Poultry Science Journal
ISSN: 2345-6604 (Print), 2345-6566 (Online) http://psj.gau.ac.ir
DOI: 10.22069/psj.2018.13880.1284

GUASNR

The Use of Housing System in the Management of Heat Stress in Poultry Production in Hot and Humid Climate: a Review

Oloyo A

Department of Architectural Technology, School of Environmental Studies, Federal Polytechnic, Ilaro, Ogun State, Nigeria

Poultry Science Journal 2018, 6(1): 1-9

Keywords
Heat stress
Laying hen
Poultry house design
Hot and humid climate

Corresponding author
Ayodeji Oloyo
ayodeji.oloyo@federalpolyilaro.edu.ng

Article history
Received: August 24, 2017
Revised: October 2, 2017
Accepted: December 4, 2017

Abstract
There is a gap between the population growth and protein supply in many tropical countries where per capita income is low and the majority of people consume less protein than a daily standard for recommended protein intake. Poultry egg production remains the fastest route to bridging the protein demand-supply gap in these regions. However, poultry are faced with heat stress in the tropics which is deleterious to health and productive performance of laying and meat production. In addition, the problem limits dietary protein supply in the affected countries. The harmful effects of heat stress may be alleviated if attention is paid to sources of heat generation in the design and construction of the open poultry houses. This review discusses the internal climatic conditions of the poultry houses, how the birds respond to them, and their implications on heat management for poultry production. Hence, this paper 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.

Introduction

The tropical region is characterized by high temperature and humidity, which can be harmful to poultry birds if it is not properly managed. High temperature and humidity can lead to heat stress and even death in extreme cases (Qureshi, 2001; Olawumi and Ogunlade, 2010). Indeed, heat stress has been reported to cause a decrease in feed intake, feed efficiency, egg quality and quantity, as well as flock activity with a subsequent increase in pulse and respiratory rates, water intake and death (Ubosi, 2001; Yunusa, 2002; Olawumi, 2011). Consequently, heat stress, if not well managed, may exacerbate the problem of low and inadequate supply of eggs and poultry meat to meet the dietary protein needs of the inhabitants of these regions. Also, while it is evident that the need for eggs and poultry meat is increasing in the tropical regions, their supply can be hindered by several constraints such as the breed of poultry birds, harsh environmental factors, type of housing, insufficient capital, and inadequate technical know-how of the farmers (Bhadauria *et al.*, 2014).

Several methods including poultry house design, use of forced ventilation, the monitoring of feed intake and adjustment of its compositions, administration of quality, cool and carbonated water, fogging system, sprinkling system, and use of lightweight breeds of birds have been adopted as strategies for

Please cite this article as: Oloyo A. 2018. The Use of Housing System in the Management of Heat Stress in Poultry Production in Hot and Humid Climate: a Review. Poult. Sci. J. 6(1): 1-9.

addressing the problem of heat stress (Lacy and Czarick, 1992; Beker and Teeter, 1994; Daghir, 2008; Holik, 2015). Of all the methods used to alleviate the heat stress problem in the poorest tropical countries, open housing system appeared to be the most favored one because of the simplicity of their design and construction cost. Unfortunately, the problem of heat stress still persists and, hence the attention of research has been focused on addressing the problem (Daghir, 2008). This is contrary to the expectation that natural ventilation allowing free flow of air within and across the open poultry house will ease heat stress on the birds.

This paper reviews the internal climatic conditions of the poultry house, 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 ensures optimum climatic conditions that will alleviate heat stress problem in poultry production in hot and humid climates.

Regulation of body temperature

Birds are warm-blooded 'homoeothermic' flighty feathered oviparous vertebrates that possess a high metabolic rate, with a normal breathing rate of 40-50 breath per minute (Gordon, 1982; Mason, 1984). On the average, birds maintain an internal body temperature of between 39ºC and 42.2ºC (Hulzebosch, 2004; Daghir, 2008; Holik, 2009). During hot weather poultry bird maintains thermo-neutral temperature by losing heat mainly through evaporative cooling and convection (Daghir, 2008; Holik, 2009; Bhadauria *et al*., 2014).

