (P≤0.05)

group in comparison to ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups . This significant ($p \leq 0.05$) difference between the OSCBH (T_0) and ECBH (T_1, T_2, T_3, T_4 and T_5) could be due to high environmental temperature of the shed leading to heat stress in the broiler chicks reared under OSCBH.

e) ***Wing flapping and preening behaviour*:** The activities of wing flapping and preening percent incidence of behavioural activity to increase rate of convecting heat loss in response to heat stress by birds during different weeks of observation was significantly ($p \leq 0.05$) higher in OSCBH (T_0) than ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups. But, within ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups there was increase in wing flapping and preening behavior as the stocking density increased.

f) ***Scratching behaviour*:** Percent incidence of scratching activity behavioural activity, indicating attempt of birds to increase conductive heat loss, was significantly ($p \leq 0.05$) higher in OSCBH (T_0) than ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups. But within ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups increasing trend of scratching activity was observed with increasing stocking density. Body scratching is an important behavior of birds to keep themselves clean, as with increasing stoking density general cleanliness of birds decreases due to limited space for movement and higher litter moisture content.

Higher incidence of panting, wing flapping and scratching and simultaneously lower incidence of feeding and resting indicated that broiler birds in OCBH groups experienced more heat stress than birds in ECBH groups. Among different ECBH groups heat stress in birds increased with increasing stocking density.

4.3.3 Body Lesions and Changes

The data on incidence and average incidence of body lesions and changes of broiler birds have been presented in Table 4.20 and Table 4.21, respectively.

a) ***Foot Pad Lesion:*** The results of foot pad lesions showed that foot pad lesion score for all the birds in different treatment groups ranged in the scale of 0 to 2 (none to minimal) and none of the bird showed severe foot pad lesion (score 3 and 4). Among different treatments, 10.00 to 26.67 % birds had score 2, 43.33 to 51.67% had score 1 and 30.00-46.67% had score 0. The average foot pad lesion score ranged from 0.63 to 0.97, which was numerically higher in T_5 followed by T_1, T_2, T_4, T_3 and T_0. However there was no significant ($p \leq 0.05$) difference in average foot pad lesion score among various treatments.

Table 4.20: Percent incidence of body lesions and changes in different treatments at 6th week of age

Parameters	Score	OSCBH	ECBH				
		Treatments					
		T_0	T_1	T_2	T_3	T_4	T_5
Foot pad lesion	0	46.67±9.28	35.00±5.00	38.33±3.33	45.00±2.89	48.33±1.67	30.00±5.77
	1	43.33±4.40	51.67±6.01	50.00±2.89	41.67±4.41	33.33±6.01	43.33±6.67
	2	10.00±5.00	13.33±4.41	11.66±1.67	13.33±6.67	18.33±4.41	26.67±8.82
	3	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Hock Burn	0	88.33±4.41	93.33±1.67	96.67±1.67	96.67±1.67	96.67±1.67	96.67±1.67
	1	11.67±4.41	6.67±1.67	3.33±1.67	3.33±1.67	3.33±1.67	3.33±1.67
	2	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	3	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Breast Blisters	0	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	1	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Gait Scoring	0	90.00±2.89	93.33±1.67	91.67±1.67	95.00±0.00	95.00±0.00	90.00±2.89
	1	6.67±1.67	6.67±1.67	8.33±1.67	5.00±0.00	5.00±0.00	6.67±1.67
	2	1.67±2.89	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.67±2.89
	3	1.67±2.89	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	4	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
	5	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	1.67±1.67
General Cleanliness	0	8.33±1.67	13.33±1.67	11.67±3.33	8.33±1.67	11.67±1.67	8.33±1.67
	1	80.00±5.77	71.67±1.67	71.67±1.67	81.67±6.01	71.67±1.67	76.67±1.67
	2	11.67±4.41	15.00±2.89	15.00±2.89	10.00±5.60	16.67±1.67	15.00±2.89
	3	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table 4.21: Average score of different body lesions and changes

Treatments	Foot pad lesion	Hock burn	Breast blisters	Gait scoring	General cleanliness
T_0	0.63±0.14	0.12±0.04	0.00±0.00	0.12±0.04	1.03±0.03
T_1	0.78±0.07	0.07±0.02	0.00±0.00	0.07±0.02	1.02±0.04
T_2	0.73±0.04	0.03±0.02	0.00±0.00	0.08±0.02	1.02±0.04
T_3	0.68±0.09	0.03±0.02	0.00±0.00	0.05±0.00	1.02±0.04
T_4	0.70±0.03	0.03±0.02	0.00±0.00	0.05±0.00	1.05±0.03
T_5	0.97±0.13	0.03±0.02	0.00±0.00	0.18±0.07	1.07±0.04

b) ***Hock Burn:*** The results of hock burn indicates that hock burn score for all the birds in different treatment groups ranged in scale of 0 to 1 (none to minimal) and none of the bird showed severe foot pad lesion (score 2, 3 and 4 ; minimal to severe). Among different treatments, 3.33 to 11.67% had score 1 and 88.33 to 96.67% had score 0. The average hock burn score among different treatments varied from 0.03 to 0.12, which was numerically highest in T_0 followed by T_1, T_2, T_3, T_4 and T_5. However there was no significant ($p \leq 0.05$) difference the various treatments.

c) ***Breast Blisters:*** The results indicate absence of breast blisters in OSCBH (T_0) and ECBH (T_1, T_2, T_3, T_4 and T_5) groups.

