



PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
UNIVERSITY OF ECHAHID HAMMA LAKHDAR - EL-OUED



Master's Thesis

In order to obtain a diploma of Master degree

Faculty of technology

Department: Mechanical Engineering

Specialty: Energetic

Title

Investigation of Thermal Comfort in Poultry Farm

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Mémoire préparé au sein du Laboratoire d'Exploitation et de Valorisation des
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University Year: 2023/ 2024

Acknowledgements

First, we thank **ALLAH**, our creator for giving us the strength to do this work.

We want to express our sincere gratitude to our supervisor **Pr. A. ATIA (UEHL) and Dr. Zobiri Oussama** , for his excellent guidance, valuable advice, strong support, and continuous encouragement throughout the course of this research work at El Oued University.

I wish to express my deepest gratitude to all my colleagues and all staff of Mechanical Engineering Department at UHL-ELOUED and LEVERES Laboratory, for their helpful technical discussions and suggestions.

Dedication

To Our parents,

To Our family,

To Our friends

Abstract:

Energy expenditure is the second highest expense for the poultry producers after the house mortgages, and is continuously on the rise. Energy related retrofits and renewable energy integration on a broiler farm can be very important to reduce the fossil energy use. The poultry growers need help in the on-farm energy use assessment and audit in order to optimize energy amount and cost. The main objective of this study is to confirm the applicability and the efficiency of geothermal heat exchangers coupling with the poultry house as function of time during the experiment on broiler farming. Furthermore, it can also allow to evaluate the level of the thermal comfort conducted by the geothermal heat exchangers through several parameters such as humidity, internal temperature, CO₂ and CO emission. The obtained results show that the proposed geothermal system effects on all these parameters.

Key Words: Poultry House, Thermal Comfort, humidity, internal temperature, CO₂ emission.

ملخص

يعد إستهلاك الطاقة ثاني أعلى إشكال لمنتجات الدواجن بعد بناء بيت الدواجن، وهو في ارتفاع مستمر. يمكن أن تكون التعديلات التحديثية المتعلقة بالطاقة وتكامل الطاقة المتجددة في مزرعة الدجاج اللحم مهمة جدًا لتقليل استخدام الطاقة الأحفورية. يحتاج مربو الدواجن إلى المساعدة في تقييم وتدقيق استخدام الطاقة في المزرعة من أجل تحسين كمية الطاقة وتكلفتها. الهدف الرئيسي من هذه الدراسة هو التأكد من قابلية تطبيق وكفاءة المبادلات الحرارية الأرضية المقترنة ببيت الدواجن. علاوة على ذلك، يمكن أن يسمح أيضًا بتقييم مستوى الراحة الحرارية التي توفرها المبادلات الحرارية الأرضية من خلال العديد من العوامل مثل الرطوبة ودرجة الحرارة الداخلية وانبعاثات ثاني أكسيد الكربون أحادي أكسيد الكربون. أظهرت النتائج التي تم الحصول عليها أن النظام الحراري الأرضي المقترح يؤثر على جميع هذه العوامل.

كلمات مفتاحية: بيت الدواجن، الراحة الحرارية، الرطوبة، درجة الحرارة الداخلية، انبعاث ثاني أكسيد الكربون.

Resumé : Les dépenses énergétiques sont la deuxième dépense la plus élevée pour les producteurs de volailles après les hypothèques immobilières et elles sont en constante augmentation. Les rénovations liées à l'énergie et l'intégration des énergies renouvelables dans un élevage de poulets de chair peuvent être très importantes pour réduire la consommation d'énergie fossile. Les éleveurs de volailles ont besoin d'aide pour évaluer et auditer la consommation d'énergie à la ferme afin d'optimiser la quantité et le coût de l'énergie. L'objectif principal de cette étude est de confirmer l'applicabilité et l'efficacité des échangeurs de chaleur géothermiques couplés au poulailler en fonction du temps au cours de l'expérimentation sur l'élevage de poulets de chair. De plus, cela peut également permettre d'évaluer le niveau de confort thermique réalisé par les échangeurs de chaleur géothermiques à travers plusieurs paramètres tels que l'humidité, la température interne, le CO₂ et les émissions de CO. Les résultats obtenus montrent que le système géothermique proposé affecte tous ces paramètres.

Mots clés : Poulailier, Confort Thermique, humidité, température interne, émission de CO₂.

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General Introduction

General Introduction

Recent developments in the field of agriculture have led to a renewed interest for the poultry farming. The national Algerian production of poultry meat has experienced a considerable evolution in recent years according to statistics of the Agriculture and Rural Development Ministry. It was reached 5.6 million quintals (Mqt) in 2019, vs 2.092 Mqt in 2009, which presents an increase of 167%.

With the expansion of the practice of this field and due to poultry farming being located in isolated area, the consumption of different energy sources is increasing because of its importance in the management of the zootechnic indicators, the role of which is to maintain animal health, welfare, and allowing it to perform and grow well. These energy sources are used for heating in winter, cooling in summer, ventilation system lighting and for automatic feeding systems in the poultry farming.