Climate plays a major role in the well-being and health of poultry birds. The climatic factors of interest include temperature, relative humidity, air composition, air velocity and movement, and lighting (Olanrewaju *et al*., 2006; Mendes *et al*, 2013; Holik, 2015). A review of literature on the effects of the climatic factors on the birds is highlighted below.

Temperature

Milligan and Winn (1964) and also Mardsen and Morris (1987) noted that generally, birds can survive under a wide range of temperatures. However, in a part of the tropical region in Southern America, Jensen (1977) observed that in hot season pullets rarely attain satisfactory body weight at maturity. Bell (1987) showed that hot months of the year (i.e. April – June) is the period of lowest egg production in USA. Payne (1966) showed that at 21 weeks pullets reared from 6 weeks of age at 33ºC were 118 g lighter in body weight with smaller egg sizes than those reared at 20ºC. Also, Smith and Oliver (1972) subjected laying birds to an environmental temperature of 21ºC and 38ºC respectively, and observed a reduction of 40% to 50% in egg production and egg weight at 38ºC. They concluded that lower egg production and poor eggshell quality were due to insufficient feed consumption and high temperature, respectively. In a similar study, Stockland and Blaylock (1974) observed the body weight of the pullets reared at 29.4ºC was 130 g lighter than those reared at 18.3ºC. Increase in egg breakage and reduction in eggshell thickness was caused by heat stress (Lin *et al*., 2004). In addition, Ebeid *et al.* (2012) reported that heat stress caused a reduction in egg weight (3.24%), eggshell thickness (1.2%), eggshell weight (9.93%), and eggshell (0.66%). Vo *et al*. (1978) reported that Leghorn pullets reared at 35ºC had 20% to 30% less body/Egg weight than those reared at 21ºC. They also found a delay of sexual maturity in the birds reared at 35ºC. North (1983) found a lower performance when laying birds were kept in a house with a temperature more than 24ºC. Data were reported in Table 1, where the values related to 16ºC considered 100 as baseline.

According to NRC (1981) optimum feed intake occurs when egg laying bird is kept in a house with a temperature of 20ºC to 21ºC and feed intake is reduced at the rate of 1.5% per 1ºC till the temperature reaches 35ºC. Similarly, Austic (1985) reported a decrease of 1.7% per 1ºC when the house temperature was out of 18ºC to 22ºC in growing birds.

In the review of literature on the effect of temperature on performance of layers, Charles (2002), concluded that a temperature range of 19ºC to 22ºC is the optimum. In other reviews done by Holik (2015), it was concluded that birds are comfortable when environmental temperature is within the range of 18ºC to 24ºC. Consequent on the above, poultry house designers must take into consideration internal housing environment temperature optimum for health of birds and productive performance in terms of mortality, egg production and quality, feed intake and feed conversion ratio, and body weight gain.

Table 1. Effect of house temperature on egg production, egg weight, and feed conversion ratio

Temperature (°C)	Egg production (%)	Egg weight (%)	Feed conversion ratio† (%)
16	100	100	100
18	100	100	95
21	100	100	91
24	100	99	89
27	99	96	86
29	97	93	85
32	94	86	84

†Feed intake (g) to egg production (g).

Relative humidity

For optimum performance the range of relative humidity for laying birds during brooding is reported to be 60% to 80% and after brooding is 50% to 70% (Winn and Godfrey, 1967). While observing the physiological behavior of birds in response to changes in temperature and relative humidity, Qureshi (2001) noted that the birds were most comfortable at 20ºC to 25ºC house temperature and 75% relative humidity. Poultry birds were moderately uncomfortable as the temperature and relative humidity increased to 30-35ºC and 100%, respectively. The birds became extremely uncomfortable and even died at temperature beyond 40ºC and 100% relative humidity.

Winn and Godfrey (1967) reported that feed efficiency, feathering, pigmentation, and weight gain of birds were adversely affected at temperature above 26.7ºC combined with high relative humidity. Furthermore, at higher temperature range of 35ºC to 37.8ºC performance of birds was poor regardless of the level of relative humidity. They noticed that higher humidity caused improvement in the birds' performance. However, the level of humidity must be checked because it could serve as a habitat for microorganisms and therefore, it increases the threat of diseases (Bruce and Drysdale, 1994; Hulzebosch, 2004). Also, high humidity combined with a relatively high temperature can make cooling due to evaporation difficult for the birds (Daghir, 2008). In general, an internal housing environment design for optimization of performance of laying birds should not exceed 85% relative humidity (Qureshi, 2001; Daghir, 2008; Holik, 2009).

