STATE-OF-THE-ART TECHNOLOGIES FOR ASSESSING THERMAL COMFORT OF BROILER CHICKENS

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Abstract: The thermal assessment of the environment where poultry birds are raised is very important to prevent them from poor welfare, poor health and poor performance. Contain evaluation of poultry environment would enable the poultry growers to understand the conditions of their flocks and also to know when there is a change in the behaviours of the birds. In order to assess the thermal comfort of broiler chickens without disturbing them, there is a need for the state-of-the-art technologies. There are different technologies adopted by various researchers to evaluate the thermal comfort of broiler chicken subjected to different environmental conditions. However, there is no comprehensive report on the techniques for assessing the thermal comfort of broiler chicken. Therefore, this study intended to comprehensively compile all the available technologies which have been used by the researchers to evaluate the thermal comfort of broiler chickens. This study has found out that, apart from thermal indices, precision livestock farming (PLF) equipment are very important tools which could be adopted by all broiler chicken growers to assess the thermal comfort of broiler chickens during hot conditions in order to prevent them from heat stress. Furthermore, it has also been reported that most farmers may not be able to afford the tools due to their high initial investment, unavailability of technical-know-how and high maintenance cost most especially in the developing countries.

Keywords: Thermal comfort; Broiler chickens; Precision livestock farming; Heat stress; hot condition.

I. THERMAL COMFORT OF BROILER CHICKENS

The thermal condition inside the animal sheds is very important if good welfare and health of animals are to be ensured. The survival of animals strongly depends on their environment (Gaughan et al., 2009) during hot periods if animal building configuration and ventilation system are improperly designed (Lima et al., 2011; Gaughan et al., 2009). It could affect livestock homeostasis, production efficiency and growth (Purswell et al., 2012; Cangar et al., 2008). For broilers to survive during hot periods, they usually change their behaviour and physiology by reducing their feed consumption in order to minimise their core body temperature (DeShazer et al., 2009). These behavioural and physiological changes have been shown to cause a reduction in body growth and meat yield and quality (Arias et al., 2008). According to Tao and Xin (2003a), the body temperature between 41.0 and 42.0 °C of broilers is expected to be maintained as the ambient temperature is within the thermal neutral zone (18.0 °C – 24.0 °C). However, broiler chickens could find it difficult to maintain homeothermy if there is an increase in the ambient temperature. This may inevitably result in high mortality and economic losses (Tao and Xin, 2003a).

Broilers are homeotherms and they rely mainly on the thermal conditions of their environment for thermal comfort, body growth and performance. As the environment becomes hot, broilers require adequate cooling (Welker et al., 2008) and minimise feed consumption to survive heat stress (Cassuce et al., 2013; Welker et al., 2008; Dozier III et al., 2011). For broilers at different stages perform optimally, the optimum temperatures within their confined environment is shown in Table 1.

Table 1: The ambient temperature required for broiler optimal performance (Cassuce et al., 2013)

<table>
<thead>
<tr>
<th>Growth stages (Days)</th>
<th>Ambient temperature ( °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 7</td>
<td>32.0 - 34.0</td>
</tr>
<tr>
<td>8 to 14</td>
<td>28.0 - 32.0</td>
</tr>
<tr>
<td>15 to 21</td>
<td>26.0 - 28.0</td>
</tr>
<tr>
<td>22 to 28</td>
<td>24.0 - 26.0</td>
</tr>
<tr>
<td>29 to 35</td>
<td>18.0 - 24.0</td>
</tr>
<tr>
<td>36 to 42</td>
<td>18.0 - 24.0</td>
</tr>
</tbody>
</table>

The factor influencing the heat transfer between broiler and the environment are; their heat and moisture demands, nature of feather and their thermoregulation as broiler chickens dispel heat and moisture during thermoregulation (Blanco and Gous, 2006). The microclimate conditions of the broiler building are usually affected (altered) as the birds dissipate heat and moisture. This alteration would also result in a new
thermal response of birds and their thermal response would cause additional environmental changes and the process continues (Gous et al., 2006). Exposure of broiler chickens to the environmental changes could be detrimental as it could affect their welfare, performance and the economy of the farmers (Lara and Rostagno, 2013).