One of the greatest challenges faced by many breeders is the increasing use of natural gas or diesel for heating and water for cooling system. The actual used system is too costly due to high energy and water consumption, in which it needs nearly to 6-14 gas bottles of LPG-B13 or 200 L of diesel per day for heating in winter and about 5000 L of water per day for cooling in summer season for one poultry house. The integration of more efficient energy systems and the use of renewable and local energy resources will help to provide the energy demand in the farm for sustainable poultry development.

The ground in the southern regions of Algeria contains very important and easy exploited geothermal energy. In which, the temperature is considered constant in the range of 26-24°C after a depth of 3 m from the surface of the earth meanwhile the ambient temperature drops to 0°C in winter and rises to 50°C in summer. The difference in temperature between the ground and the atmosphere can be exploited in the field of air conditioning in poultry farming via geothermal heat exchangers [1].

The advantages of geothermal energy systems are: (1) can be used for both heating in winter and cooling in summer; (2) decarbonization of the farm: zero carbon emissions; (3) scalable for large system; and (4) reduce the cost of energy by 50-70% (low capital cost and eliminate the fuel cost) [2].

The present thesis aims to investigate the thermal comfort inside poultry house with the integration of geothermal heat exchanger.

*Chapter I: Introduction on Poultry
farming*

I.1. Introduction

For a chicken farm, housing and equipment make up the majority of the fixed capital. A careless, costly home with low efficiency could be the difference between the farm's success and disaster. Research on the planning and building of chicken homes for tropical environments is scarce. The majority of the advice provided in textbooks is derived from data gathered from western nations in addition to insights gained from our nation's actual chicken farmers' experiences. Therefore, visiting the nearby chicken farms could be a good way to talk about the advantages and disadvantages of our nation. Therefore, it might be helpful to go to the nearby chicken farmers and talk about the advantages and disadvantages of the proposed house.

I.1.1 Location of a poultry farm:

Poultry should be kept in areas with strong markets for eggs and chicken meat, as well as areas where common poultry feed is easily accessible and reasonably priced. The farm has to have good access to the road network and other forms of transportation. Water and electricity ought to be easily accessible and at a fair price. Because it might not be able to move or demolish a permanent building upon legal notice or objections, poultry farms shouldn't be built in a city close to residential areas where they are objectionable or prohibited by law.

It ought to be far from congested areas and have adequate room to grow in the future. The chicken farm should be as far away from noise and other distractions as feasible. [3]

I.1.2 Factors controlling the construction of poultry houses:

For the correct and approved construction of poultry houses, the following conditions must be observed: [3]

.Strategic location of the residence

In order to build a strategic dwelling, the following factors should be taken into account:

- A source of electricity and clean water
- The building should be close to the main transport route
- The building should be at least 500 meters away from other residences

. Purpose of the building

- It is desirable that the longitudinal axis of the building be in the east-west direction

. Poultry Building area

- The choice of space is due to the number of poultry, so that each m² contains from 1 to 15 chickens

I.1.3 Types of famous poultry houses

There are three famous types

I.1.3.1 Open chicken house

- These houses are in areas where the climate is always mild, and this type of houses depends on the ventilation of nature so that there is a hole on each wall and the size of the hole depends on the prevailing climate in the area

I.1.3.2 Semi-closed poultry house

- In these houses there are windows with fans that draw air and these windows are on one side of the dwelling, when there is a suitable air current, these windows are opened and the fans are turned off for ventilation, but the rest of the days the fans are turned on with the windows open

I.1.3.3 Closed poultry houses

- These houses do not have outlets that allow air or lighting to enter, in these houses the air is drawn by electric fans (fans), as for the fresh air, it enters through special openings that do not allow lighting to enter, and instead of natural lighting, lamps are used that facilitate the process of controlling the degree of lighting

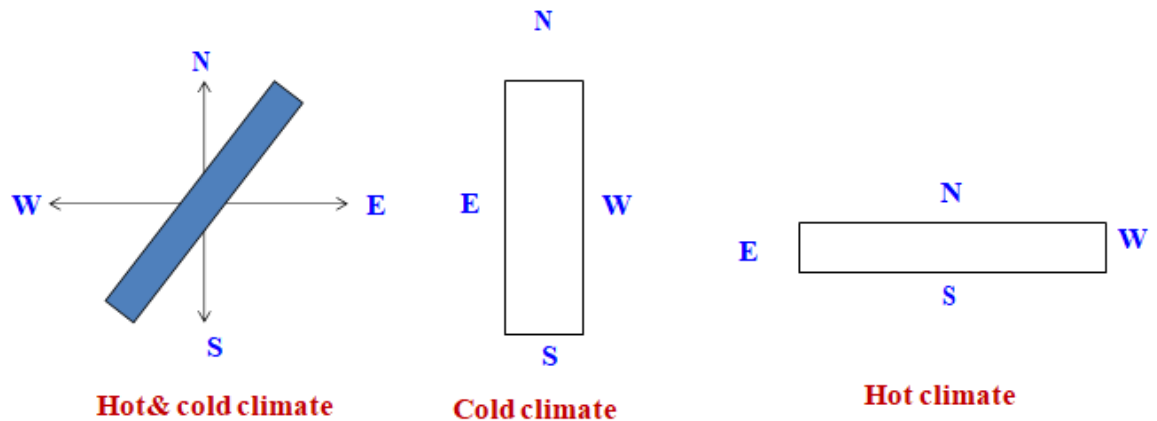
I.2 Tips on the design of poultry houses