d) ***Gait Score:*** The results of gait were on the scale of 0 to 5. Birds of T_5 showed 1.67% of score 5 (unable to move) whereas, none of the birds exhibited the score of 4 (severe), 1.67% of birds of T_0 showed score 3 (ability to move affected) whereas, score 2 (definite abnormality) was seen in T_5 and T_0, 5 to 8.33% showed score 1(slightly abnormal) and 90 to 95% birds did not show any gait abnormality. The average gait score (Table 4.21) varied from 0.05 to 0.18, being numerically highest in T_5 followed by T_0, T_2, T_1, T_3 and T_4. However, there was no significant ($p \leq 0.05$) difference between OSCBH (T_0) and ECBH (T_1, T_2, T_3, T_4 and T_5) groups.

e) ***General Cleanliness:*** The results showed that the broiler birds in T_5 were most dirty in comparison to other treatments, general cleanliness score for all the birds in different treatment groups ranged in scale of 0 to 2 (clean to evident) and none of the bird showed unclean (score 3).

Among different treatments, 10 to 16.67% showed score 2, 71.67 to 81.67% showed score 1 and 8.33 to 13.33% birds showed score 0. The average score of general cleanliness varied from 1.07 to 1.02, which was numerically highest in T_5 followed by T_4, T_0, T_1, T_2 and T_3, however, there was no significant ($p \leq 0.05$) difference between OSCBH (T_0) and ECBH (T_1, T_2, T_3, T_4 and T_5) groups. The maximum number of dirty broiler birds in T_5 could be due to high stocking density.

Average foot pad lesion, hock burn, breast blisters, gait score among different treatment groups ranged from 0.63- 0.97, 0.03-0.12, 0.00 and 0.05-0.18, respectively. These results of average score of different body lesions indicating injury and health status of bird as a measure of broiler welfare revealed that birds even at highest stocking density did not experienced any welfare problem.

Contrary to these results, Weeks *et al* 2000, Dozier *et al* 2006 and Skrbic *et al* 2009 also reported significant ($p \leq 0.05$) increase of the frequency of poor scores for walking ability (gait score), hock burns and foot pad lesions with increase of stocking density. The difference in the results with the current study might be due to comparatively less space allowance and higher final body weight of birds.

4.3.4 Biochemical Changes

The data on level of anti-oxidant enzymes indicating level of oxidative stress have been presented in Table 4.22 and graphically represented in Figure 17 to 22.

During 3^{rd} and 6^{th} week, for similar stocking density plasma level of GPx, LPO, CAT and G6PD were significantly ($p \leq 0.05$) higher in OSCBH (T_0) than ECBH (T_1). However, level of SOD was significantly ($p \leq 0.05$) higher in OSCBH (T_0) than ECBH (T_1) only during 6^{th} week of age, while, level of GPx did not vary significantly ($p \leq 0.05$). In ECBH group, level of LPO, SOD, catalase and G6PD trends to increase with increase in stocking density and this increase was more evident for G6PD. Over the period from 3^{rd} to 6^{th} weeks of age, level of anti-oxidant enzymes, mainly LPO, SOD, catalase and G6PD also increased for different treatment groups.

Earlier, several workers Altan *et al* (2003), Mujahid *et al* (2005, 2006 and 2007) and Lin *et al* (2006, 2008 and 2010) reported oxidative injury induced by high ambient temperature resulting into production of anti-oxidant enzymes like SOD, CAT, GPx, LPO and G6PD as a first line of anti-oxidant defense (Feng *et al* 2008).

Table 4.22: Stress related biochemical changes in broiler chicks in different treatments

Weeks	Treatments	Parameters				
		GPx (µ/g Hb)	LPO (nmole MDA/ml)	SOD (µ/g Hb)	Catalase (µmole H_2O_2 decomposed/min/g Hb)	G6PD (µmol NADPH/min/g Hb)
3rd	T_0	$0.72^{a}\pm0.01^{A}$	$1.72^{e}\pm0.01^{A}$	$21.85^{ab}\pm0.73^{A}$	$6.93^{e}\pm0.21$	$212.05^{f}\pm2.15^{A}$
	T_1	$0.67^{a}\pm0.02$	$0.94^{a}\pm0.01^{A}$	$21.20^{a}\pm0.69^{A}$	$5.30^{a}\pm0.09^{A}$	$150.19^{a}\pm0.39^{A}$
	T_2	$0.82^{b}\pm0.01$	$1.04^{b}\pm0.02$	$23.75^{ab}\pm0.22$	$5.71^{ab}\pm0.04^{A}$	$155.93^{b}\pm1.05$
	T_3	$0.82^{b}\pm0.00$	$1.23^{c}\pm0.01^{A}$	$22.64^{ab}\pm1.32$	$6.03^{bc}\pm0.01$	$161.49^{c}\pm0.59^{A}$
	T_4	$0.69^{a}\pm0.03^{A}$	$1.21^{c}\pm0.02^{A}$	$24.45^{b}\pm0.33^{A}$	$6.35^{cd}\pm0.08$	$171.90^{d}\pm1.12^{A}$
	T_5	$0.82^{b}\pm0.01$	$1.63^{d}\pm0.01^{A}$	$22.34^{ab}\pm0.30^{A}$	$6.72^{de}\pm0.06$	$182.70^{e}\pm1.28^{A}$
6th	T_0	0.88 ± 0.03^{B}	$1.79^{c}\pm0.02^{B}$	$28.30^{c}\pm0.08^{B}$	$7.15^{d}\pm0.03$	$230.10^{f}\pm0.51^{B}$
	T_1	0.89 ± 0.03	$1.03^{a}\pm0.01^{B}$	$25.99^{a}\pm0.61^{B}$	$6.15^{a}\pm0.05^{B}$	$155.48^{a}\pm1.11^{B}$
	T_2	0.89 ± 0.03	$1.05^{a}\pm0.01$	$26.10^{ab}\pm0.02$	$6.16^{a}\pm0.05^{B}$	$160.76^{b}\pm0.69$
	T_3	0.91 ± 0.02	$1.32^{b}\pm0.01^{B}$	$27.29^{bc}\pm0.08$	$6.30^{b}\pm0.01$	$172.03^{c}\pm0.64^{B}$
	T_4	0.90 ± 0.00	$1.31^{b}\pm0.01^{B}$	$27.25^{bc}\pm0.05^{B}$	$6.40^{b}\pm0.01$	$186.28^{d}\pm0.39^{B}$
	T_5	0.90 ± 0.02	$1.80^{c}\pm0.02^{B}$	$28.31^{c}\pm0.08^{B}$	$6.90^{c}\pm0.01$	$196.00^{e}\pm0.54^{B}$

