
A COMPREHENSIVE REVIEW ON THE POULTRY BROODING REQUIREMENTS AND FORCED AIR METHODS OF HEAT GENERATION FOR BROODING

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ABSTRACT

Brooding is among the most sensitive stages in the poultry production cycle because neonatal chicks bear premature thermoregulatory body systems making them rely totally on external sources of heat for growth and development however, the inadequacy and the inconsistency of the heat supply remain a major challenge as such, the design and construction of air heating system is vital in the chick's production sector. This review discussed brooding requirements, different air heating systems and their operational principles including construction guidelines, material selection, insulation and the automation in poultry brooding are discussed. The study identified that Computational Fluid Dynamics is an important tool for optimization of aspects such as air flow velocity and temperature distribution pattern. The study further identified the existing research gaps from where the corresponding future directions were suggested. The study concluded that, performance of the system doesn't only rely on the heat source or mode of heat transfer but also on the construction workmanship while considering material selection and insulation.

Keywords: brooding requirement; forced air heating methods; construction; insulation; material selection

1 INTRODUCTION

Poultry production has become one of the rapidly-growing sectors in agriculture globally. In spite of the rapid growth rate recorded in the past few years, the adoption is highly dependent on the capacity to provide the indispensable requirements necessary for the birds to survive during the early stage of growth and development. The provision of these vital requirements is termed as brooding where naturally, the mother hen provides to ensure newly hatched chicks adapt to the environmental conditions especially self-regulation of body temperature (Collin *et al.*, 2020).

Artificially, quite a number of traditional heat generation technologies have been developed such as charcoal stoves, kerosene heaters, firewood furnaces, coal burners, and open-flame gas for providing the conducive thermal conditions for the day-old chicks (Bekele, 2021). These heat generation methods portray several drawbacks such as non-uniform temperature maintenance, generation of harmful combustion gases, risk of fire hazards, environmental pollution, including the drudgery associated with maintaining the fuel quantity for a 24-hour production, (Okonkwo *et al.*, 2022).

The fast technological improvement in agricultural engineering has sprung the innovation of better-quality heating technologies for example heat lamps, radiant heaters which have the capacity to bridge the bottle-neck related to inefficient brooding systems. Recent poultry brooding technologies have incorporated intelligent systems which uses microcontrollers such as Arduino, Proportional-Integral and Derivative (PID), fuzzy logic, raspberry-pi to automatically regulate the thermal condition within the brooding chamber. These innovations have meaningfully improved the temperature regulation processes including control of other environmental parameters (Zhang *et al.*, 2024).

In Nigeria, Okonkwo *et al.*, (2025) developed a micro-physical element monitoring device for Trombe wall solar energy poultry brooding chamber for real time measurement of brooding temperature, relative humidity and daily solar radiation using data logger. Furthermore, Ezema *et al.*, (2021) designed and implemented an embedded poultry brooding system that monitors and automatically controls the climatic conditions such as temperature and humidity where the digital values were being displayed on the Liquid Crystal Display (LCD) screen. The Arduino ESP-32 type was used to provide the overall operational controls of the system and heat lamps was used as the heat source.

Forced air heat generation methods though not commonly utilized in poultry brooding have the ability to eliminate localized heating unlike radiant heaters that primarily warm only a spot in the brooding chamber or surfaces directly underneath the heat source and to drive out unwanted gases. In addition, forced-air heating systems can be incorporated with an air filtration unit there by improving on the quality of air supplied in the brooding area. It employs a blower or a fan to distribute heated air homogeneously throughout the brooding perimeter (Mohamed, 2015).

Therefore, the aim of this study is to examine the poultry brooding requirements and investigate the potential of forced air heating systems for efficient regulation of brooding temperature with specific objectives such as; to understand the various types of forced-air heaters for brooding and construction guidelines, material's selection and insulation requirements, to understand the possibility of automation in forced-air heaters for brooding and to discover the research gaps associated with forced-air heating systems for brooding.