Air composition

Naturally, dry air is composed of nitrogen (78.09%), oxygen (20.95%), argon (0.93%), carbon dioxide (0.04%), small amounts of several other gases and water vapor (Zimmer, 2013). Oxygen (O_2) is essential for respiration in birds. It is inhaled and carbon dioxide (CO_2) is exhaled (Hulzebosch, 2004). Under the intensive production poultry droppings in the presence of suitable environmental conditions cause production of unpleasant and polluted gases, which decrease the quality of indoor air (Reddy *et al*., 2007). Ammonia (NH_3), methane (CH_4), and hydrogen sulphide (H_2S) are products of the biodegradation of the faecal material (Reddy *et al*., 2007). Voermans *et al*. (1995) observed that constant collection of faecal materials from birds on walls and floors increased odor and gaseous emissions. The gases are of particular importance because of their deleterious effects on the birds' productive and health performance, deterioration of poultry cages, the poultry house's roofing sheets, and the hazard they pose to human health.

Ammonia has been recognized to cause problem in poultry production (Wang *et al*, 2010). Several authors have shown that a high level of ammonia lowered feed efficiency, body weight, and stunted growth rate (Reece *et al*., 1981; Beker *et al*., 2004; Miles *et al*., 2004). Also, it irritates the mucous membrane causing respiratory diseases and increases mortality in extreme cases (Reece *et al*., 1980; Smith, 1998; Kristensen and Wathes, 2000; Hulzebosch, 2004; Dong *et al*., 2006). It is recommended that NH_3 concentration within a poultry house be kept below 25 ppm for optimum production (Czarick and Fairchild, 2002).

Carbon dioxide is a product of respiration in birds (Hulzebosch, 2004). High concentration of CO_2 could develop poor health conditions characterized by high blood pressure, convulsion, asphyxia, dyspnea, and ultimately death might result (Czarick and Fairchild, 2002). For optimum poultry production, the concentration of carbon dioxide must not exceed 2500 ppm (Hulzebosch, 2004).

Methane (CH_4) produced twenty three times the greenhouse effect of carbon dioxide (Brouček and Čermák, 2015). Meda *et al.* (2011) noted that an average of 13 mg CH_4 was produced per chicken daily amounting to 800 g per bird in a period of 60 days. Similarly, Calvet *et al.* (2011) asserted that CH_4 gas production rate depended on litter management and conditions, and produced at the rate of 0.44 mg.h^{-1} per bird in summer. Low concentration of hydrogen sulphide (H_2S) is fatal to poultry and human health (Hulzebosch, 2004).

Due attention should be paid to waste management by modifying housing design to reduce the area of gas-emitting surfaces, allow for easier removal of faecal materials, and permit better control of temperature and ventilation.

Air velocity and movement

When the weather is hot the air within the building heats up by the heat radiating from the building surfaces, birds and other mechanical equipment (Daghir, 2008). Air velocity and air movement are very important in convectional cooling and regulation of air quality (Hulzebosch, 2004; Daghir, 2008). Hulzebosch (2004) reported that if the temperature remains within the range of 25°C to 30°C, air velocity of 0.1 m/s to 0.2 m/s can be maintained, but if the temperature goes beyond that an increase in air velocity will help aid convectional cooling. Furthermore, at air velocity of 0.1 m/s to 0.2 m/s the movement pattern of air can be easily controlled through building design and ventilation within the building.

Lighting

Lighting in poultry house remarkably influence health and productive performance of chickens, and hence regarded as a critical environmental factor in poultry production (Olanrewaju *et al.*, 2006; Mendes *et al*, 2013; Holik, 2015). Lighting affects feed intake pattern, growth, physical and physiological activities (including bone metabolism, immune responses, sleep, and rest), and mortality rate (Classen *et al.*, 1991; Riddell and Classen, 1992; Classen *et al.*, 2004). Consequently, determination of optimum lighting program for general wellbeing and performance of chickens has attracted research attention.

