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Controlled system for cooling naturally ventilated poultry house: Review

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Abstract
The review discusses control systems for cooling naturally ventilated poultry houses, highlighting the importance of maintaining optimal climatic conditions for poultry birds' growth. With the increasing need for proper climate control due to diverse climatic challenges, the paper highlights the significance of natural ventilation and cooling systems, such as fogging and evaporative cooling, in enhancing productivity and quality. The review summarizes various studies demonstrating these cooling methods effectiveness in regulating temperature, relative humidity, and temperature humidity index (THI). Additionally, it explores the impact of improper climate conditions on production, particularly focusing on temperature and humidity effects on growth and yield. The paper concludes by discussing automated control systems developed for poultry house management.

Keywords: Temperature humidity index (THI), Poultry houses, natural ventilation

Introduction
An essential component of the Indian economy is livestock. In 2019-20, the livestock industry accounted for 4.35% of the total gross value added (GVA). The overall number of poultry in India was 851.81 million in 2019, a 16.8% rise from the roughly 729.2 million recorded in the last livestock census in 2012. The number of backyard chickens in the nation was 317.07 million in 2019, a 45.8% increase from the 217.49 million recorded in the previous census. There were 534.74 million commercial chickens in the nation in 2019, up 4.5% from the previous census, which found that there were around 511.72 million. Approximately 8.8% of Indians are employed in the commercial poultry industry (Livestock Census, 2019) [1]. According to estimates from the All-Indian Poultry Breeders Association, poultry provides direct and indirect jobs, feeding 50 million people and contributing USD 17.31 billion to the Indian economy. According to the IMARC report (2023), In 2022, the Indian poultry market was valued at INR 1905.3 billion. The market is expected to increase at a compound annual growth rate (CAGR) of 10.18% from 2023 to 2028, reaching INR 3477.8 billion, according to the IMARC group. Poultry meat is the segment of the global meat demand that is growing at the fastest rate. In 2014-15, the nation produced 6.69 million tons of meat; in 2021-22, that amount increased to 9.29 million tonnes (Rupala, 2023) [20]. During 2018-19, India exported 5,44,985.06 MT of chicken products to the global market, valued at Rs 687.31 crores (98.42 USD million) (Anonymous, 2020) [3]. The major export destinations in 2018-19 were Oman, Maldives, Japan, Vietnam Soiet Rep, and Indonesia (Anonymous, 2020) [3]. The poultry industry in India has made remarkable growth ever since its inception and is presently emerging as a sunrise sector with a growth rate of 8.51% and 7.52% in egg and broiler production, respectively (BAHS, 2019) [4]. The broiler and layer segments of the poultry industry account for approximately 65.3% and 34.7% of the total, respectively, with a monthly turnover of 400 million chicks and 8,400 million eggs (ICRA, 2020) [10]. India ranks third in the world for egg production and eighth for meat production, according to FAOSTAT 2020 production data. In 2014-15, the country produced 78.48 billion eggs; in 2021-2022, that number increased to 129.60 billion. Poultry manure is the richest source of minerals other than livestock manure. The poultry industry is expanding rapidly in India, the world's second-largest developing country. Structured poultry farms are extensive operations, typically commercial, featuring specialized housing, feeding mechanisms, and management techniques designed to optimize egg or meat output.

In contrast, household poultry consists of smaller groups, generally raised for personal consumption and minimal excess, with less specialized facilities and management practices.

Tamil Nadu, Andhra Pradesh, and West Bengal are the three states that produce the most poultry Production. In 2019, Maharashtra experienced a 4.49% drop in poultry production, reducing its output from 77.8 million in 2012 to 74.3 million. Some of the main factors encouraging the market include the growing popularity of protein-rich and egg-based diets among gym-goers and fitness enthusiasts, the growing adoption of a healthy diet, and various initiatives by governing organizations to improve the quality and productivity of poultry products. While in today's climate change era, crop productivity is affected negatively, so poultry farming gives stability to farmers' income. With the increasing population, the consumption of poultry meat is also increasing. To fulfill the demand, there is a need to increase the productivity of poultry enterprises. A judicious combination of proper climate control inside the poultry, an organized structure of poultry house, and superior genetic stock would help in achieving the targets.