2 METHODOLOGY

This review was conducted by retrieving relevant literatures from reputable scientific databases such as Google Scholar, ScienceDirect, SpringerLink, Semantic Scholar, and Taylor & Francis Online. Further materials were got from technical reports, poultry management manual, engineering handbooks including publications by international organizations, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

The literature search was primarily limited to publications between 2020 and 2026 to guarantee the latest advancement in the forced-air method of heat application for brooding. The earlier information from engineering textbooks and article publications were selectively considered to capture fundamental engineering principles and thermodynamic equations. Boolean search operators (AND, OR, and NOT) were used to quicken the process of relevant literature identification. A bunch of keywords were equally used to improve on the accuracy of the literature which includes; forced-air heating system, poultry brooding, electric resistance heating, hot-air generator, heating chamber, brooding temperature and humidity, ventilation, fabrication, heat system construction, Computational Fluid Dynamics, material selection and insulation.

After the initial search, the titles and abstracts of the obtained publications were carefully scrutinized to ascertain their relevance to the objectives of the study. It was equally necessary to evaluate the full-text articles to prove their appropriateness for inclusion. Lastly, the choice on the final selection of the literature were grounded on studies that discussed application of intelligent and automation systems for control of environmental parameters during brooding most especially temperature management. The exclusion criteria were focused on studies that didn't explore related poultry brooding aspects, studies that didn't consider any form of brooding requirement or lacked engineering or scientific information related to automation of brooding systems and forced-air heating technology.

3 RESULTS AND DISCUSSION

3.1 Poultry brooding requirements

3.1.1 Temperature requirement from day 1 to Week 6

The normal body temperature of a healthy chick according to Bekele, (2021) ranges from 32°C to 36°C which is supposed to be maintained by ensuring the chick's environment is well conditioned. If environmental temperatures drop below this recommended range, chicks spend substantial energy from metabolic process such as trembling and dietary diversion to produce

metabolic heat. The appropriate brooding temperature is greatest as soon as they are hatched and continuously reduces by 5°C each week as chicks mature as shown in table 1 since the development of their thermoregulatory capacity occurs as they grow. Feather establishment, body weight gain raises the rate of metabolic heat generation thereby improving the insulation to retain a reasonable quantity of heat that help reduce the extent of dependence on supplemental heat.

Table 1: Recommended brooding temperature profile

Age	Ranges of suitable temperatures (°C)	Remarks
Day 1–7	32–36	High supplemental heating required.
Week 2	27–31	Chicks become more active
Week 3	22–26	Feather development
Week 4	17–21	Reduced dependence on artificial heating for ambient conditions

Sources: (Collin *et al.*, 2020; Bekele, 2021)

3.1.2 Humidity requirements

All through the brooding cycle, chicks endlessly give out moisture as respiration occurs, whereas extra water vapor emanates from drinkers as spillages, watery droppings, wet litter, and the reaction of hydrocarbon fuels with oxygen. In a situation where this moisture is not properly removed through ventilation process, relative humidity intensifies, creating environmental conditions favourable for microbial organism proliferation, conglomeration of litter, ammonia gas generation, and respiratory tract infection. In contrast, extremely dry air accelerates evaporative water loss from chicks, leading to desiccation which causes irritation of the respiratory tract, and high volume of dust evolution within the poultry house. Majority of the poultry production guides recommends running a poultry brooding activity with relative humidity as shown in table 2. This range controls dehydration extent while avoiding extreme moisture accumulation in the litter material (Mutibvu *et al.*, 2021).

Table 2: Recommended relative humidity during brooding

Age	Recommended Relative Humidity (%)	Remarks
Week 1	60–70	Prevents dehydration and supports chick adaptation after hatch.
Week 2–3	55–65	Facilitates a good feather development and litter drying.
Week 4–6	50–60	Supports efficient exchange of gases and diminishes ammonia generation

Source; (Mutibvu *et al.*, 2021; Onagbesan *et al.*, 2023)

The benefit of humidity management outspreads beyond just moisture accumulation control because it improves the bird's surrounding temperature condition. In situations of high relative humidity, evaporative cooling occurring on the bird's surface area turns out to be less effective. Ultimately, birds go through thermal stress even though ambient temperatures continue to be within

the preferred range. Contrarily, low humidity increases evaporative heat loss, which may be of advantage throughout the hot weather period though harmful at the initial stage of the brooding period that chicks highly require heat supply (Onagbesan *et al.*, 2023).