The microclimate of broiler chickens is very important when monitoring the thermal conditions on the building where the birds are kept. It replicates the environmental parameters (temperature, relative humidity and air velocity) felt by the birds either during hot or cold conditions (Reiter and Bessei, 2000). Against the believe of some farmers that the thermal conditions above the birds could represent the microclimate at the broiler level (0.2 m above the floor), a report by Purswell et al. (2008) had shown that temperature above 0.2 m differed by about 4.0 °C from that obtained at the broilers’ microclimate which was found to be higher than that ambient temperature above the broiler chicks. The results of the study were obtained by fitting an integral temperature sensor to the back feather of the broiler chicks to evaluate the temperature in the animal occupied zone. At the same time, some thermocouples were positioned above the floor to assess the ambient temperature inside the building.

II. HEAT TOLERANCE OF BROILERS

Heat tolerance is the ability of livestock to maintain core body temperature when subjected to hot condition. The quantity of metabolic heat production and heat dissipation by animals determine the extent of heat stress they are subjected to (Berman, 2012). The productivity and welfare of animals are influenced by the heat from their immediate environment. As a result, consideration of potential heat-tolerant strains and heat stress relief for optimal production of livestock is unavoidable. Poultry production has recently witnessed progress in the genetic modification of fast-growing and high meat yield broiler chickens. But the genetically selected birds lack complete visceral organs development which makes them susceptible to heat stress during acute environmental conditions (Piestun et al., 2008a, 2008b). Hot environmental conditions are detrimental to broiler chickens they could increase the metabolic heat production, economic losses, mortality rate, poor meat quality and meat production of broiler chickens (St-Pierre et al., 2003).

The high body temperature and high metabolic heat production of broilers during hot periods could occur as a result of non-functional nervous thermoregulatory mechanisms and thermoregulatory control system (Janke et al., 2002). Thus, body temperature regulation and the control of metabolic heat production of broilers could be attained by using an environmental control system and through the thermal modification of broiler chicks during embryogenesis (Tzschentke, 2008). Some research works have indicated that the exposure of broiler chicks to high temperature during embryogenesis could enable broiler chicks to survive hot conditions up to about 10 days after hatching (Yahav et al., 2004b), 28 days after hatching (Loyau et al., 2013) and adult broiler chickens (Piestun et al., 2011). However, Collin et al., (2007) showed that thermal manipulation of broiler chicks during embryogenesis could not improve heat tolerance of broiler for a long time but could influence the breast muscle yield of broilers at 42 days.

III. METHODS OF EVALUATING THE THERMAL COMFORT OF BROILER CHICKENS

Different methods could be used to assess the thermal comfort of broiler chickens under any climatic condition. Various research works have been carried out globally to assess the thermal comfort of broilers at different growing stages in order to measure the effect of hot conditions on broiler chickens’ health, production and welfare. However, there is no comprehensive report concentrated on the methods that could be used for assessing the thermal comfort broiler chickens. This paper intended to fill the gap by providing in details the different ways that the thermal comfort of broiler could be assessed.