I.2.1 Separation distance between poultry houses

- The distance between the chicken coops should not be less than 20 to 50 meters



I.2.2 How to determine the destination of poultry houses



I.2.3 Specifications of poultry houses

Base.[4]

- The base of poultry houses must be concrete



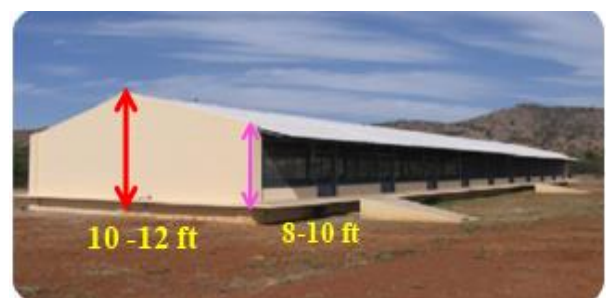
Width

- The display of poultry houses should be about 33 feet . [4]



Distance between foundation and ceiling

- The distance between foundation and surface edge should be between 8-10 feet and position 10-12 feet [4]



I.3 Housing Environment

I.3.1 Movement of air inside poultry houses

- Introduction of clean air into poultry houses and production of polluted air outside poultry houses

- Remove air containing high temperature, humidity and ammonia outside poultry houses
- Attempt to reduce the accumulation of harmful gases in and out of poultry houses
- Adequate oxygen must be provided [4]

I.3.2 Natural Ventilation

- The poultry house should be exposed to air.
- The wind reduces the movement of natural air. It is therefore recommended to keep the poultry houses within 100 feet of the wind.
- Increase the speed of natural air movement by electric fans
- Windows must be installed in places that allow easy entry of natural air [4]



Figure I.2 : Warm Weather

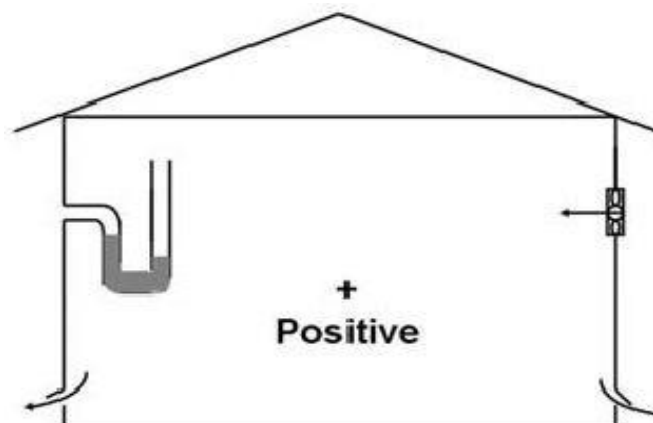


Figure I. 1 : Cold Weather

I.3.4 Mechanical ventilation system

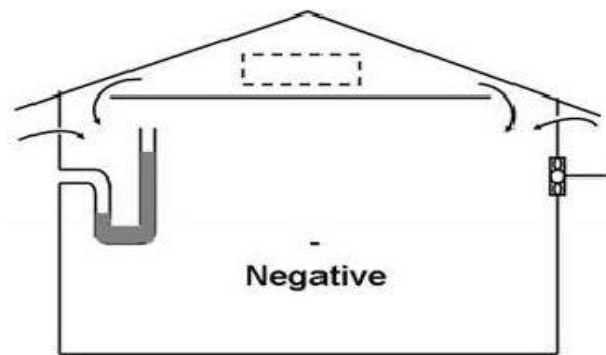
I.3.4.1 Positive pressure system

Positive pressure is the case when the air pressure inside the poultry houses is higher than normal pressure and this is done by fans and ventilation systems. The tube shows a positive ventilation tube, which pushes the air into the poultry yot, thereby increasing the air pressure inside the house and thus preventing the entry of outside air, thereby increasing the efficiency of the poultry house



FiguerI. 3 : Positive pressure**I.3.4.2 Negative pressure system**

Negative pressure when the air pressure inside the poultry houses is less than the air outside of it. This means that the outside air will enter through openings or windows. Among the reasons why the poultry house under negative pressure leaves the suction fan running[4]

**FiguerI. 4 : Negative pressure****I.3.5 Ventilation system of poultry houses:**

The necessary air velocity and exchange rate are regulated by the design of the tunnel ventilation system. However, the type of bird in question dictates the required air speed. Specific air speeds are recommended for raising different types of chickens. [5]

I.3.5.1 Poultry house fan capacity and air speed :

The process used to determine the capacity of the input ventilation system is also applied to determine the capacity of the fan poultry houses. The average air speed required inside an inlet ventilation system is different from a system that uses a fan to circulate the air to maintain a proper air speed. The following formula is used to calculate the tunnel house

$$\text{Air speed} = \text{poultry house fan capacity} / (\text{cross-sectional area of the House}) \times 3600$$

I.3.5.2 Air flow distribution:

It is generally believed that air velocity in a tunnel house remains constant throughout. However, it can vary slightly due to air-deflecting obstacles, poultry equipment, and the

smoothness of the building surfaces. There can be a 15% to 40% difference in air velocity between the center of the house and its sides. [6]

I.3.5.3 Two-way poultry house:

It is a type of poultry house that uses a ventilation system that allows air to flow in both directions inside the poultry houses. This design aims to improve the air distribution evenly and provide a better environment for poultry.[6]

I.3.5.4 Tunnel fan placement :

The fans' performance is unaffected by where they are positioned; they can be placed on the sides or at the end. However, when the fan is placed on the sides, a dead region may be seen as the width of the homes expands.