Means with different superscripts differ significantly ($P\leq0.05$)

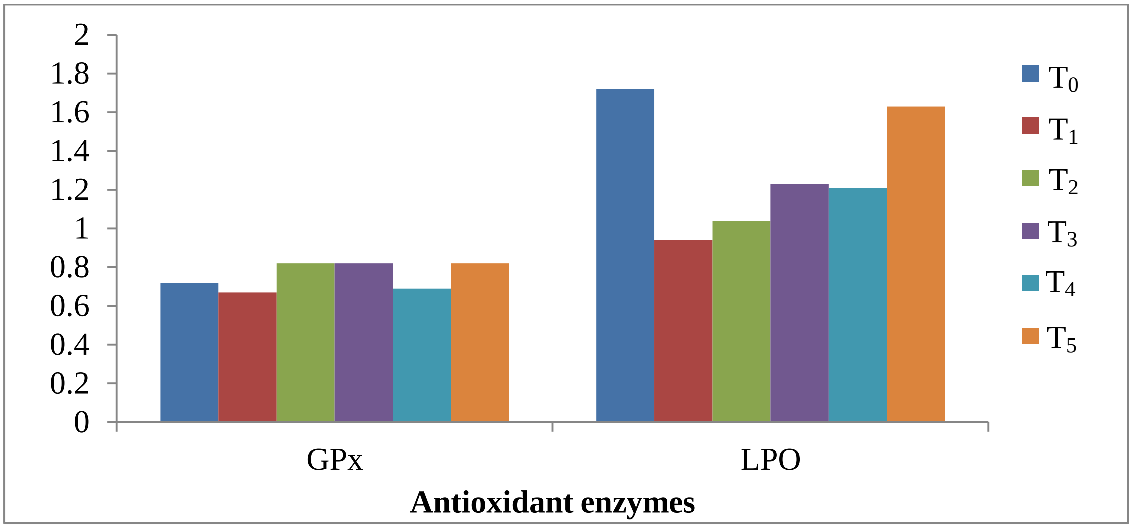

Figure 17: Antioxidant enzymes- GPx and LPO at 3rd week

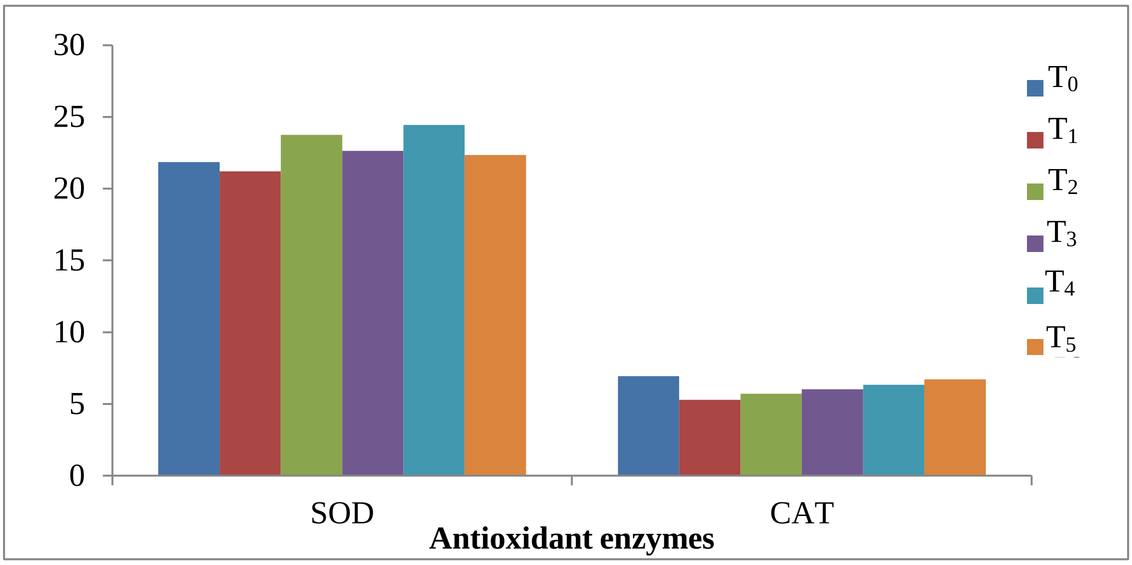

Figure 18: Antioxidant enzymes- SOD and CAT status at 3rd week of age

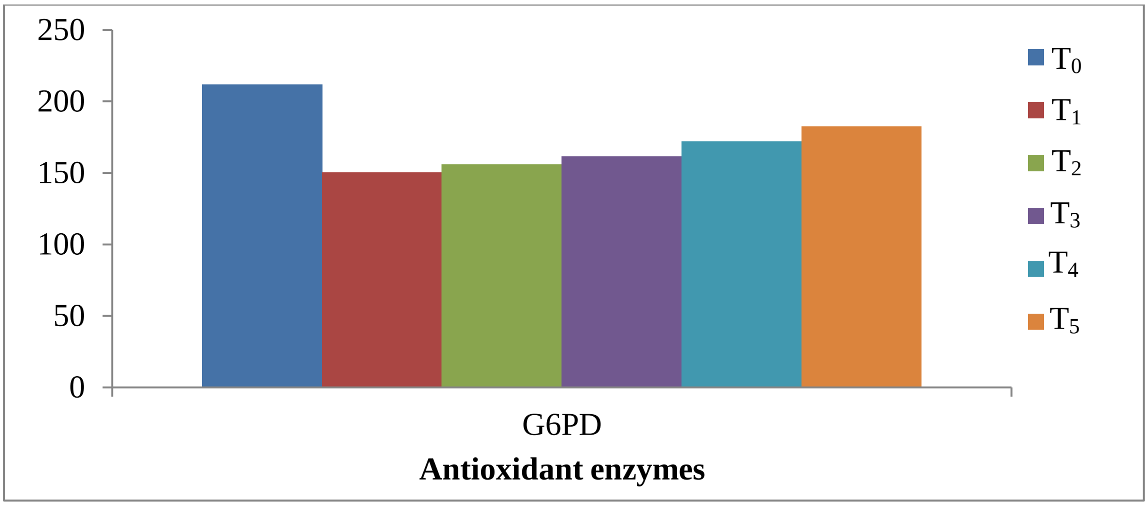

Figure 19: Antioxidant enzymes- G6PD status at 3rd week of age

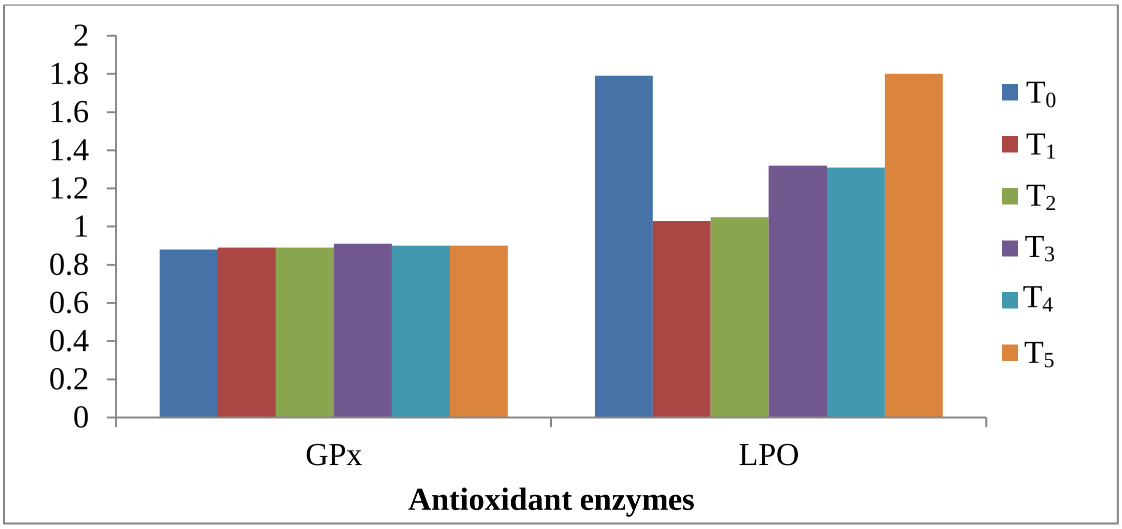

Figure 20: Antioxidant enzymes- GPx and LPO status at 6th week of age

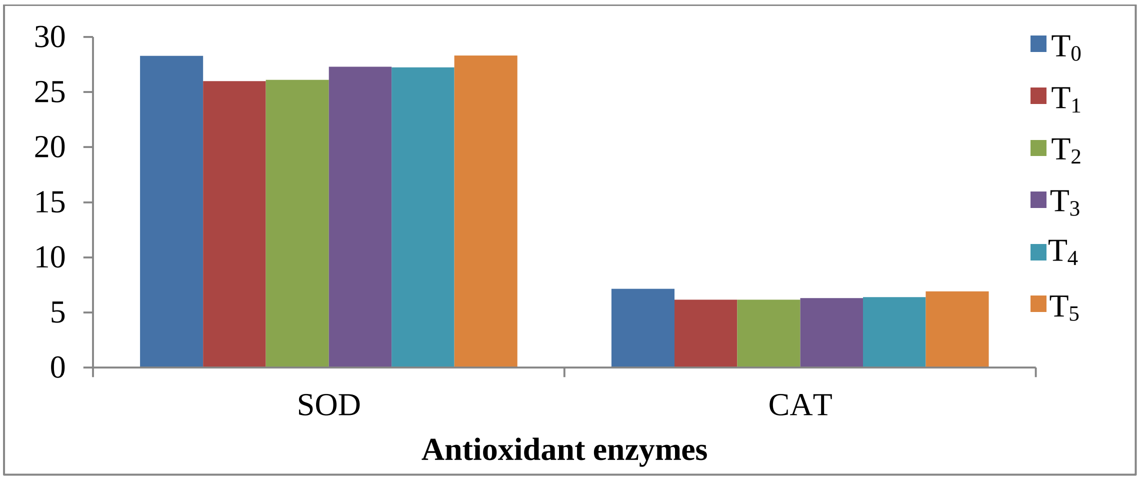

Figure 21: Antioxidant enzymes- SOD and CAT status at 6th week of age

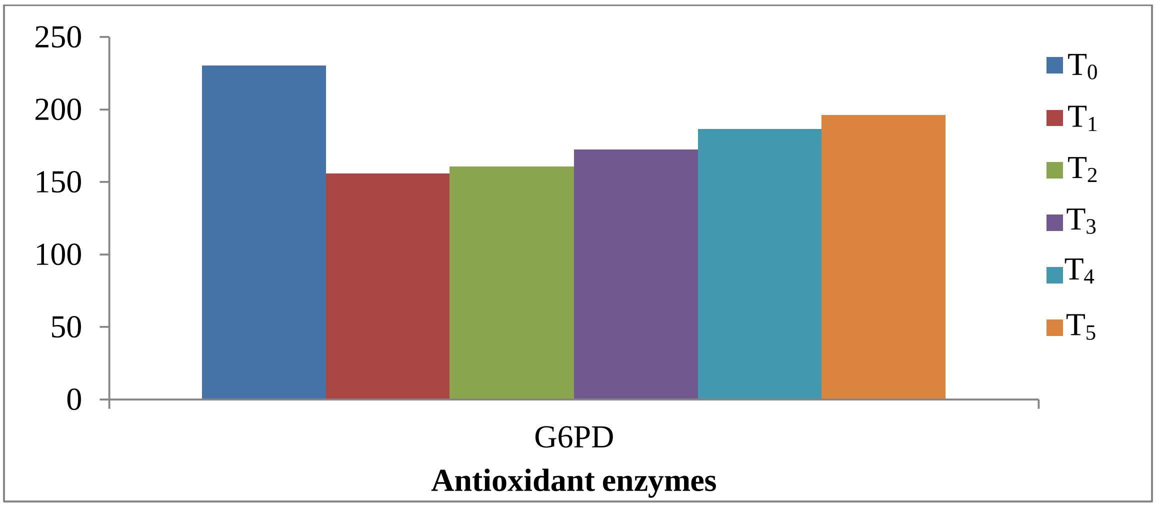

Figure 22: Antioxidant enzymes- G6PD status at 6th week of age

Therefore, in present study significantly ($p \leq 0.05$) higher level of anti-oxidant enzymes in OSCBH group can be explained due to higher heat stress to broiler chicks due to higher shed THI (Table 4.1).

4.4 Carcass Characteristics

The data on carcass characteristics after 6th week of age have been presented in Table 4.23.