A continuous lighting program of 16 hrs light and 8 hrs darkness is the conventional lighting and had proved successful for overall performance and productivity of birds (Gordon, 1994; Davis *et al.*, 1997; Rozenboim *et al.*, 1999; Holik, 2015). However, further improvement in the productive performance of birds was achieved with application of intermittent lighting (IL) schedules where duration of lighting (photoperiod) and darkness were varied depending on the type of housing, light intensity, and age of birds (Saxena, 2000; Olanrewaju *et al.*, 2006). Furthermore, introduction of light at midnight for 2 hrs at pullet of 0-18 or 4-18 weeks age resulted in increased egg production and weight gain (Leeson *et al.*, 2003a,b). The additional lighting provided at midnight provided the birds with an advantage of feeding in a cooler night environment. Also, Nishibri *et al.* (1989) recommended provision of light at cooler periods of the day (i.e. 6 pm – 6 am) instead of the hot periods to ensure minimal heat stress. Consequently, this development calls for a more controllable lighting system within the building for the duration of the day.

Furthermore, the source of artificial light used in the poultry house contributes to heat generation within the house. For example, 6-8 W light emitting diodes (LEDs), 60 W incandescent light bulbs and 13-115 W compact fluorescent (CFLs) emits 3.6 kJ/h, 89.7 kJ/h and 31.7 kJ, for production of 800 Lumens light output (Abhishek, 2016).

Housing system

Internal heat within the poultry house is the sum of heat generated by the birds, the atmosphere, the roof, biodegradation of the fecal material, and sunny or shaded ground all of which add to heat load on the chickens (Gordon, 1982; Mason, 1984; Clark, 2013). Generally, dark-colored surfaces tend to absorb more heat when exposed to direct solar radiation than brighter surfaces under the same conditions (Walsberg, 1983). Also, feces if kept for too long in the poultry house without removal or treatment emit heat among various other harmful gases such as NH_3, CH_4 and H_2S from decomposition (Reddy *et al.*, 2007). Finally, exposure of the roof to direct solar radiation throughout the day due to the east–west orientation of poultry house makes the roof one of the major sources of internal heat generation. Therefore, the housing system to be adopted for efficient management of heat stress in poultry production must take into account the various sources of heat generation in the pen house and how to quash their harmful effects on the birds.

Open housing system

Open house system has been adjudged a good method of housing in a hot climate. However, the open houses are prone to insects and some small animals that can disturb the welfare of birds, production, and health. Also, environmental control is too poor in such poultry houses. In order to control the menace of the unwanted insects and other predator animals, the dwarf sidewalls of the poultry house were raised to the roof level with strong corrugated iron wire netting or mesh. Furthermore, ant-proof gutter is constructed round the outer perimeter of the house. The gutter is usually filled with insecticides to prevent insects, particularly ants from gaining entrance into the house (Oluyemi and Roberts, 1979).

It is easier and more economical to manage heat within the building through natural ventilation (Saxena, 2000; Qureshi, 2001; Daghir, 2008). However, careful attention should be paid to architectural design and construction materials, installed mechanical facilities, and location/orientation to alleviate heat stress-associated problems in the rearing of laying birds. Some of the key poultry house construction features are reviewed here.

Orientation

Research has shown that a building receives less direct radiation if orientated east-west rather than north-south (Bond, 1967; Costa and Hunton, 1979; Clark, 2013). This is important to note, because direct sun radiation on the birds can create a situation of heat stress. In some cases, birds move away from the sun's rays if possible, which lead to clustering. This greatly increases the effective density of the birds thereby reducing convection cooling (Daghir, 2008).

Roof overhang

An appropriate roof overhang design helps shade the building sidewalls from direct and indirect heat radiation from the sun. The height of the building's sidewall and height of its opening to the ground is directly proportional to the length of the roof overhang (Daghir, 2008). When the sun is above 45^{o} zenith angle, 70% of the sidewall's height requires shading (Clark, 2013). From 07:00 to 09:00 hours and 15:00 to 17:00 hours, when the heat radiation intensity on the east and west-facing wall is the highest (Anon, 1975), only the bottom quarter of the wall would be exposed. However, Shades at 45^{o} reduces the length of roof overhang to shade the whole wall (Clark, 2013). If shading is done appropriately heat load radiating from the sun is reduced by 30% (Clark, 2013).