I.3.5.5 Tunnel inlet opening :

It is recommended that the intake area be at least 10% greater than the cross-sectional area of the home if evaporative cooling pads are not used. Meanwhile, the type of pad used determines the intake size for tunnel homes equipped with evaporative cooling pads. It is suggested that the sidewall intake holes be placed as close to the end wall as possible. If the house width is greater than 15 meters, the inlet ports should be mounted on the end wall.[5]

I.3.5.6 Cold weather entrance system for poultry houses with ventilation:

In hot weather, using a tunnel ventilated system is recommended since cool weather lowers the air exchange rate. Therefore, before switching to tunnel ventilation, it was suggested that the previous intake system control at least 60% of the tunnel fan capacity for easy switching in the winter months [5]

I.3.5.7 Requirement of floor Space, feeders and waters

size and the age, and type of birds that need to be maintained determine what kind of floor space and equipment are needed. Less floor area per bird can be permitted in larger houses than in smaller ones since the larger houses have more useable space per bird than the smaller ones. little homes. [3]

I.4 Orientation of House

Weather-related factors have highly directed effects. Building orientation with regard to the sun and wind has an impact on various external surfaces' forces, precipitation, temperature, and light. When there is room to move around freely, it is best to orient constructing in order to have the most control over the microclimate. It is evident that a house's broad face experiences more wind pressure than its narrow dimension when the same wind speeds are

applied. This might be advantageous in areas with high temperatures, but it becomes problematic in areas with extremely strong or frigid winds.

The guidelines that control the relationship between site exposure and sunshine also apply to building orientation. The eastern and southeast portions of the Northern Hemisphere receive the most insulation.[3]

I.4.1 Humidity

Maintaining the correct humidity is crucial for the optimal performance of birds in the shed at various life stages. High humidity levels can be detrimental, as they promote the growth of pathogenic microorganisms that cause diseases in birds. Conversely, low humidity results in dry, dusty litter, which can lead to respiratory issues. Therefore, the relative humidity in poultry sheds should be kept between 40% and 60%..[3]

I.4.2 Light in poultry house

Only a portion of the 400–700 MHz radiant energy spectrum is comprised of visible light. It seems that chickens see better in the light.[3]

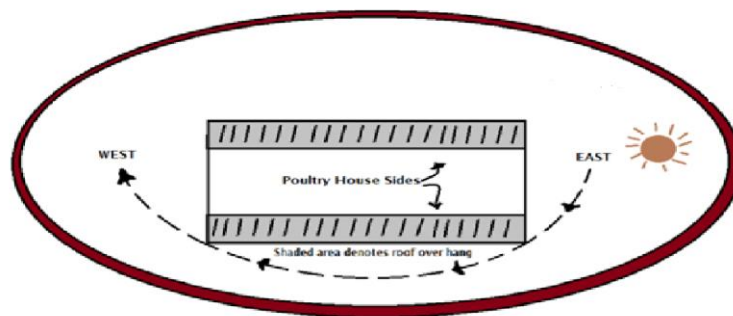
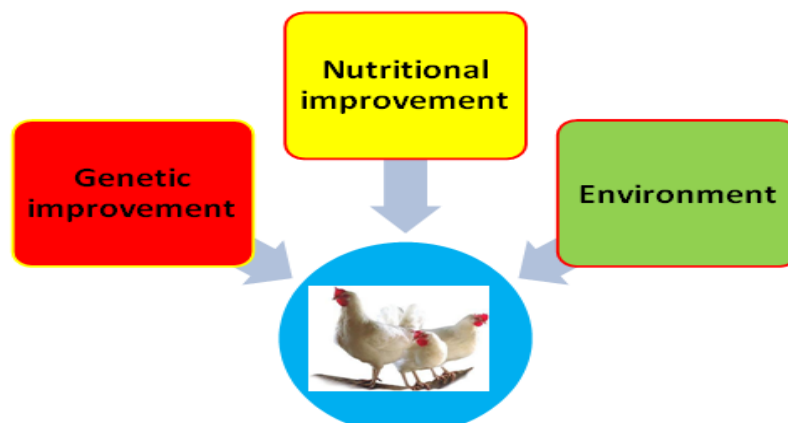


