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Poultry Housing and Management

Ayodeji Oloyo and Adedamola Ojerinde

Abstract

Majority of the people in the poorest regions of the tropics rely on poultry production as their major source of protein supply. However, poultry production is hindered by the harsh environmental conditions in this regions therefore, reducing the daily supply of protein. It is believed that understanding heat stress in birds by paying detail attention to the sources of heat generation in a poultry house can help manage the heat stress situation in this region. This text reviews the internal climatic conditions of the poultry houses, how the birds respond to them, and their implications for heat management in poultry production. Thus, it provides pertinent information for guidance on parameters for open poultry houses architectural design that ensures optimum climatic conditions that will alleviate heat stress problem in poultry production in hot and humid climate.

Keywords: heat stress, poultry house design, poultry production

1. Introduction

Poultry production has occupied a leading role in the agriculture industry world-wide in recent years. The compound annual growth rate of poultry protein between 2015 and 2025 is estimated to be +2.4% [1]. Asia, South America and Africa characterized by rapid urbanization, poverty and hot climate recorded the highest growth increment in poultry production [1, 2]. The trend of continuous growth of poultry production in those regions is obvious because it remains the fastest route to bridging the protein demand-supply gap.

Extreme weather conditions in the tropical regions of the world have proven generally detrimental to livestock production and is particularly of interest in chicken because of the latter's high sensitivity to temperature change [3–6]. Just like mammals, the avian species have the ability to regulate their body temperatures by losing or generating heat in response to environmental temperature. If the body temperature of a bird, which normally runs between 39.4 and 40°C, is allowed to increase, the bird will not perform well. Heat stress in poultry production had resulted in under-nutrition, stunted growth, reduction in egg production and size, laying of premature eggs and even death [7–11]. This problem is further compounded by the high body heat generated by genetically improved laying birds with increased metabolic activity resulting from the high rate of egg production [12–15].

Poultry housing design plays a vital role in the determination of the internal climatic conditions of the house for optimum health, growth and productive performance of the birds. Consequently, the type of poultry housing system employed by the proposed poultry farm is a function of the prevailing climatic conditions of the region where the farm is located. While open poultry house system has been adjudged a good method of housing in the tropical countries because of the

simplicity of its construction, ease of heat management and minimal management cost, the controlled housing system is the most common in the temperate regions of the world [16, 17].

2. Poultry birds and their thermoregulatory mechanism

Birds are warm-blooded 'homoeothermic' flighty feathered oviparous vertebrates that possess a high metabolic rate, with a normal breathing rate of 40–50 breaths per minute [17]. On the average, birds maintain an internal body temperature of between 39 and 42.2°C [18–20]. During hot weather, poultry birds maintain thermo-neutral temperature by losing heat mainly through conduction, convection, radiation and evaporative cooling [2, 20, 21].

Sensible heat loss through convection, radiation and conduction is only effective if the environmental temperature is below or within the bird's thermoneutral zone. However, evaporative cooling accounts for about 60% of the heat dissipated during body temperature regulation within the thermoneutral zone [2]. Sensible heat loss includes heat loss through opened surfaces such as wattles, shanks and other featherless areas around the neck and wings [21]. Heat loss for body temperature regulation through this process does not alter the bird's behavioral patterns, feed intake, or metabolism [22]. The effectiveness of sensible heat lost is a function of the temperature difference between the bird and its environment.

Where the environmental temperature exceeds 24°C evaporative cooling (latent heat loss) becomes the major method of dissipating heat in birds regardless the age [21]. Loss of heat through evaporative cooling at temperatures beyond the thermoneutral zone requires the bird to re-direct energy required for growth and development to panting. However, panting can lead to dehydration and respiratory alkalosis because of inadequate water supply and drop in blood pH due to excessive ejection of carbon dioxide [21]. During panting, evaporative cooling occurs when water evaporates from the respiratory system of the bird. However, this can be hindered by high humidity. This is problematic in high humid environments where poultry farmers employ evaporation cooling as the primary method of air-temperature reduction during the hot periods of the year [2].