A. The level of vocalisation of broiler chickens -

Vocalisation is an important aspect of livestock production. In poultry production, broiler chickens have the capacity to produce about thirty different sounds (Moura et al., 2008) based on their conditions at that moment. The sounds of broilers vary from aggression due to separation from other birds (Marx et al., 2001), pain due to thermal environments (Moura et al., 2008), hunger and need (Weary and Fraser, 1995), to inability to eat properly due to stress exposition (Zimmerman and Koene, 1998). In order to use the sound of broiler chickens as a thermal comfort indicator, it must predict exactly the condition of the birds and must be constant (Zimmerman and Koene, 1998). For broiler chicks, it is possible to assess their thermal comfort by their sound’s amplitude and frequency (Moura et al., 2008; Fontana et al., 2014). Moura et al. (2008) carried out a study to assess the thermal comfort of broiler chicks that were subjected to different thermal conditions. In their research work, broiler chicks were subjected to warm condition (24.0 °C – 29.0 °C) and cold condition (15.0 °C – 23.0 °C). The amplitude and frequency of the sound of the broiler chicks were monitored with microphones and the behaviour of the chick to environmental conditions were observed with the real-time video camera. It was observed that thermal conditions to which the birds were subjected to affected their migration within the shed and their level of vocalisation. It was found out that as the air temperature increased, there was an increase in the chick migration from one region to another within the shed and...
an apparent increase in the vocalisation of the chicks. As the air temperature reduced below the thermal comfort zone, there was a decrease in the chicks’ vocalisation compared with that of the period when the air temperature was over the thermal comfort zone. It was concluded that when broilers chickens are subjected to heat stress, their stress level could be assessed whenever there is an increase in their sound’s amplitude and frequency (Moura et al., 2008).

B. Behavioural and productive responses

The way the microclimate affects different strains of broiler chickens differs. Broiler chickens, bred for fast growth tend to adapt to hot conditions by changing their behaviours (distribution) while those with slow growth genes survive cold climatic conditions by altering their rate of feed consumption (Nielsen, 2012). Ferraz et al. (2014) evaluated the behavioural and productive responses of broilers chicks that were subjected to various air temperature. The chicks were at day one of age introduced an air temperature of 33.0 °C in a wind tunnel ventilated building. The behavioural response such as clustering, rates of drinking and feeding and distribution of the chicks subjected to different air temperatures were observed with the real-time video camera mounted above the chicks. Similarly, the feed consumption, water intake and body weight gain which were tagged as the productive response of the chicks were appraised. They found out that the chicks expended about 68 % and 12 % of the time huddling together and spreading apart respectively at a temperature of 27.0 °C. When the air temperature was increased to 36.0 °C, there was a reduction of about 51 % and 16 % in the time spent huddling and spreading respectively. In addition, the broiler chicks, subjected to 36 °C were found spending about 28 % and 5 % of the time feeding and drinking respectively. The authors added that a high correlation of about 96 % was found between the behavioural and productive responses of the broiler chicks and their thermal comfort. From this result, it could be concluded that behavioural and productive responses of broiler chickens could be used as indicators for evaluating their thermal comfort.

The thermal comfort zone of broiler breeders was assessed by Pereira and Nääs (2008) using their behavioural response. They implanted electronic identification transponders in the female broiler breeders while radio frequency identity (RFID) transponder-reader was positioned in the drinker area to monitor breeders’ drinking behaviour. They discovered that the female broiler breeders were found spending their time drinking from the drinkers at about 67 % when the air environmental temperature was between 20.0 °C and 29.0 °C and relative humidity between 70.0 % and 80.0 %. The conclusion from the study was that behavioural pattern such as the time spent drinking water could be used to determine when the birds are experiencing heat stress or not and that the pattern could be adopted by poultry growers to control the climatic conditions inside the commercial broiler sheds.

C. Surface temperature

A crucial parameter in the birds’ thermal biology, which could contribute significantly to the thermal comfort of broiler chickens is the surface temperature (Cangar et al., 2008). With the latest technological development, the surface temperature of broiler chickens could easily be estimated using non-invasive technology called infrared thermography (IR). The technique of thermography involves the collection of emission (radiation) from the object’s (for example broiler chickens) surface and then converts it to an electrical signal. The signal then creates an image of the exposed surface using various colours to express temperature distributions of the surface measured (Naas et al., 2014). Generally, the physiological response of the object such as broilers subjected to heat stress usually results in the skin temperature’s fluctuation (Shinder et al., 2007). The rate of blood flow rate in birds could be influenced by the thermal stress to which they are subjected. According to Altan et al. (2003), broilers subjected to dehydration could reduce the rate of blood flow to its skin in order to control thermal exchange between their core body and the skin surface.