3.1.3 Air velocity

The speed at which air traverses across the poultry house is another key brooding factor that can't be overlooked. Appropriate air velocity allows uniform heat distribution, enhances oxygen concentration, drives out excess moisture and harmful gases, and contains the occurrence of thermal stratification. In contrast, air movement beyond a preferred velocity may initiate convective heat loss from chicks, especially in the first week of the brooding process. Convective heat loss from chicks can be quantified using Newton's Law of Cooling, illustrated by expression (1).

$$Q = hA(T_s - T_a) \dots \dots \dots (1).$$

Where; Q = rate of heat loss (W), h = convective heat loss coefficient ($W m^{-2} K^{-1}$), A = chick's surface area (m^2), T_s = chick's surface temperature ($^{\circ}C$), T_a = ambient air temperature ($^{\circ}C$). Therefore, as air velocity surges, the convective heat loss coefficient (h) equally surges, triggering a large quantity of heat removal from the chicks (Çengel & Ghajar, 2020).

This principle enlightens why just moderate drafts can cause cold stress irrespective of whether air temperatures are within the acceptable range. The recommended air velocities based on the brooding period are as illustrated in table 3. During the process of bird's growth, more metabolic heat is generated as such, increase in air velocities become advantageous in expelling excessive body heat hence modifying thermal environment (Liang *et al.*, 2022).

Table 3: Recommended Air Velocity

Age	Air Velocity ($m s^{-1}$)	Purpose
Week 1	0.10–0.15	Prevent chilling and drafts.
Week 2–3	0.15–0.30	Improve air circulation while maintaining warmth.
Week 4–6	0.30–0.50	Enhance convective cooling and toxic gas removal.

Source; (Liang *et al.*, 2022 ; Onagbesan *et al.*, 2023)

3.1.4 Ventilation requirements

The fact that brooding requires external heat supplement, ventilation remains crucial because it expels unwanted gases and retains a greater percentage of oxygen that supports respiration process, exits evaporated moisture, direct aerosols out of the facility and maintaining a recommended humidity level. A common misconception is that ventilation minimization during cold conditions help to retains heat within the facility when it just causes problems associated with high relative humidity therefore, adequate poultry house ventilation systems must be maintained in order to strike the balance between heat conservation and maintaining air quality (Sarai *et al.*, 2023).

3.2 Automation in brooding systems

Klotz *et al.*, (2020) discussed that, automated brooding systems continuously monitors crucial environmental variables such as temperature, humidity, and helps in ventilation management. Automated control mechanisms manipulate the heating devices, ventilation fans, and air inlets to maintain the atmosphere favourable for poultry growth and development. The monitoring and regulation of these variables is possible with the help of a series of electronic devices e.g. integrated

sensors, microcontrollers, and a digital display system for a physical observation of values in real time.

In a study conducted by Kalu et al., (2023) microcontroller-based temperature monitoring and control system for broiler's brooding was developed. The LM35 analog temperature sensor was used to detect the temperature in the brooding chamber and sends information to the ATmega 328 microcontroller. The microcontroller was configured to perform a task of temperature maintenance for a particular value which is displayed on the Liquid Crystal Display (LCD). When the LM35 sensor sends a temperature value lower than the configured value, the microcontroller commands the relay to turn on the halogen heater and the fan turned off. Meanwhile, when the LM35 sensor sends a temperature value higher than the configured value, the heater turns off and the fan turned on hence maintaining the configured temperature desirable in the brooding chamber.