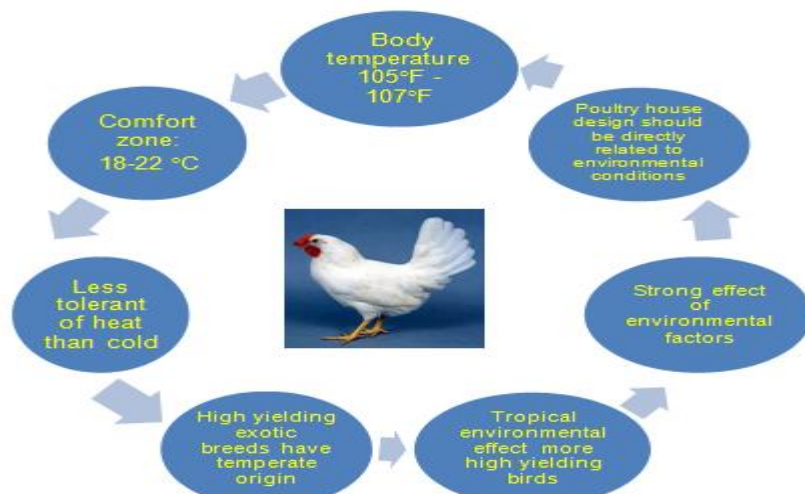
Figure I.5 : show the passage of sun over poultry house oriented east to west

I.5 General study on poultry

I.5.1 Introduction[5]



I.5.2 Poultry Physiology[5]



I.5.3. Poultry birds and their temperature regulation mechanism:

Birds are avian, feathered, high-metabolism, oviparous animals that breathe between 40 and 50 times per minute[7] Typically. The typical internal The body temperature of birds typically ranges between 39 and 42.2 degrees Celsius. [8,9]. When the weather is warm, Poultry birds[8] mostly lose heat by conduction, convection, radiation, and evaporative cooling[9], which helps them maintain thermoneutrality. [6,12]

The ideal circumstances for effective heat dissipation through convection, radiation, and conduction occur when the external temperature remains within or aligns with the bird's thermoneutral range. Nevertheless, evaporative cooling contributes to approximately 60% of the overall cooling within this thermoneutral range.[6]

the heat produced when the body regulates its temperature. It makes sense to allow heat to escape through exposed surfaces like wattles, shanks, and other places without feathers surrounding the neck and wings. The behavior, feed intake, or metabolic processes of the bird are unaffected by this mode of heat loss for body temperature regulation. [13]The difference in temperature between the bird and its environment determines the efficiency of sensible heat loss[14]. For birds of all ages, evaporative cooling, or latent heat loss, takes over as the main method of heat dissipation when the outside temperature climbs over 24°C. At temperatures higher than the thermoneutral zone, the bird loses heat through evaporative cooling, and the energy required for expansion and maturation needs to be focused toward panting. However, because of inadequate water delivery and excessive carbon dioxide ejection, panting can result in dehydration, respiratory alkalosis, and a drop in blood Ph . Water evaporating from the bird's respiratory system during panting causes evaporative cooling. Extreme humidity, though, might make this challenging.This is a problem in high-humidity regions since

evaporative cooling is the main strategy used by poultry farmers to lower summertime air temperatures.[13]

Enhancing the volume and speed of airflow over birds enhances heat dissipation via convection, expels trapped heat within the poultry house, and reduces the influence of high humidity on evaporative cooling.

In research conducted by Simmons et al[15], Three-week-old male broilers were exposed to a cyclic temperature of 25–30–25°C in a controlled environment for four weeks at varying wind speeds: still air (0.25 m/s), 2 m/s, and 3 m/s. Higher wind speeds proved advantageous for the growth and development of older birds.[6]

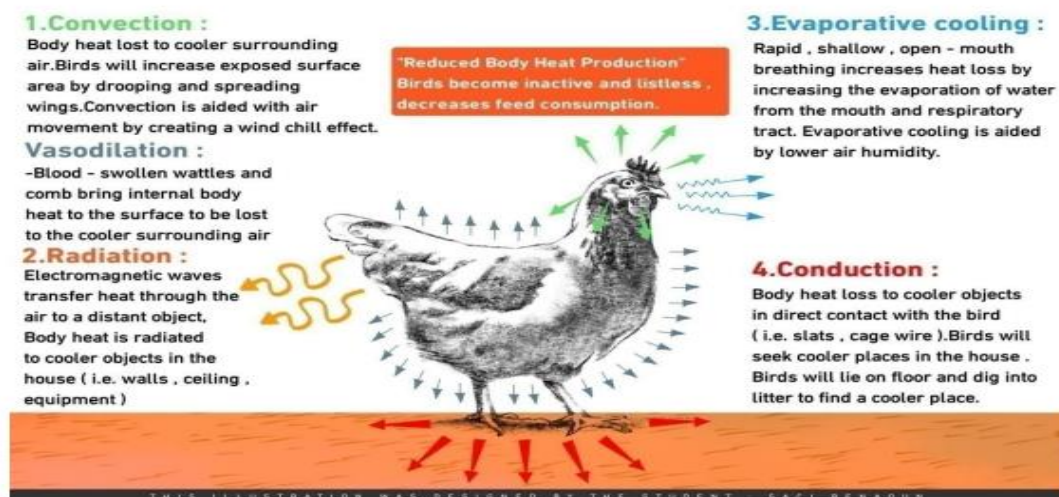


Figure I.6: thermoregulation.