Increasing the volume and velocity of air moving over birds enhances heat loss in birds due to convection, removal of heat trapped within the poultry house, and reduction of the effect of high humidity on evaporative cooling [2]. Simmons et al. [23], conducted a study that subjected 3 weeks old male broilers in a controlled environment for 4 weeks to a cyclic temperature of 25–30–25°C at varying wind speed of still air (<0.25 m/s), 2 m/s and 3 m/s. It was observed that the increased wind speed favored older birds in growth and development.

Water is an essential commodity in poultry production for the nutrients it possesses and its impact on feed consumption [24]. Nipple drinkers to provide cleaner water, reduce water spillage and labour for drinker cleaning has replaced the conventional open water system. May et al. [25], observed that chicken consumed more water when reared with conventional open water system in an experiment that compared the conventional open water system to nipple drinking. However, when these drinkers were used to rear chicken in a controlled room with air velocity of 0.25 and 2.1 m/s, birds in the higher air velocity with nipple drinkers did not differ from those on open water drinkers, but experienced increased weight gain and better feed conversion than birds at the lower air velocity [26]. Therefore, it is important to provide and maintain the required ventilation to ensure that the poultry house is conducive for the birds to regulate their body temperature by sensible heat loss.

3. Heat stress in chicken

Heat Stress is a general problem in the poultry industry, especially in the production of chicken meat and egg. Heat stress is experienced by chicken when the environmental temperature equals or rises above 26.7°C. At this temperature and beyond the birds begin to pant and can be detrimental to attaining the bird's optimum growth rate, hatching ability, egg size, egg shell quality and egg production. The problem of heat stress can be further compounded in a hot environment when the humidity rises. Heat stress has been reported to have adverse effect on broilers comfort, growth rate, feed conversion, and live weight gain [21].

In poultry production, the sudden exposure of birds to high temperature short periods is referred to as acute heat stress while exposure for extended periods is referred to as chronic stress. Chronic stress has deleterious effects on birds reared in open-sided houses, which is commonly used in the tropics. It has been reported to have adverse effect on growth and production efficiency, egg quality, meat quality, embryonic development, reproductive performance, immunity and disease incidence's in broilers, laying hens and breeders [21, 27–31].

4. Effects of internal climate conditions on chicken

It is important we understand the effect of internal climatic conditions of the poultry house on the birds, how the birds respond to them, and their implications on heat management for poultry production. The information will provide guidance on parameters for the open poultry house architectural design that will alleviate heat stress to ensure optimum poultry production in the tropics. The climatic factors of interest include temperature, relative humidity, air composition and velocity, and lighting condition.

4.1 Temperature

There is a huge debate on the ideal temperature range required for the various classes and age groups of chicken to attain optimum production. This could be because of other climatic factors such as humidity and wind velocity, which influence temperature change and previous adaptation of chicken to climatic change. Generally, chicken perform under a wide range of temperature regardless of its class (broiler, pullet or breeder) or age. However, exposure of chicken to high temperature has been reported to hinder the performance in chicken production [17]. It could also be further compounded by increased relative humidity for its negative effect on evaporative cooling [32].

Ketelaars [16] recommended a temperature of 30–32°C at chicken height for day old chicks. Thereafter, the temperature should be decreased by 3–4°C till the chicks are 4 weeks old as shown in **Table 1**. Dagher [19] reported that a temperature range

Age of chicken (week)	Temperature range (°C)
1	30–32
2	30–26
3	26–23
4	23–20
≥5	20

Table 1.
Recommended temperature schedule.

of 18–22°C is required for growing broilers. In other reviews done by Holik [15], it was concluded that birds are comfortable when environmental temperature is within the range of 18–24°C. However, it should be noted that the optimum performance of chicken is dependent on the market value of the product in relation to feeding cost.

It is a challenge to maintain the optimum production temperature in the tropics therefore, it is important that the poultry house designer pay considerable attention to temperature change.

4.2 Relative humidity

In a review done by Oloyo [17], it was reported that internal temperature above 26.7°C combined with high relative humidity adversely affected the feed efficiency, feathering, pigmentation, and weight gain of chicken. Furthermore, at internal temperature range of 35–37.8°C the birds' performances were poor regardless of the change in relative humidity. This means higher humidity can improve the performance of the birds at lower temperature. However, humidity must be controlled for it can provide habitat for microorganisms thus, exposing the birds to the threat of disease [18, 33].

