Low Cost Cooling System for Poultry Shed

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Abstract

India has a meat eating population of about 60 percent and increasing. The poultry industry is a rapidly growing sector with annual growth rate of about 8-10 percent. Ambient conditions, especially high temperature in combination with high relative humidity in poultry shed leads to heat stress in poultry birds and in turn reduces their productivity and increases mortality significantly. India, being predominantly a tropical country, the day time temperatures during summer reaches as high as 45°C at many places. The capital and operational cost of conventional evaporative air cooling system is very high as compared to the investment standards of poultry management in India. Apart from this, poultry sheds are generally located in rural areas where schedule power cuts are normal affair. The operation cost of cooling system on generator power is 3-5 times higher. Hence, majority of the poultry operators do not use proper cooling system which makes them susceptible to the adverse effects of temperature on production cost and hence profits. The present work is directed towards developing low cost cooling effect through operational interventions. It incorporates use of different techniques and management practices to eliminate effect of heat stress in poultry birds. The system reduces mortality, improve productivity and thereby increase profit for the farm owner.

Keywords: *Heat stress, evaporative cooling, poultry management.*

1. Introduction

In India, poultry industry has made rapid progress in the last three decades. Its development has not only been in size but also in productivity, technology up gradation and quality of its products measuring to strictest norms. Egg production was around 73.89 billion in 2013-14, while poultry meat production was estimated at 2.68 million tons (Eco Survey 2015). For calendar year 2016, broiler production is projected to increase by approximately eight percent to 4.2 million tons on rising demand from growing middle class. Post estimates demand for processed chicken meat is growing between 15-20 percent per year. Calendar year 2016 layer production is forecast at 80 billion eggs, up five per cent from last year. [GAIN Report IN5124]

Problem of heat stress, though being seasonal and of variable duration, its effects can be economically significant. As birds body temperature rises, feed consumption, growth rate, feed efficiency, egg shell quality and survivability decline. Many solutions have been proposed, but no sure cure exists for this dilemma (Robert G. Teeter *et al,* 1996).

Heat stress not only causes suffering and death in the birds, but also results in reduced or lost production that adversely affects the profit from the enterprise. Therefore, there is a need to re-evaluate the management of poultry and equipment used in hot weather so that heat stress is minimized.

Motivation:

There have been different studies conducted to safeguard the poultry birds from high ambient temperatures through cooling of poultry sheds using fans and coolers. But, due to inefficient temperature maintenance within desired range and large investment required, adaption of such management practices remained questionable. Further, use of these cooling systems becomes impractical during monsoon season, when both temperature and humidity remains high. Likewise, environmental controlled poultry houses are yet uncommon in India and such facilities may increase the cost of production. This will lead to uneconomical poultry production.

The environmentally cooled closed poultry houses are used by big players and integrators but these are not economically affordable to medium and small poultry farm owners. Apart from this, poultry sheds are generally located in rural areas where schedule power cuts are normal affair. The operation cost of cooling system on generator power is 3-5 times higher. Hence, majority of the poultry operators do not use proper cooling system which makes them susceptible to the adverse effects of temperature on production cost and hence profits.

Moreover, the authors were approached by a layer farm owner from Pune district of Maharashtra, who is facing losses in productivity and profits due to heat stress in birds caused during summer months. With increasing instances of extreme temperature conditions, the losses due to heat stress are aggravating every year.

This work is undertaken to study this problem from the point of view of thermal engineer and to find out engineering solution that is easy to implement and affordable to medium to small farm owners.

2. Literature Survey

Heat stress is developed in birds during hot weather. DEFRA report states that birds are 'heat stressed' if they have difficulty achieving a balance between body heat production and body heat loss. Also this can occur at all ages and in all types of poultry.

Butcher *et al* observed that high ambient temperatures can be devastating to commercial broilers and when it is combined with high humidity, they can have more harmful effects. Thus heat stress interferes with broiler comfort and suppresses productive efficiency. Further the team observed that during periods of heat stress, broiler has to make major thermo-regulatory adaptations in order to prevent death from exhaustion. Full genetic potential of broilers is not often achieved due to all these reasons (Gary D Butcher *et al)*.