a) ***Eviscerated carcass yield:*** Eviscerated carcass yield at 6th week of age among different treatment groups varied from 57.63 to 62.64 %, which was highest in T_5 followed by T_0, T_1, T_2, T4 and T3. Eviscerated carcass yield did not differ significantly ($p \leq 0.05$) among different treatment groups.

b) ***Drum stick*:** Drum stick yield at 6th week of age among different treatment groups varied from 14.26 to 15.20%, which was highest in T_2 followed by T_1, T_3, T_4, T_0 and T_5 but did not differ significantly ($p \leq 0.05$) in different treatment groups.

c) ***Thigh*:** Thigh yield at 6th week of age among different treatment groups varied from 12.34 to 13.64%, which was highest in T_2 followed by T_4, T_5, T_1, T_3 and T_0 but did not differ significantly ($p \leq 0.05$) in different treatment groups.

d) ***Breast*:** Breast yield at 6th week of age among different treatment groups varied from 25.13 to 28.22%, which was highest in T_2 followed by T_0, T_4, T_3, T_1 and T_5 but did not differ significantly($p \leq 0.05$) in different treatment groups.

e) ***Neck:*** Neck yield at 6th week of age among different treatment groups varied from 2.43 to 3.37%, which was highest in T_0 and followed by T_3, T_2, T_5, T_4 and T_1, but did not differ significantly($p \leq 0.05$) in different treatment groups.

f) ***Back*:** Back yield at 6th week of age among different treatment groups varied from 23.26 to 26.77%, which was highest in T_1 and followed by T_5, T_0, T_4, T_3 and T_2, but did not differ significantly($p \leq 0.05$) in different treatment groups.

g) ***Wing:*** Wing yield at 6th week of age among different treatment groups varied 7.66 to 9.70%, which was highest in T_5 and is followed by T_0, T_3, T_2, T_4 and T_1 but did not differ significantly ($p \leq 0.05$) in different treatment groups.

h) ***Giblet:*** Giblet yield at 6th week of age among different treatment groups varied 7.82 to 9.03% being highest in T_4 followed by T_3, T_5, T_1, T_2 and T_0 but did not differ significantly ($p \leq 0.05$) in different treatment groups.