Olalekan *et al.*, (2021) developed an automated temperature and humidity regulation system by using Arduino microcontroller for the poultry brooding house where, in the first week, the temperature was maintained between 32°C and 35 °C. When temperature falls below this range, heater is turned-on and the fan off while when the temperature goes beyond this range, the heater is turned off while the fan is turned on. Temperature and humidity sensors were used to detect the heat levels and relative humidity respectively. The relay was used to control the heater by switching it on and off as instructed by Arduino microcontroller. The running of the fan was equally facilitating ventilation within the brooding facility. The similar working principles applied to the subsequent weeks until the last week of the brooding period. Remote monitoring of the data was possible using a WiFi System-on-Chip (SoC) module, an IoT technology where the farmer can view the data from his smart phone.

3.3 Forced air heating systems

ASHRAE (2021) described an air heating system as a thermodynamic system that converts primary energy into heat energy and transfer of heat energy to air occurs when air gets in contact with the heat emitting surface. The objective is to generate heat, supply and maintain a desired indoor temperature by striking the balance between heat generation and heat losses. The heat losses fundamentally occur through conduction, convection, radiation, infiltration, and ventilation process.

3.3.1 Direct-fired air heaters

Montaser *et al.*, (2021) explained that, the sequence of operation of the direct-fired air heater involves supply of fuel into the burner through a fuel delivery system especially a horse pipe and a control valve if Liquid Petroleum Gas is the source of fuel. An ignition device is used to initiate combustion process. A blower forces ambient air longitudinally through the combustion chamber where heat is produced. Heat generated from combustion is transferred in to the moving air stream and because of the ability of air to absorb heat, its temperature raises. The heated air and the combustion products mixture is discharged into the brooding house. A thermostat or electronic controller controls the burning operation to adjust the temperature to the desired range. Because the heated air is not passed through a heat exchanger, thermal losses are minimal and this allows direct-fired heaters to attain combustion efficiency close to 100% measured in terms of the sensible heat delivered in to the space.

3.3.2 Indirect-fired air heaters

The working principle of indirect heating system follows a chronological sequence where fuel burns inside a well-designed combustion chamber and high-temperature gases is allowed to pass through the heat exchanger. A blower sucks fresh air and forces it across the outer surface of the heat exchanger that has gained heat, and as a result, the stream of air getting in contact with the wall of the heat exchanger absorbs heat. Only clean hot air enters the brooding house while combustion gases exit through the exhaust chimney. The fact that combustion gases do not mix with the heated air, the concentration of carbon monoxide and nitrogen oxides inside the production room are greatly minimized. For large scale brooding operation, indirect-fired heaters are highly preferred because

good air quality is a priority, in spite of their high initial investment and operational cost (Lienhard, 2001).

3.3.3 Electric hot-air generators

According to Lee (2010), the working principle of an electric hot-air follows the three chronological processes which are; conversion of electrical energy into heat using a resistant heating element, heat transfer to the fluid and heat distribution within the brooding chamber. The heat generated by the heating element increases the temperature of the air that passes across its hot surface. A blower aids the flow of air across the heating element's surface and distribution into the brooding chamber. In summary, the overall process involves the electrical energy conversion, heat transfer to the air and heat distribution.

Electric air heating systems can easily be integrated with electronic controllers, solid-state relays for on and off switching, digital temperature sensors, and affordable microcontrollers. This has elevated the rate of adoption of electric air heating systems in the current precision livestock practices. This integration enables effective temperature regulation through intermittent heating schedules, remote monitoring with IoT technology, and efficient energy utilization. These contributes to the ease of operation of brooding system while lowering the production costs (Yang *et al.*, 2022).

3.4 Construction of forced air heating systems for poultry brooding

3.4.1 Fabrication process

Fabrication generally involves the measurement, marking, cutting and joining the metal component of the construction by welding, a common metal joining technique based on the engineering drawings. During measurements, allowances are considered to cater for bends, seams, and flanges. Cutting involves sheet metal portioning in to required sizes using guillotine shears, plasma cutters, angle grinders, Computer Numerical Control laser cutters. Accurate cutting minimizes misalignment of parts during assembly and material wastage. Forming where the cut metal sheets are folded with the help of a press brake or manual folding machine to come up with the required profile is another element of fabrication (Bruce, 2015). A summary of common fabrication defects is presented on table 4.