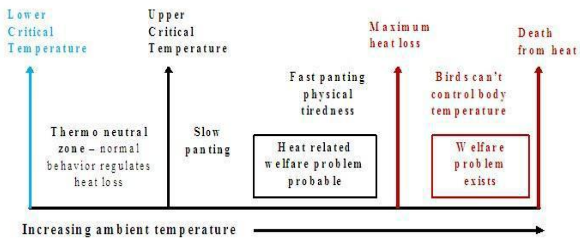

Fig 1: Thermo-neutral zones

As illustrated in figure 1 by DEFRA report, between the lower and upper critical temperature, birds can lose heat at a controlled rate using normal behavior. There is no heat stress and body temperature is held constant. According to John Watt, this range lies between 21 to 26.7 ^{0}C. When 'upper critical temperature' ie 26.7 ^{0}C is exceeded, birds must lose heat actively by panting. Panting is a normal response to heat and is not initially considered a welfare problem. But as the temperature increases further the rate of panting increases. Beyond 29.4 ^{0}C, birds reduce their feed consumption and as temperature cross 32.2 ^{0}C, the egg size and production decreases in layers. Watt observes that beyond 35 ^{0}C, hens start losing weight. If heat production still increases beyond 'maximum heat loss' by the bird's body, either in intensity (acute heat stress) or over long periods (chronic heat stress), birds will die. As per Watt's observations, birds start dying beyond 37.8 ^{0}C ambient temperature. DEFRA report observed that body temperature of the broiler must remain very close to 41 ^{0}C (106 ^{0}F). If body temperature raises more than 4 ^{0}C above this, the bird will die. As per Watt, body temperature of broiler is 41.7 ^{0}C. It is important to note that a welfare problem is likely to occur somewhere between the 'upper critical temperature' and 'maximum heat loss', i.e. before bird losses occur (DEFRA, 2005). Teeter et al have observed through experiments that 32 ^{0}C and 50% relative humidity are the benchmarks for beginning of heat stress in hot environments (Teeter Robert *et al.* 1996).

Medlin et al has stated in their patent report that poultry houses must be ventilated and cooled to prevent the mortality of the poultry when the sum of the ambient temperature and the relative humidity inside the poultry house exceeds a known value. It is generally accepted that when the sum of the ambient temperature, measured in degrees Fahrenheit, and the relative humidity exceeds about 180, the poultry can easily suffer mortality. Most poultry farmers agree that it is necessary to reduce the ambient temperature inside the poultry house when the sum of the ambient temperature and the relative humidity exceeds about 160. To this end, it is desirable to maintain the ambient temperature inside the poultry house at or below about 82 degrees Fahrenheit i.e. 27.7 ^{0}C. It can be seen that where relative humidity is less, little higher temperatures could be acceptable as comfortable for birds.

How is body heat produced?

As mentioned in DEFRA report, heat is produced by metabolism within the body, which includes maintenance, growth and egg production. Heat production is affected by body weight, species and breed, level of production, level of feed intake, feed quality and, to a lesser extent, by amount of activity and exercise (DEFRA, 2005). Gupta et al has noticed that metabolic rates are high in modern day poultry due to their high growth rates and this further aggravates the situation during heat stress (Rohit Gupta *et al*, 2013).

Heat is also added from the roof, walls, working litter and electric bulbs used in the shed.

How do birds lose heat?

According to Lara et al, heat stress leads to certain behavioral and physiological effects, suppresses the immune response and thus ultimately affects the poultry production (Lucas J Lara *et al,* 2013).

Yahav et al stated that the main environmental factors affecting performance of broiler chicken are ambient temperature, relative humidity and air velocity. At high temperatures, it is important to maintain body energy and water balance. Further they observed that birds, as homeotherms, can balance body energy by reducing heat production, increasing evaporative heat loss (via panting) and increasing sensible heat loss (convection and radiation) or a combination of these (S. Yahav *et al,* 2004).

DEFRA report has explained the ways by which birds lose heat in normal ways. These are discussed below.