The heat production of broiler chickens could be used as a mechanism for assessing their thermal comfort (Nascimento et al., 2011). The surface temperatures of broiler chickens at different ages (7 days to 35 days old) exposed to different air temperatures were assessed by Nascimento et al. (2011) using an infrared thermal camera. The authors discovered that the surface temperature of broiler chickens was found increasing with an increase in air temperature from 18.0 °C to 32.0 °C. They also found that the age of broilers only had little or no impact on their surface temperatures. They added that broilers’ surface temperature was found to be at its peak when the birds were 14 days old but dropped as the broilers approached table size (35 days old). Similarly, Nääs et al. (2010) assessed the thermal comfort of 42-day old broilers before the birds were taken to the abattoir. They found out that the body regions of the birds without feathers responded quickly to changes in the thermal environment compared to the feathered areas of the broilers’ body. The temperature of the surfaces with feathers was found to be similar to the thermal temperature of the environment to which the birds were subjected to. It could be concluded from these studies that surface temperature of broiler chickens if regularly assessed could be used to determine their thermal comfort and at the same time used as a control measure for monitoring the environmental conditions inside the broiler buildings.
The spatial surface temperature distributions of broilers using infrared thermography were quantified by Cangar et al. (2008). They reported that the surface temperatures of broiler at different body parts such as shanks, feet, wattles, comb, back, and head differed by more than 10 °C when the birds were subjected to a fixed environmental condition. However, they recorded that the rate of blood flow in body parts without feathers was higher than the areas with feathers. This is an indication broiler could easily thermoregulate with their featherless body parts, where the blood flow rate is higher than the feathered parts during hot conditions. As reported by Tessier et al. (2003) contrary to that of Nascimento et al. (2011), the surface temperature gradient of birds increased with age showing that there is an interaction between broiler’s age and their surface temperature distributions. From the report of Tessier et al. (2003), the surface temperatures of the younger birds were higher than the mature broilers due to their body-surface area ratio and the thickness of their feathers. This indicates that mature broilers would find it hard to lose body heat as the environmental conditions exceed their thermal comfort zone.

D. Thermal indices -

Thermal indices are mathematical expressions, that contain some environmental parameters such as temperature, humidity and air velocity, which could be used for estimating the thermal comfort of livestock and for determining the level of heat stress in livestock production (Sejian et al., 2012). The losses related to heat stress could be monitored and prevented by weather safety indices (Hahn et al., 2009). In addition, they could serve as a standard for categorising the environmental conditions in all livestock productions including animal transportations (Samal et al., 2017). They could also be used as a “basis for the strategic management practices” in livestock productions (Samal et al., 2017). They are also useful in the prediction of the effects of thermal conditions on animal productivity (Purswell et al., 2012). The level of sensitivity of different animals to heat stress differs (Bohmanova et al., 2007). Ruminants (cows, sheep and goats) could survive warm conditions longer than other animals such as broilers and pigs due to their lack of sweating glands. Broiler chickens could not lose heat by sweating but could do so by panting when subjected to a warm environment.

Some studies, as shown in Table 2, have shown that the thermal comfort of fast-growing birds (broiler chickens) could be assessed by using thermal indices based on their physiological and productive responses (Chepete et al., 2005; Tao and Xin, 2003b). Environmental factors such as air velocity, air temperature and relative humidity have been indicated as the main factors affecting the physiological and productive responses livestock. Tao and Xin (2003) established an index called temperature-humidity-velocity index (THVI) which was based on the body temperature response of adult broilers exposed to different combinations of environmental conditions for evaluating the thermal comfort of the adult broiler. The homeostasis of the birds was determined using the index. They reported that homeostasis state of broilers could be considered normal if the body temperature rise threshold is 1.0 °C. As the body temperature rise threshold reached 2.5 °C, it could be considered as an alert. Danger and demand for an emergency could occur as the body temperature threshold reached 4.0 °C and above.