Importance of control environment in poultry

General environmental conditions in the poultry house greatly affect productivity. For sound health and high performance, birds require comfortable environments. During planning and designing of building, indoor and outdoor environmental conditions are important factors need to be considered for effective poultry production as poultry birds are more sensitive to changes in the environment. Temperature, relative humidity, air movement, and sun radiation are examples of environmental elements that fall under the category of thermal factors and have an impact on the growth and productivity of birds. Social factors include bird density and their behaviour in a group and physical factors include space, light and sound. Some other factors include dust, odour, gases, parasites, etc. Temperature, ventilation rate, and genetic strain are the main factors that influence broiler chicken performance. (Baracho *et al*. 2019) [5]. When it comes to environmental problems, particularly heat stress, birds are more sensitive to temperature. According to observations, heat stress in poultry production can be either acute or chronic (Emery, 2004) [9]. Birds are severely stressed out by high temperatures, especially when they are combined with high humidity, which lowers performance. Body heat is the main source of heat. In hot weather environmental temperature increases, so the temperature of the ventilating air in the house also increases. In addition to the temperature of the air that circulates around the home, heat is also provided by the walls and roof. Sweat glands do not exist in birds. In an attempt to regulate their body temperature, birds change their behavior and physiological homeostasis in high-temperature environments (Lara and Rostagno, 2013) [15]. The temperature of the circulating air in the house rises as a result of the rise in ambient temperature during hot weather. In dry litter, birds use dust baths more readily to aid cooling. A severely dehydrated bird may show neurological symptoms like severe head tilts and inability to perch or fly. (Rath *et al*., 2015) [19]. According to a recent research (Mack *et al*. 2013) [17] birds under heat stress spend more time drinking, panting, and resting than they do eating, moving, or walking. Increased panting under heat stress causes the body to produce more carbon dioxide and raise blood pH, which inhibits the availability of blood bicarbonate for eggshell mineralization and increases the availability of organic acid, which lowers blood levels of free calcium. This procedure is crucial for laying hens and breeders since it influences the quality of the eggshell (Marder and Arad, 1989) [18].

Impact of heat stress, RH, THI IN poultry house

According to research reviews, broiler growth requires a temperature between 18 °C and 22 °C for optimal performance (Charles, 2002). According to experiments, broilers subjected to heat stress at 35±2 °C had a greater feed conversion ratio (+ 25.6%), a lower body weight (-32.6%), and a considerably lower feed intake (-16.4%) at 42 days of age (Sohail *et al*. 2012) [22]. The bird's behavioral and physiological thermoregulatory systems are less effective in the cramped environment of the transit containers. Therefore, heat stress during transportation may result in a high death rate (Warriss *et al*. 2005) [25]. The productivity and meat quality of broiler production are negatively impacted by heat stress. High temperatures during the broiler chickens' growth phase have been linked to poor meat quality and attributes (Lu *et al*. 2007) [16]. When poultry was exposed to temperature treatments between 35 and 37 °C, a decrease in egg production, egg weight, body weight, body weight gain, and daily feed intake of between 4.99% to 57.3%, 2.78% to 14.3%, 3.74% to 32.6%, and 11% to 50%, respectively, was observed. Although, an increase was seen in feed conversion ratio (FCR) ranging from 0.67% to 99.51%. (Sohail et al. 2012) [22].

High temperatures and humidity are the primary causes of the high broiler mortality rate. They are more susceptible to heat stress when kept in environments with high relative humidity and temperature profiles. It is one of the most influencing environmental factor on bird performance which includes reduction in feed intake, growth rate, egg production, egg quality, meat quality, fertility, semen quality, weight, etc.

According to Joseph *et al*. (2012) [12] broiler performance considerably decreased and body temperature increased up to 1.7 °C over the normal body temperature of 41 °C when THI exceeded about 21 °C. In this result, THI calculated by Tao and Xin, (2003) [23] formula:

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

Where

$THI_{broilers}$ = Temperature-humidity index, °C

T_{db} = Dry-bulb temperature, °C

T_{wb} = Wet-bulb temperature, °C

Logics used for poultry cooling

In addition to improving feed conversion and weight growth, evaporative cooling systems may reduce the impacts of heat stress and lower mortality. A variety of devices, including fans, fan-equipped foggers, cooling pads, curtains, static pressure controls, and thermostats, are used to regulate the atmosphere. Intermittent light exposure had a beneficial effect on reducing chicken heat output (Ketelaars *et al*. 1986) [13]. The building's orientation, insulation, and roof overhang all affect the chicken house's interior temperature. For effective ventilation, air must flow throughout the house. Radiation, conduction, convection, and evaporation are the ways that body heat is released into the environment (Mustaf *et al*. 2009) [8]. Evaporative pad systems are very effective in reducing broiler heat stress (Simmons and Deaton, 1989) [21], and are cost-effective (Timmons and Gates, 1989) [24]. The average temperature drop caused by sprinkling on the head and appendages was 2.2 °C. The effectiveness of two distinct evaporative cooling system types in broiler houses in the Eastern Mediterranean region was examined by Cayli *et al*. (2021) [27]. Two distinct broiler houses were used for this investigation; one was utilized to test a fan pad, while the other was used for water spray evaporative cooling. The broiler houses had a floor space of 151.2 m^2, measured 21.0 m in length and 7.2 m in width. On both long sides of the houses, there was a 6.0 m^2 air intake that measured 1.0 × 3.0 m. Fans with a 48,000 m^3/h capacity were used for ventilation. In the water spray evaporative cooling systems, the pressure of the system was 60 psi and spray about 22 L of water per hour with a nozzle diameter of 0.61 mm. In contrast to the water spray system, which had a cooling efficiency of 92.2% and a maximum temperature depression of 17 °C, the fan-pad system had a maximum cooling efficiency of 79.9% and a maximum temperature depression of 12.5%. Although the cooling efficiencies differed daily depending on the outdoor conditions, the water spray cooling system was more effective. According to Xin & Puma (2001) [28], laying hens in the Midwest of the United States require cooling systems that are affordable and simple to retrofit in order to reduce heat stress. High pressure (1000 psi) foggers placed along the eave air inlets of a commercial high-rise layer house (100,000 Hy-line w-98 hens) are used in this field research to assess the effectiveness of cooling ventilation air. When the house temperature increased over 30 °C and the relative humidity (RH) was less than 76%, fogging was set to activate. Depending on the outside relative humidity, the device was able to reduce the temperature of the air within by as much as 7 °C. The fogging system could lower dry bulb temperature in houses by 3.3 to 4.4 °C (6 to 8 °F) with operating pressure (500 psi) (Wilson *et al*. 1983). The poultry industry has largely embraced the use of misting systems as a reasonably priced evaporative cooling technique in broiler grow-out facilities (Lacy and Czarick, 1992) [14]. For several reasons, including cheaper initial costs and relative simplicity of retrofitting to existing structures, misting systems are the more popular option. Tunnel ventilation has been used with both misting systems and evaporative pad cooling (Czarick and Tyson, 1989) [7]. Due to the substantial convective cooling, or "wind-chill" effect, produced by the combination of fast air speed and decreasing dry bulb temperature, this combination is thought to be highly effective. Pad systems are sometimes more costly and challenging to install in existing houses, although the fact that they are normally more effective at evaporating water than misting systems.

Controller developed for naturally ventilated poultry house

As the temperature rises, air expands, and its moisture-holding capacity increases. This moisture-holding capacity doubles for every 12 °C increase in air temperature. For example, if the air temperature is 27 °C and the RH is 100% at 5.00 a.m., and if the temperature rises to 38 °C (by afternoon), the moisture holding capacity of the air doubles, and the RH would now be only 50% (Alchalabi, 2015) at that time evaporative cooling is not required in the morning time and the night time as RH is always higher than the daytime RH on any given day. When it is a cloudy weather day at that time, the temperature is less and RH is more, so in that situation, no fogging is required. The ideal conditions for rearing poultry are a temperature of 22-30 °C (70-85°F) with an RH of 30-60% and litter moisture content between 15-25% (ICAR, 2012). There are two measures of temperature: (a) Actual air temperature as measured by the thermometer; (b) Effective temperature that the bird actually feels, which increases with humidity and increases with air movement. According to the temperature and relative humidity, we have to on or off the fogging system after some time intervals. Suppose that we fail to off the system it will wet the bird and increase the diseases in poultry. To handle this system we require a separate person to on/off the system. If we manually set the system, then after every ½ hour it will run for 2 to 3 minutes a day but in the morning there is no need for the fogging system. According to weather conditions, we have to set again and again. To overcome these problems, develop an automatic fogging system, which will sense the temperature & relative humidity if the temperature is more than required and RH is less than required then the signal goes to the motor and the motor will automatically start and vice versa.

Conclusion

The factors affecting the growth and production of birds in poultry houses are temperature, relative humidity, moisture content of litter, temperature humidity index, transportation of flocks, wind velocity or air movement, and the quality of the air inside the house. All these factors are greatly interrelated. The key factors include temperature and relative humidity. Effective management of temperature, relative humidity, and air movement is essential for maximizing yields and ensuring healthy birds' growth. Evaporative cooling systems can enhance feed conversion, weight growth, and mortality reduction while reducing the impacts of heat stress.

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