Radiation- Heat will be lost from the body by radiation if the surrounding surfaces are below bird surface temperature. Conversely, hot walls and roofs may radiate heat to the bird surfaces. In short, it is difficult for birds to lose heat by the way of radiation if the ambient temperatures are higher.

Convection- Heat loss will occur from the natural rise of warm air from around a bird's hot body. Providing moving air can assist convection, but only if the air moves fast enough to break down the boundary layer of still air that surrounds the body. Gupta et al had found that exhaust fan and ceiling-fan both have significant effect on the comfort and production efficiency of broiler chicks during hot humid season. Further they found that exhaust fan system was more efficient than cooling fan system (Rohit Gupta *et al*, 2013).

Conduction- Heat will transfer from one surface in contact with another surface, for example, if the birds are seated on litter that is cooler than their bodies, then they lose heat to the litter as long as it is cooler than the bird's body. However, the litter immediately under the birds soon assumes a temperature close to that of the body. Birds also lose heat to cooler surfaces like walls; cement blocks which are cooler than bird's body via conduction.

Further DEFRA reports that, after the birds can no longer maintain its body heat balance by one of these three methods, it must use "evaporative heat loss", or panting. Evaporative heat loss, whilst essential to the bird, does not contribute to heating the house.

Evaporation is very important at high temperatures as poultry does not sweat but depend on panting for losing extra heat. This is only effective if the humidity is not too high. Hot, humid conditions are therefore much more stressful than hot dry conditions (DEFRA, 2005).

Yahav et al observed that panting is an evaporative kind of heat loss and is a much higher energy cost pathway for heat loss than sensible heat loss. Panting further affects blood acid-base balance and body water balance thus adversely affecting the ability to maintain body temperature in a normothermic range. Importance of air velocity at high ambient temperatures lies in its effect on body energy and water balance.

Yahav et al observed that any shift from evaporative to sensible heat loss may reduce maintenance energy and thus increase the amount of energy available for growth. Sensible heat loss can also prevent hyperthermia caused by dehydration, which results from severe panting. Unbalanced energy and water budgets are detrimental to broiler performance. At high ambient temperatures, optimal air velocity may enable cooling to be partially shifted from the evaporative to the sensible pathway and so to improve both water and energy balance (S. Yadav *et al,* 2004).

This means that evaporative cooling should be used as next option to ventilation and high air speeds for cooling.

Field survey:

Field data was collected showing mortality of birds over last one year at a layer farm located in Pune district of Maharashtra. The flock size is 13000 birds and the bird variety is White leg horn BV 300.

Table 1: Field data showing monthly mortality of birds at layer farm in Pune district

Month/year	Mortality	Percentage	Reason
18 Apr to 30 Apr 2015	90	0.71	Summer + Dehydration
May '15	87	0.70	Summer + Dehydration
June '15	130	1.00	Summer + Entritis
July '15	64	0.50	Summer + Entritis
Aug '15	33	0.26	
Sept '15	35	0.26	
Oct '15	24	0.22	
Nov '15	32	0.26	
Dec '15	27	0.28	
Jan '16	54	0.42	
Feb '16	37	0.27	
March '16	70	0.54	Summer
Apr '16	331	2.62	Summer

The data in above table clearly shows that the problem of heat stress is seasonal and summer heat has distinct effect on the mortality of birds. The mortality increases significantly in the months of March, April, May and June which are typically summer months.

It is observed that the effect of heat stress is amplified as we move towards the continental part of the country. Mainly north, central and south central parts of India covering Uttar Pradesh, Madhya Pradesh, Maharashtra, Telangana, Andhra Pradesh and Karnataka which is major area with poultry farms and has higher average summer temperatures and wide diurnal temperature ranges.

3. Objectives and Scope:

Objectives of this work involves study of the effects of heat stress on poultry birds, use different techniques for cooling the poultry sheds and thereby reduce mortality in birds caused during hot summer months and to develop the instrumentation set up required.

Scope of the work is limited to avoiding the mortality in the birds caused due to peak heat stress during summer months of the year. It is also aimed to develop an operational protocol to avoid the heat stress in the birds.