Table 4.23: Effects of different treatments on carcass characteristics

Parameter (%)	Carcass Characteristics					
	T_0	T_1	T_2	T_3	T_4	T_5
Fasting body weight	1423.75±61.89	1726.00±52.17	1641.00±84.01	1535.00±92.15	1450.00±104.00	1613.75±76.09
Eviscerated carcass*	62.18±1.08	61.48±1.89	61.35±0.72	57.63±0.69	58.28±0.88	62.64±1.07
Drumstick**	14.68±0.22	15.11±0.52	15.20±0.20	15.01±0.86	14.87±0.74	14.26±0.66
Thigh**	12.34±0.31	13.33±0.84	13.64±1.09	12.89±0.61	13.56±0.30	13.44±0.82
Breast**	27.67±0.82	26.06±1.12	28.22±1.30	26.91±1.64	27.30±1.42	25.13±0.80
Neck**	3.37±0.34	2.43±0.28	3.09±0.58	3.14±0.79	2.59±0.30	2.98±0.34
Back**	25.00±2.01	26.77±0.60	23.26±2.50	24.33±1.43	24.62±0.61	25.78±1.78
Wing**	9.12±0.67	7.66±0.33	8.27±0.66	8.74±0.07	8.03±0.94	9.70±0.70
Giblet**	7.82±0.50	8.64±0.80	8.32±0.27	8.98±0.62	9.03±0.28	8.71±0.15
Blood *	4.18±0.21	4.03±0.56	3.25±1.11	5.02±1.47	4.88±0.89	5.31±0.97
Feather*	5.41±0.20	5.19±0.44	4.55±0.46	3.93±0.55	5.01±0.49	5.68±1.73
Skin*	6.99±0.33	6.69±0.32	6.07±0.39	7.28±0.69	7.73±0.76	6.64±1.36
Head and shank*	6.74±1.42	7.56±0.23	8.40±0.13	8.19±0.39	7.65±0.38	8.60±0.47
Intestine*	7.58±0.38	9.46±1.86	9.24±0.37	10.54±0.71	10.00±0.60	7.30±0.28
Abdominal Fat*	1.07±0.24	1.47±0.25	1.83±0.33	1.21±0.15	1.64±0.12	1.18±0.30
Total Inedible Offals*	31.97±0.96	34.40±2.07	33.33±0.44	36.16±0.73	36.90±1.17	34.71±0.86

Means with different superscripts in a row differ significantly ($P \leq 0.05$)
****Indicates percent of fasting body weight***
*****Indicates percent of eviscerated carcass weight.***

i) ***Inedible offal:*** Inedible yield at 6^{th} week of age among different treatment groups varied 31.97 to 36.90%, which was highest in T_4 followed by T_3, T_5, T_1, T_2 and T_0 but did not differ significantly ($p \leq 0.05$) in different treatment groups.

Among the different treatment groups no significant ($p>0.05$) difference was observed in carcass and prime cuts yield. These results were in agreement with Nogueira *et al* (2013), Fairchild (2005) and Tong *et al* (2012) who reported that carcass and parts yield was not influenced ($p \leq 0.05$) neither by stocking density nor by dietary energy level.

4.5 Economics of Broiler Production

The data of economics of broiler production on per bird and unit live body weight basis have been presented in Table 4.24 and Table 4.25.

a) ***Feeding cost*****:** On per bird basis, at the end of 5^{th} and 6^{th} week of age, in comparison to T_0, feeding cost only in T_1 and T_2 was lower but in T_3, T_4 and T_5 feeding cost was higher than T_0.

On unit live body weight basis, at the end of 5^{th} and 6^{th} week of age, in comparison to T_0, feeding cost only in T_1 and T_2 was lower but in T_3, T_4 and T_5 feeding cost was higher than T_0. Lower feeding cost in T_1 and T_2 could be attributed to higher body weight gain and FCR (Table 4.5 and 4.9)

b) ***Working expenditure***: On per bird basis, at the end of 5^{th} and 6^{th} week of age, in comparison to OSCBH (T_0), working expenditure was highest in all other ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups which was due to the additional electricity cost for running of cooling system.

On unit live body weight basis, at the end of 5^{th} week, in comparison to OSCBH (T_0), working expenditure was less in T_1, T_2 and T_3, whereas it was higher in T_4 and T_5. However, at the end of 6^{th} week, working expenditure was highest in all other ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups.

c) ***Margin of receipt*****:** Margin of receipt on per bird basis, at the end of 5^{th} week for respective treatment groups was higher than margin of receipt at 6^{th} week of age. Margin of receipt per bird at 5^{th} week of age Rs. 9.02 was highest for T_1, followed by Rs. 8.21 for T_2, Rs. 4.05 for T_0 and Rs. 2.44 for T_3. While, in T_4 and T_5 a loss of Rs. 3.52 and Rs. 4.24 per bird was incurred. However, margin of receipt on per bird basis after 6^{th} week of age was maximum Rs. 2.36 for T_1, Rs. 1.32 for T_0 and Rs. 0.18 for T_2 but, there was loss of Rs. 5.22 for T_3, Rs. 10.33 for T_4 and Rs. 13.01 for T_5.