Relative humidity has a strong relationship with temperature change. At the brooding stage, particularly in the earlier weeks the internal relative humidity may be low or too low because of the warming the chicken requires at that age or when the chicks are thirsty or hatched at higher temperature. Soon enough, the internal relative humidity increases because of the water vapor generated by the evaporative cooling act of chicken to regulate their body temperature as they grow [16]. Consequently, ages 3 weeks and above are very critical periods in chicken production regardless the class of chicken.

In Oloyo [17], it was reported that laying birds during brooding and after brooding require a relative humidity range of 60–80 and 50–70% respectively for optimum performance.

4.3 Air composition

The decomposition of bird's fecal material produces unpleasant and polluted gases, which include ammonia, carbon dioxide, methane and hydrogen sulphide. These gases are of particular interest because of their adverse effects on the performance of birds, cages, human poultry houses and the environment at large [16, 18, 34–38]. Consequently, for optimum production for chicken a concentration level of 25 ppm and not more than 2500 ppm for ammonia and carbon dioxide was recommended [18, 39]. It was recommended for good birds' health management that removal of fecal material from the poultry house should be done frequently to reduce the volume of gas emission [17].

4.4 Air velocity

High internal temperature can be controlled to an extent by varying the air velocity within the poultry house. Also, Air velocity plays an important role in convective cooling and the regulation of air quality [2, 18]. In hot climatic regions, it is recommended that the ventilation capacity should be at least “5m³ per chicken per hour, with inlets amounting to 1.5cm² per m³ ventilation” [16]. Hulzebosch [18] reported that still air velocity (0.1–0.2 m/s) could be maintained if the temperature remains within 25–30°C. However, Lacy and Czarick [40], under the same temperature condition reported a better growth rate at 2 and 3 m/s air velocity respectively for broilers.

In the quest to further understand the effect of air velocity on chicken, [23], factored the ages of chicken within the temperature range 25–30°C with varying air velocity. The study demonstrated that 6 weeks old broilers benefited from increased air velocity of 2 and 3 m/s than 4 weeks old broilers. This could be because of the high temperature required by younger birds at brooding stage.

4.5 Lighting

Lighting at early age in birds have little or no effect on hormonal system, it merely aids birds' activeness including feed intake, growth, and physical and physiological activities [15, 41, 42]. Subsequently, increase in lighting periods and light intensity may cause tiredness, cannibalism, immune responses, leg abnormalities and even death [41, 43–47].

The lighting program commonly used is the continuous lighting program of 16 hours light and 8 hours darkness and it has proven successful for overall chicken performance [15, 48–50]. However, it has been reported that alternating short light and dark period known as intermittent lighting enhances chicken performance [16, 51–54]. The continuous lighting program with a minimum light intensity of 20 lux is recommended at post-hatch stage (1–7 days old) to help the chick adapt to their environment and aid feeding [41]. Consequently, the light intensity is reduced to about 3–5 lux and intermittent lighting system is introduced for easy control of the birds' activeness for better performance and productivity [16, 41].

Birds reared under yellow, green, and blue light sources have been reported to have improved body weight compared to those reared under red and orange light sources [55–57]. Lewis and Morris [55] in a review concluded that the birds reared under blue light show docile trait while those reared under red light were more active and aggressive. In addition, it was noted that the red light improved sexual activities in birds.

5. Poultry housing system

The importance of the type of poultry housing system employed for chicken production cannot be over emphasized. It protects the birds from the harsh environmental climatic conditions, which may have adverse effect on the chickens' performance and productivity. In a poultry house, the overall heat generated is the sum of heat generated by the birds, the surrounding environment and biodegradation of fecal material [58–60]. Thus, the type of housing system to be used is a major determinant factor in the type of management to be adopted in the poultry farm. The housing systems used in the tropical region that is, naturally ventilated open housing system and mechanically ventilated open housing system are discussed here.

5.1 Naturally ventilated open housing system

The open poultry housing system has been identified with the tropical region for its simplicity, economic implications and ease of management of heat generation within the building through natural ventilation [2, 32, 61]. However, it is prone to the invasion of insect, rodents, birds and other small predators that can disturb the welfare, productivity and performance of chicken. In the quest to alleviate this problem, dwarf sidewalls are raised to the roof eaves with corrugated wire mesh to keep predators away. Also, gutter filled with insecticides to prevent the invasion of insects are built around the house. Discussed below are design considerations to be factored in when designing an open poultry house for optimum poultry performance and productivity.