4. Methodology and experimentation:

Some interventions could be made at different stages of poultry management. Design level changes could be introduced in the design of the poultry shed itself along with arrangement and use of cages. The technological interventions to be done for the use of medium and small poultry farmers, therefore, needs to be technically feasible, economically viable, easy to develop and install and be easy to operate. Operational interventions need to be specific, easy to understand and effective.

Experimental work:

In this work, we are mainly focusing on reducing radiation heat gain through roof, convective cooling by air ventilation and air circulation by using ceiling fans and evaporative cooling if required in extreme cases.

Experimental set up involves two portions of shed 10 x 30 ft. floor area each enclosed and separated from each other. In one portion, experimental arrangements are done while the other portion is used to compare the results. Each portion contains 60 birds each. The feed is given by automatic feeder for both the sections. Water supply is also automatic through nipple waterers connected to pipeline.

Heat radiation from roof is reduced by application of reflective paint. The inner surface temperature of the cement sheets of roof is expected to be reduced by 15 ^{0}C to 20 ^{0}C. This will significantly reduce the heat gain by the bird's body by radiation from the roof.

Air ventilation is provided with the help of exhaust fans. Appropriate number of air exchanges will be provided depending on the stock size. Following figure 2 shows the schematic of proposed ventilation system.

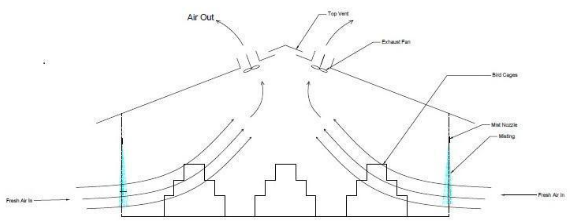

Fig 3: Schematic showing Air Ventilation and Evaporative Cooling.

Air ventilation will help in keeping the heat built up inside the shed to a minimum. Air movement will be provided over the bird's body surface by use of ceiling fans at appropriate locations. Moving air with appropriate velocity will increase the convective heat transfer from the bird's body. Attempt will be made to run these fans on solar energy to reduce the operating cost. Use of evaporative cooling will be made in extreme climatic conditions to keep the inside temperatures of the shed within acceptable limits.

The system will be tested one by one. First of all, the effect of reflective paint will be measured on temperature inside the shed. This will be measured by comparing the inside temperature of the roof sheet in the experimental portion with that in the control portion. After that ceiling fans will be operated and cooling effect will be measured by measuring ambient temperature inside the shed. Next, the exhaust fans will be run and the effect of air ventilation on both ambient temperatures in the shed and relative humidity will measured. Lastly, in the extreme temperature conditions, the evaporative cooling system if started so as to reduce the inside temperature of the poultry shed. If it is possible to maintain the ambient temperature inside the shed within the set limit that is 35 ^{0}C, then the next sub-system is not operated.

Measuring instrument:

An instrument set has been developed for measurement, data collection and data transfer purpose. It includes two flow meters, one energy meter, one universal scanner- all MASIBUS make, two sets of 12 VDC power supply of ANALOGIC make, one data logger, one SMPS and an instrument box holding them all.

Fig 2: Measuring instrument for data collection and storage

This instrument is used to measure parameters like ambient temperature, drinking water consumption, energy consumption etc. the data will be collected in a data logger through universal scanner. Arrangement is made to send the data remotely for analysis with the help of a communication device installed inside the instrument.

5. Results:

The mortality data for both samples is given in the following table.

Table 2: Mortality data of layers over 10 week trial period

Week	Mortality	
	Controlled portion	Normal portion
1	0	1
2	0	0
3	0	0
4	0	0
5	0	1
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
Total	0	2
Percentage	0	3.33

It is possible to maintain the ambient temperature inside the poultry shed within the acceptable limits. This reduces the mortality in the chicken caused by heat stress. Also bird comfort is improved due to which feed conversion also increases improving the production efficiency.

6. Conclusion:

Environmental cooling and tunnel ventilation are cost intensive and affordable only to large integrators and big farmers. Small and medium farmers can use simple and cost effective operational interventions to avoid the mortality and loss in production caused due to heat stress. Better management practices are beneficial for improving profits for small farmers.

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