Table 4.24: Economics of broiler production on per bird basis

Parameter	Treatment (5th week)						Treatment (6th week)					
	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5
Feeding cost per bird	59.39	68.67	68.36	65.68	62.80	62.52	80.02	92.18	91.04	87.63	83.56	84.17
Electricity cost per bird	0	5.69	5.13	4.51	3.97	3.40	0	9.11	8.22	7.22	6.35	5.44
Chick Cost	24	24	24	24	24	24	24	24	24	24	24	24
Working Expenditure (Rs.)	83.39	98.36	97.49	94.19	90.77	89.92	104.02	125.29	123.26	118.85	113.91	113.61
Average body weight of bird (Kg)	1.15	1.41	1.39	1.27	1.15	1.13	1.39	1.68	1.62	1.50	1.37	1.32
Receipt from sale of per bird sold @ Rs.75/Kg live weight	87.44	107.38	105.71	96.64	87.25	85.68	105.34	127.66	123.44	113.62	103.58	100.60
Margin of receipt per bird over feed, electricity and chick cost (Rs.)	4.05	9.02	8.21	2.44	-3.52	-4.24	1.32	2.36	0.18	-5.22	-10.33	-13.01
Difference in margin of receipt over control per bird	0	4.97	4.16	-1.61	-7.57	-8.29	0	1.04	-1.14	-6.54	-11.65	-14.33
Margin of receipt per unit area (Rs.)	4.05	9.02	9.13	3.05	-5.02	-7.07	1.32	2.36	0.20	-6.53	-14.77	-21.69
Difference in Margin of receipt per unit area over control per bird	0	4.97	5.08	-1	-9.07	-11.12	0.00	1.04	-1.12	-7.85	-16.09	-23.01
Cost Benefit Ratio	1:1.04	1:1.09	1:1.08	1:0.96	1:0.96	1:0.95	1:1.01	1: 1.02	1:1.00	1:0.95	1:0.90	1:0.89

Table 4.25: Economics of broiler production on live unit body weight basis

Parameter	Treatment (5th week)						Treatment (6th week)					
	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5
Feeding cost per Kg live weight (Rs.)	51.64	48.70	49.18	51.71	54.61	55.33	57.57	56.55	56.20	58.42	60.99	60.55
Electricity cost per Kg live weight (Rs.)	0.00	4.04	3.69	3.55	3.45	3.01	0	5.59	5.07	4.91	4.64	3.91
Chick price per Kg live weight (Rs.)	20.86	17.02	17.26	18.90	20.86	21.23	17.26	14.28	14.81	16	17.51	18.18
Working Expenditure (Rs.)	72.5	69.76	70.13	74.16	78.92	79.57	74.77	76.42	76.08	79.33	83.14	82.64
Margin of receipt over feed, electricity and chick cost sold @ 75 Rs./Kg live weight	2.50	5.24	4.84	0.84	-3.92	-4.56	0.17	-1.42	-1.08	-4.33	-8.14	-7.64
Difference in margin of receipt over control per Kg live weight	0	2.74	2.37	-1.66	-6.42	-7.06	0	-1.54	-1.25	-4.50	-8.31	-7.81
Margin of receipt per unit area per Kg live weight	3.52	6.40	6.57	2.40	-4.37	-6.26	0.95	1.40	0.12	-4.35	-10.78	-16.43
Difference in Margin of receipt per unit area over control per Kg live weight	0	3.52	3.65	-0.79	-7.89	-9.84	0	-0.62	-0.69	-5.23	-11.74	-17.43

On unit live body weight basis also, margin of receipt after 5th week of age for respective treatment groups was higher than margin of receipt after 6th week of age. Margin of receipt per unit live weight after 5th week of age Rs. 5.24 was highest for T_1 followed by Rs.4.87 for T_2, Rs. 2.50 for T_0 and Rs. 0.84 for T_3. While, in T_4 and T_5 a loss of Rs. 3.92 and Rs.4.56 per unit live weight was incurred. However, margin of receipt on per unit live weight basis after 6th week of age was highest Rs. 0.17 for T_0, whereas, for all ECBH treatments there was loss Rs. 1.42 for T_1, Rs. 1.08 for T_2 and Rs. 4.33 for T_3, Rs. 8.14 for T_3, Rs. 8.14 for T_4 and Rs. 7.64 for T_5.

***Margin of receipt per unit area*:** On per bird basis, after 5th week of age was maximum Rs. 9.13 for T_2, Rs. 9.02 for T_1, Rs. 4.05 for T_0 and Rs. 3.05 for T_3 but, there was loss of Rs. 5.02 for T_4 and Rs. 7.07 for T_5. However, margin of receipt from live bird per unit area after 6th week of age was maximum Rs. 2.36 for T_1, Rs. 1.32 for T_0 and Rs. 0.20 for T_2 but there was loss of Rs. 6.63 for T_3, Rs. 14.77 for T_4 and Rs. 21.69 for T_5.

On unit live body weight basis, after 5th week of age was maximum Rs. 6.57 for T_2, Rs. 6.40 for T_1, Rs. 3.52 for T_0 and Rs. 2.40 for T_3 but, there was loss of Rs. 4.37 for T_4 and Rs. 6.26 for T_5. However, margin of receipt from unit live weight per unit area after 6th week of age was maximum Rs. 1.40 for T_1, Rs. 0.95 for T_0 and Rs. 0.12 for T_2 but there was loss of Rs. 4.35 for T_3, Rs. 10.78 for T_4 and Rs. 16.43 for T_5.

These results indicated that margin of receipt per bird basis, live unit weight basis and live weight per unit area basis in different treatments in both OSCBH and ECBH decreased after 6th week of age, this decrease may be attributed to growth and FCR depression after 5th week of age and more expenditure due to operating cost of cooling system**.** Margin of receipt on per bird and on per Kg live weight basis in ECBH was highest in T_1, on similar space allowance of 1ft^2 per bird, as provided in OSCBH. However, margin of receipt per bird and per Kg live weight in ECBH treatment groups, decreased with increasing stocking density but margin of receipt in per bird per unit floor area and Kg live weight per unit area was highest in T_2 with stocking density of 0.9/ft^2/bird. It can be inferred from these finding that tunnel ventilated evaporative cooling systems increased economic return through improving growth performance of broiler and increasing space use efficiency by 10%. In comparison, to control margin of receipt per bird and per Kg per unit area was 55% higher even at 10% reduction (T_2) of floor space in ECBH group.