<table>
<thead>
<tr>
<th>Authors and years</th>
<th>Indices</th>
<th>Animals</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tao and Xin (2003)</td>
<td>$THVI = (0.8S_\text{wa} + 0.15S_\text{wb})V^{-0.08}$</td>
<td>Ross male broiler chickens</td>
<td>The model was developed based on the core body temperature rise of adult broiler chickens subjected to severe thermal conditions in a controlled environment.</td>
</tr>
<tr>
<td>Chepete et al. (2005)</td>
<td>$THI = 0.62T_\text{wa} + 0.38T_\text{wb}$ for 3-4 weeks old broiler chickens</td>
<td>Cobb 500 Broiler chickens</td>
<td>The indices indicated that broiler chickens kept in a non-controlled semi-arid environmental condition were mostly affected by the air temperature compared to another environmental factor such as relative humidity.</td>
</tr>
<tr>
<td></td>
<td>$THI = 0.71T_\text{wa} + 0.29T_\text{wb}$ for 5-6 weeks old broiler chickens</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

where $THI = $ temperature-humidity index, $THVI = $ temperature-humidity-velocity index, $T_\text{wa} = $ wet-bulb temperature (°C), $T_\text{wb} = $ dry bulb temperature (°C).

Table 2 Summary of the environmental indices for assessing the thermal comfort of farm animals

IV. TECHNOLOGY FOR ASSESSING THE THERMAL COMFORT OF BROILER CHICKENS

Precision Livestock Farming (PLF) is a newly designed scientific discipline where data obtained from animal behaviour and their surroundings, using sensors, could be unified with the real-time monitoring of animal welfare, health and productions (Ismayilova, 2013). PLF could afford the animal growers the opportunity to monitor their livestock in order to provide better care and environment for the animals (Ismayilova, 2013). An important aspect of PLF is the use of non-invasive and non-destructive sensors for the monitoring of behaviours of farm animals. The detained of the available techniques or instrumentations used in PLF and their applications can be found in Table 3. In this section, the uses of PLF technologies for assessing animal thermal comfort were discussed.
Table 3: Techniques for evaluating the thermal comfort of broiler chickens

<table>
<thead>
<tr>
<th>Authors</th>
<th>Indicators</th>
<th>Instrumentation</th>
<th>Research findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moura et al. (2008)</td>
<td>Distributions of broiler chicks; vocalisation amplitude and frequency</td>
<td>Real-time video camera, microphone</td>
<td>The hot environment had a significant impact on the broiler chicks’ distribution and noise level.</td>
</tr>
<tr>
<td>Pereira and Näss (2008)</td>
<td>Drinking behaviour</td>
<td>Real-time video camera</td>
<td>As the air temperature increased, birds were found visiting drinkers more often.</td>
</tr>
<tr>
<td>Nielsen (2012)</td>
<td>Migration and feed consumption</td>
<td>Real-time video camera</td>
<td>Non-uniformity of the environmental condition within the broiler building caused the birds to migrate to the cooler region within the broiler building.</td>
</tr>
<tr>
<td>Nascimento et al. (2011)</td>
<td>Surface temperature</td>
<td>Infrared thermography (IRT)</td>
<td>The surface temperature of broiler chickens was directly proportional to the air temperature changes in the broiler building.</td>
</tr>
<tr>
<td>Baracho et al. (2011)</td>
<td>Surface temperature</td>
<td>Infrared thermography</td>
<td>Skin temperature of birds at different locations within the poultry building differed.</td>
</tr>
<tr>
<td>Pereira et al. (2005)</td>
<td>Aggressive behaviour</td>
<td>Real-time video camera</td>
<td>Low air temperature triggered the aggressive behaviour of broiler breeders when offered food.</td>
</tr>
<tr>
<td>Näss et al. (2012)</td>
<td>Broiler distribution</td>
<td>Real-time video camera and algorithm</td>
<td>Birds clustered around feeders when the air temperature was low. Separation from one other in order to increase heat loss increased as the air temperature increased. Similarly, the time spent on drinking water increased as the air temperature increased.</td>
</tr>
<tr>
<td>Cangar et al. (2008)</td>
<td>Skin temperature</td>
<td>Infrared thermography</td>
<td>The maximum difference between the broilers’ skin temperature and their immediate environment occurred when the birds were 14 days old. This could indicate that optimal air movement could be needed at age 14 days old compared to their other growth stages.</td>
</tr>
<tr>
<td>Pereira et al. (2012)</td>
<td>Cluster index</td>
<td>Real-time video camera</td>
<td>The rate of clustering among the broiler breeders was reported to be affected by the air temperature in the broiler building. Clustering rate reduced as the air temperature increased and vice versa.</td>
</tr>
</tbody>
</table>
A. Real-time monitoring of broiler chickens with the time-lapse video camera -