5.1.1 Building orientation

In order to reduce the exposure of sidewall to direct to direct sun radiation the poultry house should be orientated in the east-west direction [2, 60]. This is very vital, because heat stress in birds can be hastened when they are exposed to direct solar radiation. Deep litter rearing may allow the birds avoid direct sunlight but this may lead to clustering or overcrowding of birds in an area of the house. Consequently, make cooling difficult and in severe cases this leads to stampede and even death [2].

5.1.2 House width, length and height

The east-west orientation of a poultry house may reduce the benefit of prevailing winds blowing from east or west. Therefore, Dagher [2] recommended that the width of the building should not exceed 12 m to prevent this problem. In addition, the problem of uneven air exchange rate and temperature within the building is eradicated.

Furthermore, the design must factor in the activities and services rendered by poultry farmers and professionals within the building. These activities may include transfer of chicken, feeding, de-pecking, waste management, vaccination, and so on. Therefore, longer pen house could be strenuous to maintain especially when the activities are carried out manually. Doors can be placed at interval of 15–30 m to make for easy circulation and service delivery [2]. Qureshi [32] recommended that for battery cages, it is rather advisable to factor in the number of tiers to be used. Two-tier cage system facilitates easy air exchange within the building whereas, three and four tier cage system can be problematic for air exchange. Therefore, it is recommend that rows of cages should not exceed three with center aisles not less than 1.2 m and a minimum height difference of 1 m from the ceiling.

5.1.3 Roof slope

A roof slope of 45° was recommended because the angle reduces the heat gain of the roof from the direct solar radiation; maximizes the distance of the bird from the heat accumulated under the roof; quick escape of the heat accumulated under the roof through ridge opening, maximizes air space to improve air exchange rate; and open space above for installation of equipment [2, 60, 62]. On the other hand, the slope in the insulated roof is dependent on the quality of the insulation.

5.1.4 Roof overhang

Roof overhang can be used to shade the sidewalls of a building from direct and indirect solar radiation. However, the length of the roof overhang is dependent on the height of the sidewalls [2]. Heat gain by the sidewall can be reduced to about 30% by roof overhang shading if properly applied at a roof slope of 45° [60].

5.1.5 Ridge opening

Naturally, hot air rises above cooler air due to difference in air density. Introduction of ridge opening can aid ventilation through stack effect in the poultry house. Adequate setback between buildings is required to prevent inadequate airflow and circulation [2, 61]. However, ridge opening has been reported to be ineffective in insulated poultry houses because of temperature uniformity within the house [63].

5.1.6 Sidewall openings

The sidewall consists of a dwarf wall built up to the roof eave with a permeable membrane such as a corrugated wire mesh and an adjustable curtain. A minimum height of 0.4 m is recommended to prevent the house from water seepage, direct and indirect solar radiation, pests and predators [2]. The corrugated wire mesh allows easy airflow within and outside the building, while the adjustable curtain is used to control the flow and air velocity. However, the curtain may be transparent or of varying colors to aid its use in managing intermittent lighting scheme [2, 15, 63].

5.1.7 Building obstruction

Adequate setback between buildings is required to prevent inadequate air exchange rates in building. Factors such as wind speed, wind direction and topography are major determinants for consideration in defining the optimal house spacing. However, the spacing between buildings can be determined by the expression below [63].

$$D = 0.4HL^{0.5} \quad (1)$$

where D, housing spacing (ridge of the closest wall of the next house); H, height of the adjacent building; L, length of the adjacent building.

Vegetation should be kept as minimal as possible and at average height to reduce the nest of wild birds and invasion of rodents and other predators. Also, the branch of trees should be kept at eaves level to prevent obstruction of airflow across the house [2].

5.1.8 Roof, end-wall and sidewall insulation

Farmers in the tropics have successfully used locally sourced materials such as thatched roof and bamboo as roofing materials for the construction of naturally ventilated poultry houses [32]. However, a minimum R-value of 1.25 m² C/W was recommended for ceiling insulation in naturally ventilated poultry house. Environmental temperature higher than 40°C would require a minimum R-value of 2.25 m² C/W [2]. The various methods of insulating poultry house ceiling include dropped ceiling, rigid board insulation, spray polyurethane insulation and reflective insulation [2].