House width, length and height

Practices have proven that for effective natural ventilation the house the width must not exceed 12 m (Daghir, 2008). This is also to eradicate the problem of uneven temperature and air exchange rate within the building. It is of optimum advantage to keep the width less or equal to 12 m in hot and humid climate. Houses may be designed at convenient length. Doors should be placed at interval of 15 m to 30 m for easy air circulation within the building (Daghir, 2008). It has been observed that the higher the height of the house the better the airflow for convection cooling. A height of 3-4 meter is recommended (Qureshi, 2001). However, for battery cages the height of the building is a function of the number of tiers of the cages employed. It is also important to note that the higher the tiers the more the production of faecal materials, which in turn can be problematic in waste management.

Side wall openings

The low solid portion of the wall should be a minimum of 40 cm in height in order to protect the house from rainwater seepage, direct and indirect radiation of the sun, predator and pests, and a surface to overlap the curtain for regulation of the temperature within the house during the cooler times of the year (Daghir, 2008). Adjustable curtains can be used to control flow of air during windy and cooler period of the year to control flow and velocity of air and temperature within the building. However, the choice of color for the curtain can also help manage birds lighting program scheme of the bird (Timmons *et al*., 1989; Daghir, 2008, Holik, 2015). The curtain should overlap by at least 30 cm at the top and bottom (Daghir, 2008).

Building obstruction

Proper offset from adjacent building must be established to prevent decreased air exchange rates and exposure to microorganism emanating from the building in question (Daghir, 2008). The minimum spacing required is expressed as $D = 0.4HL^{0.5}$, where D, H and, L are the distance from, height and length of the next building, respectively (Timmons, 1989).

Ridge openings

Since hot air tends to rise above cooler air, ridge opening can be effective in letting out hot air from the building in houses with un-insulated roofs (Saxena, 2000; Daghir, 2008). Note, it is however not effective in houses with insulated roofs because the temperature is uniform within the building.

Roof slope

For un-insulated roofs, a steep roof slope of 45^{o} is strongly recommended because the roof absorbs less heat radiation from the sun, maximizes the distance of the roof to the birds, increases the rate of air exchange through ridge openings and increases open environment for air exchange (Anon, 1975; Daghir, 2008; Clark, 2013). On the other hand, the slope in the insulated roof is dependent on the quality of the insulation.

Roof insulation

For a naturally ventilated poultry house, a minimum R-value of 1.25 m^2 C/W is recommended for ceiling insulation, whereas houses having high temperatures over 40°C would require a minimum R-value of 2.25 m^2 C/W or more depending on the severity of the temperature (Daghir, 2008). Locally sourced materials including thatched roof and bamboo are used as roofing materials for construction of naturally ventilated poultry houses (Qureshi, 2001).

Cooling system

Roof may be cooled substantially by use of rooftop sprinklers (Daghir, 2008; Clark, 2013). However, due attention should be paid to choice of material for roofing because constant introduction of water to the surface of some materials causes staining and rusting (Daghir, 2008). Fogging system is another method of aiding evaporative cooling, and it is more effective than rooftop sprinkler (Daghir, 2008; Clark, 2013). It requires high water pressure to produce better mist. It should be noted that fogging tends to increase relative humidity. Circulation fan can be used to increase air movement so as to increase convection cooling. Generally, circulation fans produce air movement at 0.5 m/s or greater that covers an area 15 times its diameter in length by five times its diameter in width (Daghir, 2008). Furthermore, installing fans at the center 1.0 to 1.5 m above the floor tilted downward at an angle can maximize air movement.

Shade trees

Trees and shrubs help reduce reflected solar radiation from the ground through convection cooling (Clark, 2013). Vegetation should be at medium height to allow for airflow into the house, and to discourage rodents and bird nest (Daghir, 2008). Also, tall trees can also serve as shading device to reduce the heat gain by the roof and sidewalls directly from the sun.

Conclusion

From the foregoing, it may be concluded that heat stress due to harsh climatic conditions in the tropics is deleterious to health and productive performance of poultry and, by implication, economics of egg and poultry meat production. In addition, the problem limits dietary protein supply in the affected countries. However, the problem may be alleviated if attention is paid to sources of heat generation in the design and construction of the open poultry houses.

References

Abhishek G. 2016. Compare LED lights vs CFL vs incandescent lighting chart. https://www.academia.edu/23350197/Compare_LED_Lights_vs_CFL_vs_Incandescent_Lighting_Chart. Retrieve on September 29, 2017.