Real-time monitoring of animals using time-lapse video cameras is an important PLF tool which has been widely adopted in livestock production (Ismayilova, 2013). In order to capture all relevant data when monitoring livestock behaviours, sophisticated image processing systems have been developed and reported many studies and tested in the laboratories and animal buildings. Systems for tracking the movement of livestock was developed by Kashiha et al. (2014b). A sensor for monitoring the behaviours and health conditions of broiler chickens was developed by Kashiha et al. (2013). The assessment of hen behaviour in response to ammonia concentration was determined using a real-time video camera (Kashiha et al., 2014a). The hen growth and activity in the poultry building was monitored with a video camera by Leroy et al., (2006). For commercial purpose, an innovative software called “eYeNamic” for automatic and continual monitoring of the activity of broiler chickens has been developed. The sophisticated tool was manufactured and supplied by Fancom BV, The Netherlands. The software directly works with video cameras to assist in distant monitoring and analyses of broiler chickens’ behaviour (Montis et al., 2013). The software has the capacity to monitor the effect of the animals’ microclimate on their activity such as eating and drinking, and distributions (Costa et al., 2014; Montis et al., 2013). The software could also detect automatically any abnormal activity in broiler chickens (Kristensen and Cornou, 2011).

B. Infrared thermography (IRT) -

Thermal imaging is another PLF tool used for monitoring the welfare and state of health of livestock. The tool used for thermal imaging is infrared thermography (IRT), a multifunctional equipment, which is a non-invasive and contactless thermal detection kit (Knizkova et al., 2007) which could be used for detecting inflammatory diseases in humans (Ring and Ammer, 2012), for diagnosing orthopaedic diseases in livestock (Knizkova et al., 2007), for assessing the state of pain, health and hoof lesions in cows (Theurer et al., 2013), evaluating the heat tolerance of livestock (Brown-Brandl et al, 2013). It could be used for measuring the surface temperature and body heat production of poultry birds (Nääs et al., 2010), for evaluating the hyperthermia induced by stress in birds (Edgar et al., 2013), and for appraising the response of livestock to management approaches (Yarnell et al., 2013). The metabolic heat production of birds could be evaluated using infrared thermography (Ferreira et al., 2011). In addition, the sensible heat exchange between confined livestock and their immediate environment could easily be quantified with IRT (Yahav et al., 2001). Furthermore, the feed consumed of livestock when experiencing heat stress could be monitored and estimated with IRT (Zhou and Yamamoto, 1997).