Due to its mineral content and effect on feed consumption, water is a vital resource in the chicken production industry. [16]The conventional open water system has been replaced by breast milk drinkers to provide cleaner water and use less water.

leaking, as well as work in cleaning the drinker. In an experiment, May et al. [17] It was found that hens raised with a conventional open water system consumed more water compared to those raised with a nipple drinking system. On the contrary, [18], Birds provided with nipple drinkers exhibited greater weight gain and improved feed conversion compared to those using open water drinkers when both types of drinkers were utilized to rear chickens in a controlled environment with air velocities of 0.25 and 2.1 m/s. Hence, ensuring adequate ventilation in the chicken house is crucial for optimizing these outcomes.

I.5.3.1 Heat stress in chicken

Heat stress is a significant issue in the poultry industry, particularly during the production of meat and eggs. It affects hens when the outside temperature reaches or exceeds 26.7°C. At this threshold and beyond, birds begin to pant, which can adversely affect their developmental rate, hatching ability, egg size, eggshell quality, and overall egg production. In hot environments, the challenge of heat stress intensifies with higher humidity levels. Heat stress has been linked to reduced comfort, growth rate, feed conversion efficiency, and live weight gain in broilers..[13]

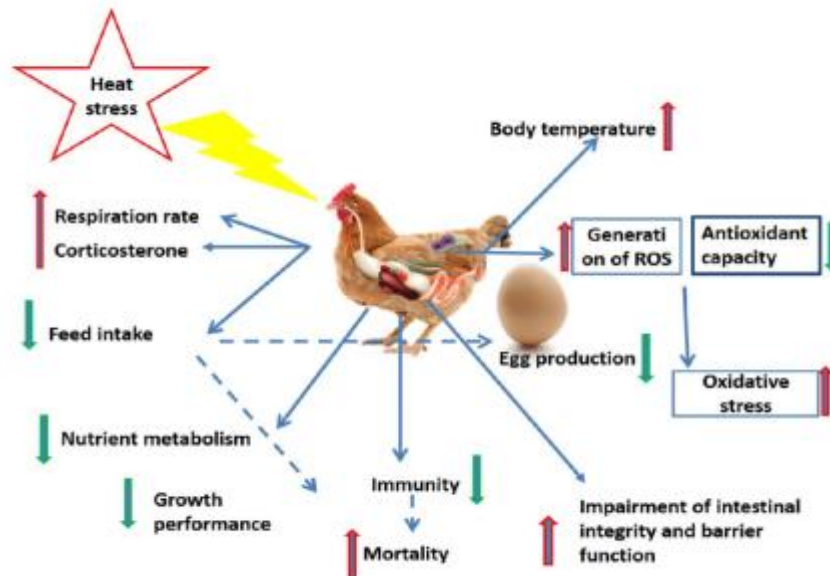


Figure I.7: Heat stress in chicken[23]

Acute heat stress denotes the sudden exposure of birds to elevated temperatures for a brief duration, while chronic heat stress involves prolonged exposure. Birds reared in open-sided huts, commonly used in tropical regions, are prone to chronic stress. Research indicates that chronic heat stress adversely affects growth and production efficiency, egg quality, meat quality, embryonic development, reproductive performance, immunity, and susceptibility to illnesses in broilers, laying hens, and breeders.[21]

[20.23]

I.5.3.2 The impact of internal climate conditions on chickens:

Understanding the effects of interior climate on poultry, how the birds respond to these conditions, and how heat control affects chicken productivity is crucial. The information will be useful for meeting the specifications for an outside a chicken coop designed to reduce heat stress and ensure maximum chicken output in arid regions. Climate factors to take into account include temperature, relative humidity, air composition, speed, and lighting conditions.

I.5.3.3 Temperature :

There is much debate regarding the ideal temperature range for different age and class groups of chicken to get the greatest results. Other environmental factors that affect temperature, such as humidity and wind speed, could be the cause of this.

shift and the chicken reaction to previous climatic shifts. Whatever their age or breed (broiler, pullet, or breeder), chickens thrive in a broad range of temperatures.

On the other side, it has been demonstrated that exposure to high temperatures lowers chicken production performance.[23] Higher relative humidity may make it worse since it negatively impacts evaporative cooling.[8] Ketelaars recommended a temperature of 30–32°C at chicken height for day-old chicks. [9]Table I.1 illustrates that the temperature needs to be lowered by 3–4°C till the chicks[10]The table below represents (Table 1) the

Age of chicken (week)	Température range (°C)
1	30-32
2	30-26
3	26-23
4	23-20
25	20

recommended temperature for poultry farming in the El-Oued area.

Table I.1 illustrates that the temperature needs to be lowered by 3–4°C tillthe chick[9].

Maintaining the optimal production temperature in tropical regions poses challenges, necessitating careful consideration of temperature fluctuations by poultry house designers.