A metal plate is rolled using a slip roller to form a circular duct or a hollow section. Joining the sections are performed with the help of lock seams, rivets, spot welding, Metal Inert Gas welding and or flanged connections with bolts. The heated air passage's joints should be sealed with heat-resistant materials like sealants or gaskets to prevent air leakages. After the completion of fabrication process, the components should undergo surface finishing in order to improve on the physical appearance. This involves grinding weld beads, removing burrs, restructuring indentations, sandblasting or wire brushing, applying high temperature primer, degreasing, applying heat-resistant paint. Surface finishing prevents corrosion by rust hence prolonged service life, especially in humid environments for instance poultry keeping environment where ammonia that accelerates metal deterioration is generated (Bruce, 2015).

Table 4: Common fabrication defects and preventive measures

Defect	Possible Cause	Recommended Solution
Air leakage	Incomplete welding	Continuous seam welding and leak testing
Chamber distortion	Excessive welding heat	Balanced welding sequence and controlled heat input
Corrosion	Inadequate surface protection	Apply high-temperature anti-corrosion coatings
Poor airflow distribution	Improper chamber geometry	Incorporate diffusers and optimize internal layout
Excessive heat loss	Insufficient insulation	Increase insulation thickness and seal gaps
Heating element contact with metal	Improper mounting	Use ceramic insulators and maintain adequate clearances

Source; (Kalpakjian & Schmid, 2020; Callister & Rethwisch, 2020)

3.4.2 Insulation

In an explanation made by Kan *et al.*, (2023), heat losses from ducts or heat chamber materials reduces the quantity of heat that is supposed to reach the intended end point in a system hence lowering the operating efficiency of the system therefore, insulation is greatly important. Insulation is equally important where heat ducts or heat chamber is exposed to the workers or can easily be reached by workers. The insulation materials such as glass wool, mineral wool, rock wool, ceramic fibre blankets possess high thermal resistant property that allows for efficient heat retention.

Heat losses can also occur due to air leakages which as well decreases system efficiency by limiting the volume of hot air required in system. The major leakage points include flanged joints, access panels, sensor positions. The prevention of leakage can be achieved by applying heat-resistant silicone sealants for example shellac, using compressible gasket papers, uniform torque bolt tightening, regular joints inspection during operation. Adhering to this construction measures improve the system's performance efficiency at a reduced rate of energy consumption. The process of thermal insulation requires that insulators be placed all-round the heat chamber. It's very vital to adhere to the procedures of insulation for instance, ceramic fibre blankets are supposed to be wrapped around the chamber followed by the outer protective casing. An air gap between the insulation and outer protective housing may further minimize heat loss through conduction (Kan *et al.*, 2023).

3.4.3 Materials selection

Material selection is one of the most crucial factors to be considered during the construction of an air heating system. Poor material selection often results in to rapid corrosion, heat loss, structural deformation, electrical hazards, and increase in maintenance costs. When carrying out material selection, Callister & Rethwisch, (2020) mentioned that it should base on a number of properties such as mechanical strength, thermal properties, corrosion resistance, manufacturability, availability, and cost. The fact that different components require materials of different engineering properties, the material to be used for a particular component should possess those properties that makes it suite the intended purpose for instance, mild steel is basically fit for the fabrication of heat chamber due to its high mechanical strength, good weldability, excellent machinability, low cost and ubiquitous with a thermal conductivity of roughly 50 W/m·K and this is the reason it permits moderate heat transfer as it maintains sufficient structural integrity to achieve the design purpose.