5.1.9 Cooling system

Rooftop sprinklers have proven to be efficient for substantially cooling the roof [2, 60]. However, material of choice in this situation must be able to withstand the constant exposure to water [2]. Evaporative cooling in birds in hot weather can be subdued by using fogging system. With high water pressure it generates mist, which aids cooling in birds. However, the level of humidity within the house must be monitored for it could be detrimental to the health of birds at high temperature [2, 60]. Circulation fan eases heat stress by providing increased air velocity to increase convection cooling. Generally, circulation fans generate air velocity of 0.5 m/s or more and cover an area 15 times its horizontal diameter by five times its vertical diameter [2]. Furthermore, for effective use of circulation fans it should be installed at the center 1–1.5 m above the floor and tilted downward at an angle 5°.

5.1.10 Vegetation

Shrubs and grasses reduce reflective and direct solar radiation by shading and convection cooling [60]. Vegetation should be kept clean and trimmed to keep away

predators and pests [2]. The planting of tall trees along the sidewalls can provide a form of canopy to shade the sidewalls from exposure to direct or reflective solar radiation during the hot periods of the day.

5.2 Mechanically ventilated open housing system

The limitation of attaining adequate internal environmental conditions required for optimum birds' performance under extreme weather conditions has led to the use of the mechanically ventilated housing system. Also, the mechanically ventilated house provides more control over air exchange, wind velocity and wind direction [2, 16]. Mechanically ventilated system entails the use of either positive or negative pressure system. The negative-pressure system which is the most commonly used in mechanical ventilated house, expels air out of the building by fans through an air inlet system to create low pressure within the house to allow fresh air to rush in through the same air inlet system [2].

The negative-pressure systems can be achieved through inlet or tunnel ventilation. Inlet ventilation system uniformly distributes exhaust fans and air inlets across the house whereas, tunnel ventilation exhaust fans are located at one end and inlet pipes at the other end. This provides the tunnel ventilation with an advantage of greater air speed in turn creating more positive air exchange [2].

5.2.1 House construction

For proper ventilation control, it is required that the house be highly insulated and tightly constructed [2]. However, the sidewall can be equipped with insulated adjustable curtains instead of solid wall for use in the cooler periods of the year or in case of power failure emergency. It is important to note that solid wall have higher insulation value than adjustable curtains.

5.2.2 Air exchange

High external temperature coupled with the heat generated from the activities within the poultry house increases the temperature of the internal air. An effective mechanical ventilation system has to exchange the air quickly to ensure the internal air temperature maintains not more than 2.8°C difference from the external air temperature. The expression below can be used to calculate the appropriate exhaust fan required for effective ventilation [2].

$$\text{Building surface heat (watts)} = (A/R) \times (T_o - T_i) \quad (2)$$

where, A, area of the building surface (m^2); R, insulation value of the wall material (m^2C/W); T_o , temperature outside ($^{\circ}C$); T_i , temperature inside ($^{\circ}C$).

The value of T_o is the hottest external temperature that is expected of the external environment. However, when calculating heat gain for roof in a house with attic space, the value T_o it is assumed to be 55°C whereas the T_o value for ceilings with insulation directly below the roof is assumed to be 65°C [2]. On the other hand, T_i is best assumed as 27°C to ensure comfort for birds. The value of R will be the overall sum of the insulation value of the wall section.

The total heat produced (sensible and latent) in commercial broiler is 7.9 W/kg while broiler, pullets and broiler breeders is 5.1 W/kg [2, 64]. The heat generated by birds is expressed below [2].

$$\text{Bird heat (W)} = \text{sensible heat (W/kg)} \times \text{weight of the bird (kg)} \quad (3)$$

where sensible heat, 50% of the total heat produced by birds.

$$\text{Total heat (W)} = \text{building surface heat (W)} + \text{bird heat (W)} \quad (4)$$

However, the air movement capacity to maintain 2.8°C between intake and exhaust air is expressed below.

$$\text{Air capacity (m}^3\text{/h)} = \text{total heat (W)} \times 3.4/2.8^\circ \text{C} \quad (5)$$

5.2.3. Air inlet system

There are a number of negative-pressure air inlet pipes used to control the internal climatic condition by controlling the entry location, speed and direction of fresh air. However, the exhaust fan determines how much air enters the house.