Anon. 1975. CIBS Guide A6 Solar Data. The Chartered Institution of Building Services, London.

Austic RE. 1985. Feeding poultry in hot and cold climates. In: Yousef MK. (Ed). Stress Physiology in Livestock. CRC Press. Boca Raton. Florida. Pages, 123-136.

Beker A & Teeter RG. 1994. Drinking water temperature and potassium chloride supplementation effects on broiler body temperature and performance during heat stress. The Journal of Applied Poultry Research, 3: 87-92. DOI: 10.1093/japr/3.1.87

Beker A, Vanhooser SL, Swartzlander JH, & Teeter RG. 2004. Atmospheric ammonia concentration effects on broiler growth and performance. The Journal of Applied Poultry Research, 13: 5-9. DOI: 10.1093/japr/13.1.5
Bell D. 1987. Flock management-quality pullets. California Poultry Letter, March, 4.
Bhadauria P, Kataria JM, Majumdar S, Bhanja SK & Kolluri G. 2014. Impact of hot climate on poultry production system - a review. Journal of Poultry Science and Technology, 2: 56-63.
Bond TE. 1967. Environment Control in Poultry Production. Carter T.C. (Ed.) Oliver & Boyd. Edinburgh. Pages, 200-211.
Brouček J & Čermák B. 2015. Emission of harmful gases from poultry farms and possibilities of their reduction. Ekológia (Bratislava), 34: 89–100. DOI: 10.1515/eko-2015-0010
Bruce J & Drysdale EM. 1994. Trans-shell transmission. In: Board RG & Fuller R. (Eds). Microbiology of the Avian Egg. Chapman and Hall. London. Pages, 63-91.
Calvet S, Cambra-lopez M, Estelles F & Torres AG. 2011. Characterization of gas emissions from a Mediterranean broiler farm. Poultry Science, 90: 534–542. DOI: 10.3382/ps.2010-01037
Charles DR. 2002. Responses to the thermal environment. In: Charles DR & Walker AW. (Eds). Poultry environment problems, a guide to solutions. Nottingham University Press. UK. Pages, 1–16.
Clark JA. 2013. Environmental Aspects of Housing for Animal Production. Butterworths. London. 528 Pages.
Classen HL, Riddell C & Robinson FE. 1991. Effects of increasing photoperiod length on performance and health of broiler chickens. British Poultry Science, 32: 21-29. DOI: 10.1080/00071669108417324
Classen HL, Annett CB, Schwean-Lardner KV, Gonda R & Derow D. 2004. The effects of lighting programmes with twelve hours of darkness per day provided in one, six or twelve hour intervals on the productivity and health of broiler chickens. British Poultry Science, 45: S31-32. DOI: 10.1080/00071660410001698137
Costa MS & Hunton P. 1979. 6th Latin America Poultry Congress, Lima, Peru.
Czarick M & Fairchild BD. 2002. Measuring ammonia levels in poultry houses. Poultry Housing Tips, 14.
Daghir NJ. 2008. Poultry Production in Hot Climates. 2nd Ed. Published by CAB International. Wallinford, Oxfordshire, UK. 387 Pages.
Davis J, Thomas PB & Siopes TD. 1997. More evidence for light-dark growing. Broiler Industry, February: 31-32.
Dong H, Mangino J, Mcallister TA, Have D. 2006. Emissions from livestock and manure management. In: 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Agriculture, Forestry, and Other Land Use. Eggleston HS, Buendia L, Miwa K, Ngara T & Tanabe K. (Eds.) Institute for Global Environmental Strategies (IGES). Hayama, Japan.
Ebeid TA, Suzuki T & Sugiyama T. 2012. High temperature influences eggshell quality and calbindin-D28k localization of eggshell gland and all intestinal segments of laying hens. Poultry Science, 91: 2282-2287. DOI: 10.3382/ps.2011-01898
Gordon RF. 1982. Poultry Disease. 2nd Ed. Billiard, Tindal, London.
Gordon SH. 1994. Effects of day length and increasing day length programs on broiler welfare and performance. World's Poultry Science Journal, 50: 269-282.
Holik V. 2009. Management of laying hens to minimize heat stress. Lohmann Information, 44: 16-29.
Holik V. 2015. Management of laying hens under tropical conditions begins during the rearing period. Lohmann Information, 50: 16-23.
Hulzebosch J. 2004. What affects the climate in poultry houses? World Poultry, 20: 36-38.
Jensen LS. 1977. The effect of pullet nutrition and management on subsequent layer performance. Proceedings of the 37th Semiannual Meeting, American Feed Manufacturers Association Nutrition Council. Atlanta, Georgia. Pages, 36-39.
Kristensen HH & Wathes CM. 2000. Ammonia and poultry welfare: a review. World's Poultry Science Journal, 56: 235−245. DOI: 10.1079/WPS20000018
Lacy MP & Czarick M. 1992. Tunnel-ventilated broiler houses: broiler performance and operating cost. The Journal of Applied Poultry Research, 1: 104-109. DOI: 10.1093/japr/1.1.104