I.5.2.4 Relative humidity :

That high relative humidity combined with an internal temperature above 26.7 degrees Celsius significantly reduced the efficiency of feeding.[6] Feathering, pigmentation, and weight gain in chickens were also significantly affected. Additionally, irrespective of changes in relative humidity, the birds exhibited poor performance when internal temperatures ranged between 35 and 37.8°C. This indicates that birds might perform better at lower temperatures despite increased humidity. Nonetheless, humidity control is necessary as it could create a

favorable environment for bacteria, potentially leading to illness in the birds.[10,24] Relative humidity and temperature are closely interconnected. Because of the warmth required by the chicks at this stage, and considering that they may be thirsty or have a low birth weight, the internal relative humidity could be low or unusually low during the brooding period., [9] This is particularly noticeable during the initial weeks..

*Chapter II: HVAC system assisted by
renewable energy sources*

II.1. Introduction

Heating, ventilation, and air conditioning (HVAC) systems play a crucial role in maintaining optimal environmental conditions within poultry houses, directly impacting the health, productivity, and welfare of the birds. By controlling temperature, humidity, and air quality, HVAC systems ensure a stable and comfortable environment, which is essential for the efficient growth and development of poultry. In recent years, geothermal heating has emerged as a sustainable and energy-efficient solution for poultry farms. This method utilizes the stable temperatures found beneath the Earth's surface to provide consistent heating, reducing the reliance on traditional energy sources and lowering operational costs. The integration of geothermal heating with advanced HVAC technologies in poultry houses not only enhances the overall efficiency of the farming operations but also contributes to environmental conservation by minimizing the carbon footprint. This synergy between modern HVAC systems and geothermal energy offers a promising approach to sustainable poultry houses .

II.2. Definition of system HVAC

An HVAC (Heating, Ventilation, and Air Conditioning) system in poultry houses is essential for maintaining optimal environmental conditions to ensure the health and productivity of the birds. These systems control temperature, humidity, ventilation, and air quality, providing a stable and comfortable environment throughout the poultry's growth cycle. Proper heating prevents cold stress, while ventilation and cooling systems mitigate heat stress and remove harmful gases. Humidity control and air quality management further enhance the well-being of the poultry, leading to improved growth rates, feed conversion efficiency, and overall productivity. Modern HVAC systems are also designed to be energy-efficient, reducing operational costs and contributing to the sustainability of poultry farming.

II .2.1 HVAC system selection

The selection of a system is influenced by three primary factors: the building configuration, the climate conditions, and the preferences of the owner. The design engineer is tasked with evaluating various systems and recommending multiple options to achieve the desired goals and meet the owner's requirements for a building. Key criteria to consider include climate factors (such as temperature, humidity, and space pressure), building capacity, spatial requirements, costs (including capital, operating, and maintenance costs), life cycle analysis, and the reliability and flexibility of the systems. [25]

II.2.2. Basic components of an HVAC system

- Mixed-air plenum and outdoor air control
- Air filter
- Supply fan
- Exhaust or relief fans and an air outlet
- Outdoor air intake
- Ducts
- Terminal devices
- Return air system
- Heating and cooling coils
- Self-contained heating or cooling unit
- Cooling tower
- Boiler
- Control
- Water chiller
- Humidification and dehumidification equipment [26]

II.2.3. HVAC system requirements

Four requirements are the bases for any HVAC systems , The fundamental requirements for HVAC systems include primary equipment, space allocation, air distribution, and piping infrastructure, as shown in **FigureII .1**

Primary equipment encompasses heating systems, such as steam boilers and hot water boilers, which are used to heat buildings or spaces. Air delivery equipment, including packaged units that utilize centrifugal fans, axial fans, and plug or plenum fans, is employed to provide conditioned ventilation air. Additionally, refrigeration equipment is utilized to deliver cooled or conditioned air into the space.

It includes cooling coils that operate using water from water chillers or refrigerants from a refrigeration process.

Space requirements are crucial in determining whether an HVAC system will be centralized or localized. These requirements encompass five key facilities: [27,28]

a. Equipment rooms: These should ideally be centrally located within the building to minimize the length and size of ducts, pipes, and conduits, simplify shaft layouts, and facilitate centralized maintenance and operation. The total mechanical and electrical space requirements typically range between 4 and 9% of the gross building area.

b. HVAC facilities for heating and refrigeration require various equipment. Heating systems need boilers, pumps, heat exchangers, pressure-reducing equipment, and control air compressors. Refrigeration systems need water chillers or cooling towers, condenser water

pumps, air-conditioning units, and control air compressors. Equipment room design must consider the size, weight, installation, maintenance, and regulatory compliance for combustion and ventilation air.

c. Fan rooms house HVAC fan equipment and various miscellaneous components. These rooms must be designed with careful consideration of installation, removal, replacement, and maintenance of fan shafts and coils, taking into account the scale of the equipment involved. This is crucial for the efficient operation and upkeep of HVAC systems within a research context. The size of fans is determined by the necessary air flow rate for building conditioning, and can be centralized or localized depending on factors such as availability, location, and cost. Optimal access to outdoor air is preferred for efficient operation.

d. Vertical shafts are essential for accommodating air distribution, as well as water and steam pipe distribution within a building. Air distribution within these shafts includes HVAC supply air, exhaust air, and return air ductwork. Pipe distribution encompasses systems such as hot water, chilled water, condenser water, steam supply, and condenser return. Additionally, vertical shafts house various other mechanical and electrical distributions that serve the entire building, including plumbing pipes, fire protection pipes, and electrical conduits/closets.