5.2.3.1 Inlet speed

The pressure difference between the internal and external environment determines the entry speed of fresh air [2]. However, the pressure is a function of the number and sizes of the air inlets. Therefore, the easy manipulation of differential pressure allows for possible control of airflow pattern within the building and of negative-pressure air inlet pipes used to control the internal climatic condition.

5.2.3.2 Inlet area

For easy control and distribution of air within the poultry house, the exhaust fan must develop a static pressure of about 12–25 Pa [2].

5.2.3.3 Air inlet control

Air inlet design should be located strategically as the direction of air depends on external climatic condition, age and class of the chicken. Normally, air inlets should be designed to direct air towards the ceiling at cooler time while another should be directed towards the floor during the hot periods of the year [2].

5.2.3.4 Air inlet control

Static pressure of about 12–25 Pa was recommended for easy control of the air inlet for a static pressure above or below that range can lead to supply of insufficient air velocity [2].

5.2.4 Types of inlet ventilation system

5.2.4.1 Cross ventilation

The exhaust fans are installed on one side while the air inlet pipes are along the other side of the poultry house. It is best suited to narrow poultry houses (less than 10 m) because it leads to difference in environmental conditions in the house with larger width [2].

5.2.4.2 Sidewall inlet ventilation

The exhaust fans are placed below the air inlet pipes on both sides of the building walls [2]. However, a distance not less than twice the diameter of the fan should be between the exhaust fans and the air inlet pipes. Air movement is directed towards the center, and drawn through the floor by the exhaust fans. It is also best suited for narrow house with not more than 12 m width [2].

5.2.4.3 Attic inlet ventilation

The exhaust fans are placed on the lower sidewalls while, air inlets are placed in the ceiling. This kind of ventilation requires proper ceiling insulation and it best suitable for hot climate areas. The ventilation method is greatly recommended for rearing laying hen [2].

5.2.5 Air movement inlet ventilated house

Fresh air enters through the air inlet pipes at a velocity of 3.5–6 m/s, however this velocity is quickly dropped to about 1 m/s depending on the size and type of the house. Hence, circulation fans are used to boost the air speed to ensure air movement is sufficient in the building [2].

5.2.6 Tunnel ventilation system

Tunnel ventilation system is designed to meet the specified air velocity and air exchange rate. However, the required air velocity is dependent on the class of birds in question. **Table 2** shows the recommended air speed required for rearing various classes of poultry birds [2].

5.2.6.1 Tunnel fan capacity and air velocity

The tunnel fan capacity is determined by the same method used for inlet ventilation system. Unlike the inlet ventilation system where the adequate air velocity is propelled by circulation fan, the required average air velocity within tunnel house is calculated by the expression below [2].

$$\text{Air velocity} = \frac{\text{tunnel fan capacity}}{(\text{cross - sectional area of the house}) \times 3600} \quad (6)$$

where air velocity, m/s; tunnel fan capacity, m³/h; cross section area, m².

However, it is important to note that the cross sectional area of the house adversely affect the air speed within the house. Therefore, it is advisable to design narrow and long house with lower ceilings [2]. Consequently the expression below can be used to design the desired air velocity.

House type	Air speed (m/s)
Broilers	2.5–3
Pullets	1.75–2.25
Broiler breeders	2.25–3
Commercial layer	2.5–3

Table 2.
Recommended air velocities in tunnel-ventilated houses.

$$\text{Tunnel fan capacity} = \frac{\text{desired air velocity}}{(\text{cross - sectional area of the house}) \times 3600} \quad (7)$$

where desired air velocity, m/s; tunnel fan capacity, m³/h; cross section area, m².

In cases where there is land constraints, air deflectors can be installed houses with large cross-sectional area to reduce the cross sectional area within the poultry house. Air deflectors are curtains that extend from the ceiling not more than 2.5–3 m from the ground. Air deflectors have been reported to increase air velocity for a distance approximately 1.2 and 6–9 m upward and downwind of the deflector respectively. However, it is important to ensure that the air deflector exceed 2.5 m from the ground to have it from disrupting the performance of fans and air exchange rate by increasing static pressure [2].