However, mild steel deteriorates quickly in ammonia generated environment because in poultry brooding, ammonia released as a result of litter decomposition, increases the humid condition of the chamber. Thus, protective coatings such as high-temperature resistant and moisture proof paint or powder coating should be applied. Application should be on points such as heat chamber casing, structural frame, support brackets, mounting plates. In a situation where corrosion is to be avoided without preventive measures, stainless steel material is supposed to be used. Stainless steel grades which include AISI 304, AISI 316 provide outstanding resistance against moisture, ammonia, oxidation, high temperatures. Stainless steel enables the system the work for a long period of time without corroding although it's a somewhat costly material. It is therefore recommended for the interior layer of the heat chamber, outside surfaces that gets exposed to moisture or air (Kalpakjian & Schmid, 2020).

Aluminum is another alternative material that can be used in the construction of air heating systems. It offers numerous advantages lightweight that makes it easily lifted, exceptional thermal conductivity of approximately 205 W/m·K, possesses best corrosion resistance property, provide ease of molding to any required shape. The truth of the matter is that, aluminum transfers heat easily which makes it best fit heat exchanger fins construction, protective covers, heat sinks, sensor mounting brackets. However, aluminum loses mechanical strength at temperatures above 200°C as such, it should not be used as an inner material directly around the heating coils (Callister & Rethwisch, 2020).

3.5 Computational Fluid Dynamics (CFD) application in air heating systems for poultry brooding

Bhatti *et al.*, (2020) highlighted that Computational Fluid Dynamics is distinct from conventional design approach that rely solely on empirical equations and experimental testing. CFD lowers development costs, minimizes design errors, and improves thermal system design by letting designers analyze the general operating conditions of the system with the aid of a computer-based simulation. Several CFD softwares have been developed which includes; ANSYS Fluent, OpenFOAM, COMSOL Multiphysics, and STAR-CCM+ and have rapidly gained popularity. Engineers currently are able to examine how heat element orientation, blower capacity, duct configuration, insulation materials, and ventilators impact the thermal condition inside the brooding chamber ahead of the physical prototype construction.

3.5.1 Airflow simulation

Muktiarni *et al.*, (2024) explained that, air flow velocity analysis presents one of the applications of CFD. Velocity contour maps illustrate the variation in air velocity across the entire system's network. CFD in this case displays velocity contour maps with different colours representing airflow speed variation at various points within the brooding house. The major illustrations produced by the contours are; horizontal velocity distribution, vertical airflow profile, duct exit velocity, floor-level velocity, recirculation zones. CFD therefore informs the designer's decision on the operation to be optimized e.g. fan speed, duct diameter, dispenser design so as to uniformize the velocity pattern without draft formation throughout the brooding chamber (Szpicier *et al.*, 2025). Coradi *et al.*, (2016) employed CFD to simulate the air flow velocity in the poultry house and the air distribution within the poultry brooding chamber, achieved using an air blower was somewhat even as seen in figure 1. The air velocity as per the simulation was found to be within the range of 0.6m/s – 0.8m/s and this range was maintained within the poultry brooding chamber. The heating of air was achieved by blowing air through a firewood furnace. This demonstrates the direct-fired forced-air heating system.

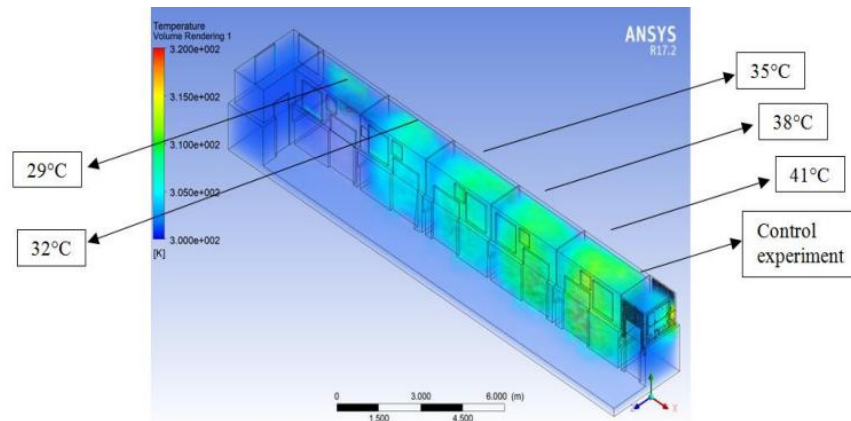


Source: Coradi *et al.* (2016)