C. Bioacoustics -

Bioacoustics technique plays an important role in the survival of all living things. It could convey information, indicate emotional state, stress and welfare conditions of all animals (Jahns, 2008). Bioacoustics is a non-contact and non-destructive PLF tool, which could be used for evaluating the thermal comfort of animals, for effective management of animals and for monitoring animals’ welfare, health and efficiency (Jahns, 2008). Animals in stress, due to changes in the environment, could respond with high sound intensity and frequency and longer duration of sound signals (Richards and Wiley, 1980) compared to animals in with the better environment. Recognising the sounds of animals in stress is nowadays possible with the advent of call recognisers also known as microphones to identify the emotional state, the needs and welfare conditions of the animals (Jahns, 2008). Adequate knowledge of the sound of heat-stressed broiler chickens could afford the poultry meat farmers to provide a conducive environment for the birds. Some research works had indicated that sound intensity, frequency and sound signal’s duration could be adopted for predicting the emotional state and welfare conditions of different animals. It had been used for distinguishing between excitement, pain and fear in livestock such as cows and sheep (Weeks, 2008), for monitoring respiratory problems such as coughs and sneezes in dairy calves and pigs (Hemeryck and Berckmans, 2015). However, as regards its application in broiler production, a few works had been reported. The available works had shown its application in determining the welfare state of broiler chicks (Fontana et al., 2015) eggs’ pipping stage in the incubator (Exadaktylos et al., 2011), determining the feed intake of broiler chickens (Aydin et al., 2015), and the assessment of broilers’ activity (Aydin et al., 2010). It has also been used for assessing an average age and body weight gain of broiler chickens (Fontana et al., 2015) including the assessment of the sound level of broiler chicks (Moura et al., 2008). Similar to other PLF tools such as IRT, bioacoustics is yet to be commercially employed in the broiler production. This could be due to the interference of other sounds such as feeder’s motors, feeder’s auger, extraction fans or ventilators, and other equipment the poultry buildings.

V. LIMITATIONS OF THE PLF TECHNOLOGIES

Frequent assessment of the thermal comfort of broiler chicken is a vital aspect of poultry meat production. The
impact of heat stress on animal welfare, health and production could be minimised if the thermal comfort of livestock could be constantly monitored so as to improve their performance all year round. However, not all tools are commercially applicable in commercial broiler buildings. Some of the tools are infrared thermography and bioacoustics. For infrared thermography, it has minimal coverage as the camera could not cover a large area at a time compared with that of a real-time video camera which has larger coverage. Another problem with the use of IRT in commercial broiler production is the effect of the background on the quality of thermal imaging and surface temperature of the object monitored. For instance, in deep litter broiler buildings, litters (dry and wet) could affect the quality of the surface temperatures measured from the birds. Similar to IRT, bioacoustics is yet to be commercially employed in broiler production. This could be due to the interference of other sounds such as feeder’s motors, feeder’s auger, extraction fans or ventilators, and other equipment the poultry buildings. Furthermore, another factor affecting their non-commercial application is their cost. All the sophisticated tools used for PLF are highly expensive and most farmers may not be able to afford more than one that will cover the whole poultry building. In addition, most farmers are not willing to invest in it due to their high cost of maintenance. For instance, a farmer in the developing countries would like to have the tools but may be discouraged due to non-availability of technological assistance in their immediate environment who could maintain the equipment. Furthermore, it will be too expensive for them to invite specialists from Europe and other developed countries to assist with the maintenance of the equipment. For small-scale farmers, investing in highly expensive equipment may not be possible due to their financial constraints.

VI. CONCLUSION

This report has shown different ways through which the thermal comfort of broiler chickens could be assessed without interfering with the broiler chickens using PLF tools. It has been confirmed in this study that it is very important to constantly evaluate the thermal comfort of broiler chickens in a confined environment either naturally ventilated or mechanically ventilated. It has also been identified that not all farmers at the moment could access the equipment most especially in the developing countries due to financial implications and non-availability of the PLF tools. Therefore, PLF tool manufacturers should intensify in their production of PLF tools with affordable price and minimal technical-know-how requirement so that all farmers could conveniently monitor their animals’ welfare, health and performance. In addition, further studies could be conducted to investigate how the PLF equipment could be developed to suit all climatic condition as some are extremely warm all year round. Since thermal indices require computation due to many environmental parameters involved and may not be used to determine the stress state of animals.

VII. REFERENCE


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thermography applied to the evaluation of metabolic heat loss of chicks fed with different energy densities. Revista Brasileira de Ciência Avícola, 13(2), 113–118. https://doi.org/10.1590/S1516-635X2011000200005


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