5.2.6.2 Air velocity distribution

Normally, the air velocity in a tunnel house is assumed uniform across the house. However, it can vary slightly depending on the smoothness of the building surfaces, presence of poultry equipment and other obstructions that deflect air. The difference between the air velocity in the center and the side of the house can vary from 15 to 40% [2].

5.2.6.3 Bi-directional tunnel house

Generally, it is best to install the fans on one end and the inlet in opposite end to ensure the maximum air speed is achieved in the tunnel house. However in cases where the poultry house is over 180 m long and the air velocity required for airflow in one direction exceeds 3.5 m/s it is advisable to apply the bi-directional tunnel house system. The fans are located at end-walls of the building and the tunnel inlet at the center of the house. The air velocity in both direction is reduce to half of the required velocity while retaining the same air exchange rate to ensure the temperature difference between the inlet and the fan remains the same [2].

5.2.6.4 Tunnel fan placement

The fans can be installed at the end-walls or the sidewalls near the end, and this installation arrangement does not affect the performances of the fans. However, dead spot can be noticed when the fan is installed on the sidewalls as the width of the houses increase.

5.2.6.5 Tunnel inlet opening

In the absence of evaporative cooling pads, it is recommended that the inlet area should be at least 10% greater than the cross sectional area of the house. Meanwhile, the pad used determines inlet size for tunnel house with evaporative cooling pads. It is recommended that inlet opening on the sidewall should be installed as close as possible to the end wall. However, if the house width exceeds 15 m it is advisable to install the inlet openings on the end-wall [2].

5.2.6.6 Cool weather inlet system for tunnel ventilated houses

It has been recommended that tunnel ventilated system should be used in hot weather because cool weather reduce the air exchange rate. Consequently, it was

recommended that a minimum of 60% of the tunnel fan capacity should be controlled by the traditional inlet system before upgrading to tunnel ventilation for easy switch during cooler weathers [2].

5.2.7 Poultry exhaust fans

5.2.7.1 Types of fans

5.2.7.1.1 Exterior and interior shutter fans

It is the simplest type of exhaust fan. Its shutters are used to when the fan is not in use. However, the exterior shutter restricts airflow as air spins off its blades on contact. In the case of interior fan on the other hand, the shutters are on the intake side of the fan thus, lessening the restriction of airflow. It has bigger shutters, which allows for more air movement. Dagher [2] reported that airflow is increased by 5–10% compared to exterior shutter fan.

5.2.7.1.2 Discharge cone fans

It increases fan performance by 5–10% as it eases the transitioning of drawn towards the fans [2].

5.2.7.1.3 Belt-drive fans

The fans blades are driven by a simple pulley mechanism. It may be upgraded with an automatic belt tensioner to prevent belt slippage [2].

5.2.7.1.4 Direct-drive fans

The fan's blades are attached directly to the motor shaft eliminating the use of belt. They are less energy efficient compared to belt-driven fans [2].

6. Conclusions

Heat loss in birds through convection, radiation and conduction is only effective if the environmental temperature is below or within the bird's thermoneutral zone. Naturally ventilated open housing system has been explored in the tropics to improve the environment for optimum production in birds. Studies show that when the volume and velocity of air is increased heat loss is enhanced in birds through convection. Also, the proper consideration of architectural elements such as building orientation, roof slope, roof overhang, landscape, building height, building width, building length, etc. have been reported to enhance naturally ventilated buildings for optimum production in chicken. In addition, the incorporation of cooling systems such as fogging system, sprinkling system and circulation fan in naturally ventilated design house systems have proven positive in optimizing birds' performances in general.

Consequently, in cases where the environmental temperature is severely high and unbearable for birds the mechanical ventilated open housing system have been introduced. The use of Tunnel and inlet ventilation system have been reported to sustain improved birds' production in this regions regardless the extreme weather conditions. However, to design an effective, mechanically ventilated house due attention should be given when calculating the fan capacity of the house, heat

generated by the birds, sizes of inlet, level of installation, positioning of inlet pipes and exhaust fan and finally the capacity of circulation fans required in inlet ventilated systems.

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