Leeson S, Caston LJ & Summers JD. 2003a. Performance of layers given two-hour midnight lighting as growing pullets. Journal of Applied Poultry Research, 12: 313-320. DOI: 10.1093/japr/12.3.313

Leeson S, Caston LJ & Summers JD. 2003b. Potential for midnight lighting to influence development of growing leghorn pullets. Journal of Applied Poultry Research, 12: 306–312. DOI: 10.1093/japr/12.3.306

Lin H, Mertens K, Kemps B. Govaerts T, De Ketelaere B, De Baerdemaeker J, Decuypere E & Buyse J. 2004. New approach of testing the effect of heat stress on eggshell quality: mechanical and material properties of eggshell and membrane. British Poultry Science, 45: 476-482. DOI: 10.1080/00071660400001173

Mardsen A & Morris TR. 1987. Quantitative review of the effects of environmental temperature on food intake, egg Output, and energy balance in laying pullets. British Poultry Science, 28: 693–704. DOI: 10.1080/00071668708417005

Mason IL. 1984. Evolution of Domesticated Animals. Longman. London. 452 Pages.

Meda B, Hassouna M, Fléchard C, Lecomte M, Germain K, Picard S, Cellier P & Robin P. 2011. Housing emissions of NH_3, N_2O and CH_4 and outdoor emissions of CH_4 and N_2O from organic broilers. In Köfer J & Schobesberger H. (Eds.) Proceedings of the 15th International Congress of the International Society for Animal Hygiene. Tribune, EU. Pages, 215−218.

Mendes AS, Paixão SJ, Restelatto R, Morello GM, de Moura DJ & Possenti JC. 2013. Performance and preference of broiler chickens exposed to different light sources. Journal of Applied Poultry Research, 22: 62–70. DOI: 10.3382/japr.2012-00580

Miles DM, Branton SL & Lott BD. 2004. Atmospheric ammonia is detrimental to the performance of modern commercial broilers. Poultry Science, 83: 1650-1654. DOI: 10.1093/ps/83.10.1650

Milligan JL & Winn PN. 1964. The influence of temperature and humidity on broiler performance in environmental chambers. Poultry Science, 43: 817–824. DOI: 10.3382/ps.0430817

NRC (National Research Council). 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. National Academy Press, Washington, DC. Pages, 109–133.

Nishibri M, Li Y, Fujita M, Ito T & Yamamoto S. 1989. Diurnal variation in heat production, heart rate, respiration rate and body temperature of laying hens at constant environmental temperatures of 23 degree centigrade and 35 degree centigrade. Japanese Journal of Zootechnical Science, 60: 529-533. DOI: 10.2508/chikusan.60.529

North MO. 1983. Layer management on floors. In: Commercial Chicken Production Manual. 3rd Ed. Avi Publishing Co. Westport. Pages, 232–243.

Olanrewaju HA, Thaxton JP, Dozier WA, Purswell J, Roush WB & Branton SL. 2006. A review of lighting programs for broiler production. International Journal of Poultry Science, 5: 301–308. DOI: 10.3923/ijps.2006.301.308

Olawumi SO & Ogunlade JT. 2010. Phenotypic correlations between reproductive traits in layer breeders and weather variables in humid zone of Nigeria. International Journal of Animal Science, 2: 113-120.