Similar to these findings, Mayers *et al* (2007) also found tunnel ventilated house as more profitable venture than conventional house with benefit cost ratio of 1.18 and 1.05, respectively. However, Salas *et al* (2013) reported 150% return over expenses in climate control houses than only 84% in conventional broiler house.

CHAPTER V

SUMMARY AND CONCLUSION

This study was conducted to assess the efficacy of tunnel ventilated evaporative cooling environment control shed to alleviate heat stress, improve performance, welfare and economic return in broiler production under different stocking densities. A total of 984 commercial Vencobb broiler chicks for 42 days reared on deep litter system, were subjected to 6 different housing treatments with 3 replicates each. The treatments comprised of housing of broilers in open sided conventional shed (OSCBH; T_0) with floor space of allowance of 1ft^2 per bird and five different treatments in tunnel ventilated evaporative cooling environment control house (ECBH) were, housing of broilers with increasing stocking densities and decreasing floor allowance of 1.0, 0.9, 0.8, 0.7 and 0.6 ft^2 per bird in T_1, T_2, T_3, T_4 and T_5, respectively.

The results of shed microclimate indicated that during entire experimental period, shed temperature and temperature-humidity index (THI) recorded at 12:00 and 15:00 IST was significantly ($p \leq 0.05$) lower in ECBH than OSCBH. Additionally, maximum-minimum temperature was also significantly ($p \leq 0.05$) lower in ECBH (T_1, T_2, T_3, T_4 and T_5) than OSCBH (T_0) treatment groups.

Litter moisture and pH among all treatment groups in both types of houses did not differ significantly ($p \leq 0.05$) and were within the permissible limits for optimum in house environment for broiler production.

The data on growth performance reveled that, in comparison to OSCBH (T_0), broilers in ECBH group, even up to 20% higher stocking density in T_3, attained significantly ($p \leq 0.05$) more final body weight and consumed more feed and protein. While feed, protein and energy efficiency of broilers up to 20% increase in stocking density in ECBH (T_3) was comparable to OSCBH (T_0), which further decreased significantly ($p \leq 0.05$) with increasing stocking density in (T_4 and T_5).

The broiler welfare assessed on the basis of rectal temperature indicated that during different weeks the rectal temperature in OSCBH (T_0) was significantly ($p \leq$ 0.05) higher than all the ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups, however, in

ECBH (T_1, T_2, T_3, T_4 and T_5) treatment groups, rectal temperature increased with the increase in age and stocking density. In behavioral activities of birds, incidence of feeding and resting activity was significantly ($p \leq 0.05$) higher in ECBH (T1, T_2, T_3, T_4 and T_5) than in OSCBH (T_0). However, panting, preening, dust bathing, wing flapping and scratching activities were significantly ($p \leq 0.05$) higher in OSCBH (T_0) group as compared to ECBH (T_1, T_2, T_3, T_4 and T_5) groups, but, within ECBH treatment groups these activities increased significantly ($p \leq 0.05$) as the stocking density increased. Stress related anti-oxidant enzyme (Glutathione peroxidase, Lipid peroxidation, Superoxide dismutase, Catalase and Glucose-6-phosphate dehydrogenase) concentrations were higher in OSCBH ($T_{0)}$) than ECBH (T_1, T_2, T_3, T_4 and T_5). Various body lesions i.e. foot pad dermatitis, breast blisters, hock burn, gait, and general cleanliness were well within normal welfare range and did not differ significantly among different treatment groups.

Eviscerated carcass and prime cut yield, did not vary significantly ($p \leq 0.05$) among OSCBH (T_0) and ECBH (T_1, T_2, T_3, T_4 and T_5) groups.

After 5th week of age, margin of receipt per bird and per Kg per unit area was 55% higher even at 10% reduction (T_2) of floor space in ECBH group than OSCBH (T_0).

Cost benefit ratio on per bird basis, at end of 5th week, 1:1.09 in T_1, and 1:108 in T_2 was higher and 1:1.02 in T_3 was lower than 1:1.04 in T_0 .Whereas, there was a loss in T_4 and T_5 with ratio of 1:0.96 and 1:0.95. At the end of 6th week, a similar profit with cost benefit ratio 1.01 was incurred only in T_0 and T_1.

From these findings it can be concluded that:

a) Environment controlled tunnel ventilated evaporative cooling system, effectively reduced maximum and minimum temperature and modified relative humidity to provide better THI to ensure comfortable microenvironment conditions to broilers than in OSCBH.

b) ECBH ensured significantly better growth performance of broilers even at 20% reduction of floor allowance than conventional house.

c) Eviscerated carcass and prime cut yield did not reduced in ECBH even at higher stocking density at 40% reduction of floor allowance.

d) Broiler welfare assessed on the basis of behavior, plasma antioxidant enzyme levels and different body lesions indicating physical injury was better ECBH than OSCBH.

e) Economic return per unit floor area was highest in T_2 group in ECBH with floor area of 0.9 ft^2/ bird.

Therefore, tunnel ventilation evaporative cooling system installed environment control houses (ECBH) can be recommended to alleviate heat stress, improve growth performance, land use efficiency and economic returns of broiler production even at 10% higher stocking density.

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