Figure 1: Hot air velocity distribution pattern within the brooding chamber

3.5.2 Heat distribution

CFD software equally generates temperature contours that brings a clear understanding on the extent of thermal gradients whereby hot spots and cold spots can easily be identified. Temperature contour plots are therefore useful in a sense that, they differentiate regions of varying temperatures by displaying colour corresponding to the temperatures at that point (Krishnaswamy *et al.*, 2020). Tehinse *et al.*, (2020) applied AYSNS-CFX software package from CFD to analyse the heat distribution within the poultry brooding chamber and the CFD profile show sections of the chamber with varying temperatures such as 41° C, 38° C, 35° C, 32° C and 29°C. The temperature profile in the building decreases along the left side as seen on the simulation figure 2 except for the control experiment where the temperature profile is determined by the ambient condition of the environment. Heating element powered by photovoltaic system was used to heat the flowing air which demonstrated the electric air heating system.



Source: Tehinse *et al.* (2020)

Figure 2: Temperature distribution inside the poultry brooding chamber in three dimensions

3.5.3 Research gaps and future direction in air heating systems

Current research on forced air heating system has focused mostly on experimental studies that are carried out under controlled laboratory conditions, with limited evidence of efficient operation in environments associated with fluctuating ambient temperatures and different atmospheric conditions therefore, future study should consider conducting field tests to ascertain the performance efficiency of this heat generation method to be confident about its sustainability and economic viability for commercial operation. A suitable experimental design should involve at least two comparable brooding houses, with one representing a conventional heating method as the control and the other equipped with the innovated forced-air heating system. Where resources permit, a randomized block

design involving three or more brooding units with at least three replications would provide stronger statistical evidence. Field experiments should be closely monitored for a period of four weeks right from the time chicks have been introduced but also depending on the breed of the chicken for example brooding broiler takes at most four weeks. The monitoring is to make sure all the brooding parameters are within the recommended range otherwise an action should be taken. Measurements should include temperatures within the brooding zone, relative humidity, air velocity, energy consumption. Biological indicators should include body weight gain, feed intake, feed conversion ratio, mortality rate. These are the parameters that enables the performance of the heating systems to be evaluated and compared.

4 CONCLUSION

This review involved exploration of several sources of information and identified numerous aspects of poultry brooding requirements and forced-air methods of heat generation with emphasis on ascertaining the conditions necessary for brooding and several technical requirements for efficient operation of the forced air method of heat generation for poultry brooding. The study demonstrated several brooding requirements which are vital during the brooding period such as temperature, relative humidity, air velocity, ventilation which must be properly managed because they determine the performance of the flock.

In the construction of forced air heating system, material's selection should consider ease of fabrication, corrosion resistance, available and affordable. Similarly, proper insulation and sealing of leakage points is necessary to minimize heat losses and air pressure losses respectively. Vibration control must be ensured to prevent the creation of lines of weakness on the system's components and to guarantee the overall durability of the system. Therefore, construction workmanship must be ensured in order to realize the very best out of the construction.

Electric forced-air heating system is strongly compatible with microcontrollers such as Arduino, fuzzy logic, raspberry pi which are basically the commonest automation systems, unlike the direct-fired and indirect-fired forced air heating systems which requires continuous fuel flow for constant heat generation. More advanced systems can combine microcontrollers with IoT intelligent system for remote monitoring of the system's performance where if a particular system is malfunctioning, an alert can be sent to the concern person for a quick response to rectify the system.

The study however identified some existing research gap especially on aspect of experimental test. No evidence of publication involving experimental studies carried out in the field which is characterized by fluctuating environmental conditions rather only conducted under controlled laboratory conditions. The review has significant contributions to knowledge based on the fact that it provides valuable technical information for researchers, engineers, equipment manufacturers, and poultry farming practitioners to utilize so as to inform their decisions in order to arrive at the next-generation of air heating systems for a precise poultry brooding.

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