Olawumi SO. 2011. Influence of breed and season on reproductive traits of three strains of commercial layers in the derived savannah zone of Nigeria. International Journal of Agriculture and Food Science, 2: 97-104.

Oluyemi JA & Roberts FA. 1979. Poultry Production in Warm Wet Climates. The Macmillan Press Ltd, London. 197 Pages.

Payne CG. 1966. Environmental temperatures and the performance of light breed pullets. Proceedings 13th Worlds Poultry Congress. Pages, 480-484.

Qureshi AA. 2001. Open house tips for layers in hot climate zone. World Poultry, 17: 32-34.

Reddy RA, Praveen P, Prasadini P & Anuradha. 2007. Assessment of air quality in a poultry house. Journal of Industrial Pollution Control, 23: 369-372.

Reece FN, Lott BD & Deaton JW. 1980. Ammonia in the atmosphere during brooding affects performance of broiler chickens. Poultry Science, 59: 486-488. DOI: 10.3382/ps.0590486

Reece FN, Lott BD & Deaton JW. 1981. Low concentrations of ammonia during brooding decrease broiler weight. Poultry Science, 60: 937–940. DOI: 10.3382/ps.0600937

Riddell C. & Classen HL. 1992. Effects of increasing photoperiod length and anticoccidials on performance and health of roaster chickens. Avian Diseases, 36: 491-498. DOI: 10.2307/1591739

Rozenboim I, Robinzon B & Rosenstrauch A. 1999. Effect of light source and regimen on growing broilers. British Poultry Science, 40: 452-457. DOI: 10.1080/00071669987197

Saxena HC & ketelaars EH. 2000. Poultry Production in Hot Climatic Zones, 3rd Ed. Kalyani Publishers. New Delhi-Ludhiana. 190 Pages.

Smith AJ & Oliver J. 1972. Some nutritional problems associated with egg production at high environmental temperatures. I. the effect of environmental temperature and rationing treatments in the productivity of pullets fed on diets of different energy content. Rhodesian Journal of Agricultural Research, 10: 3–20.

Smith RA. 1998. Impact of disease on feedlot performance: a review. Journal of Animal Science, 76: 272-274. DOI: 10.2527/1998.761272x

Stockland WL & Blaylock LG. 1974. The influence of temperature on the protein requirement of cage-reared replacement pullets. Poultry Science, 53: 1174-1187. DOI: 10.3382/ps.0531174

Timmons MB. 1989. Improving ventilation in open-type poultry housing. Proceedings of the 1989 Poultry Symposium, University of California. Pages, 1–8.

Ubosi CO. 2001. Poultry management in the northeastern region of Nigeria. SEEPC Nigeria Limited Symposium. Maiduguri, Borno State, Nigeria.

Vo KV, Boone MA & Johnston WE. 1978. Effect of three lifetime temperatures on growth, feed and water consumption and various blood components in male and female leghorn chickens. Poultry Science, 57: 798–803. DOI: 10.3382/ps.0570798

Voermans JAM, Verdoes N & den Brok GM. 1995. The effect of pen design and climate control on the emission of ammonia from pig houses. Proceedings of the 7th International Symposium on Agricultural and Food Processing Wastes, June 18-20, Chicago, IL, ASAE, St. Joseph, MI, 252-260.

Walsberg GE. 1983. Coat color and solar heat gain in animals. American Institute of Biological Sciences, 33: 88-91. DOI: 10.2307/1309169

Wang YM, Meng QP, Guo YM, Wang YZ, Wang Z, Yao ZL & Shan TZ. 2010. Effect of atmospheric ammonia on growth performance and immunological response of broiler chickens. Journal of Animal and Veterinary Advances, 9: 2802-2806. DOI: 10.3923/javaa.2010.2802.2806

Winn PN & Godfrey EF. 1967. The effect of humidity on growth and feed conversion of broiler chicken. International Journal of Biometeorology, 11: 39-50. DOI: 10.1007/BF01424274

Yunusa MM. 2002. Poultry production in Yobe State and the challenges of the weather. 1st National Conference Organized by COEASU. Gashua, Nigeria.

Zimmer C. 2013. Earth oxygen: A mystery easy to take for granted. New York Times Web. http://www.nytimes.com/2013/10/03/science/earths-oxygen-a-mystery-easy-to-take-for-granted.html. Retrieved 3 October 2016