e. Equipment access: Large, heavy equipment must be easily movable within the equipment room for maintenance, replacement, and installation. Air distribution involves ductwork that delivers conditioned air to target areas efficiently, quietly, and directly. It includes fan-powered terminal devices like diffusers and grilles for low-speed air supply, terminal units for mixed air distribution, variable air volume units for adjustable air supply, and air-water induction units with coils. Insulating plumbing and ductwork prevents heat loss and conserves energy. Sufficient ceiling space should be provided to support ductwork in the suspended ceiling and floor slab, which can also serve as a return air plenum to reduce return ducting needs

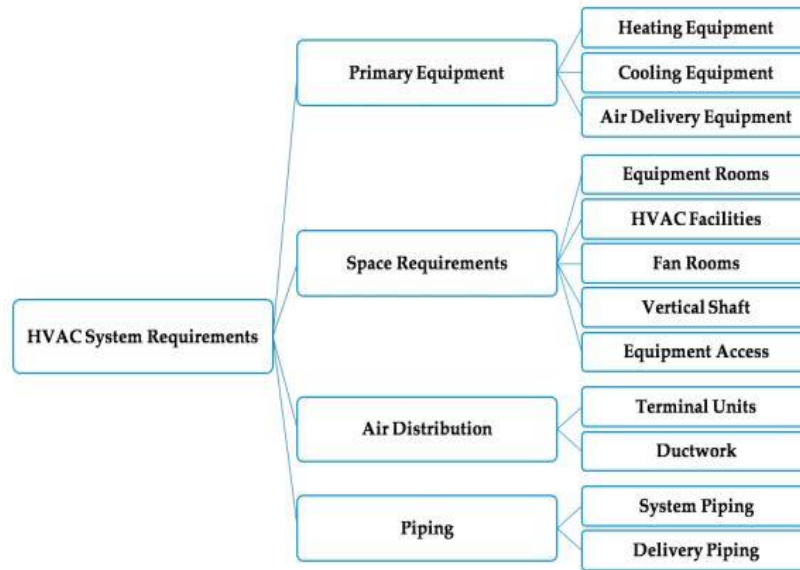


Figure II.1 shows the requirements for an HVAC system. [27]

II.2.4. HVAC systems in the center

One or more thermal zones may be served by a central HVAC system, and its main equipment is situated outside of the served zone(s) in a central position that is appropriate, whether it be within, outside, or next to the building. Zones must be condition-matched to their corresponding thermal load by central systems. There will be multiple control points, such as thermostats, for central HVAC systems. for every zone. The central HVAC system is subclassified by the medium utilized in the control system to supply the thermal energy, as seen in **Figure II 2**. [27,28]

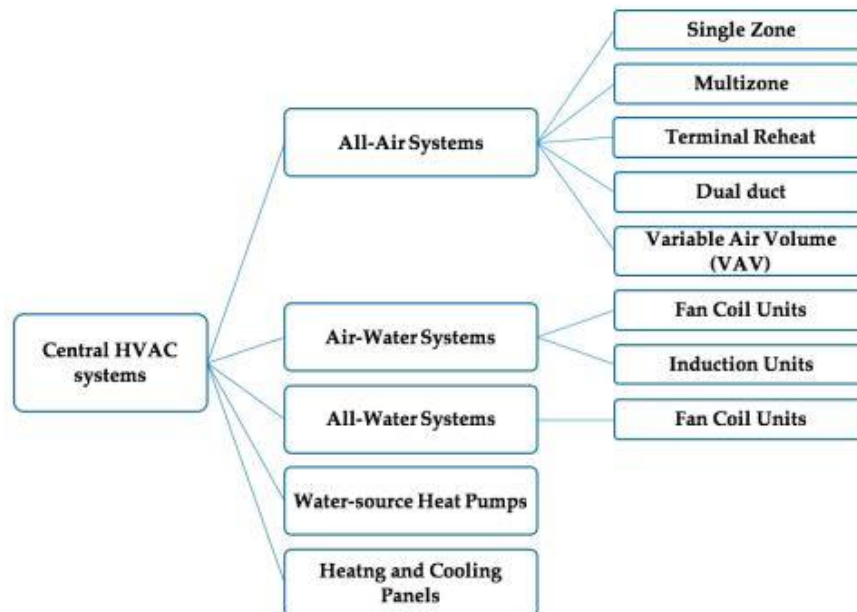


Figure II.2 The main types of central HVAC systems. [27,28]

Air, water, or both can be used as the thermal energy transmission medium; these combinations are known as all-air, all-water, or air-water systems. Heating and cooling panels as well as water-source heat pumps are components of central systems. The discussion of each of these subsystems follows. As seen in **Figure II.3**, the components of a central HVAC system are grouped together in an air handling unit together with supply and return air blowers, a humidifier, reheat coils, cooling coils, preheat coils, mixing boxes, filters, and outdoor air.

II.2.5. All-air systems:

Air serves as the thermal energy transfer medium in building delivery systems. The zones of single and multizone all-air systems, the airflow rate for each zone as constant air volume and variable air volume, terminal reheat, and dual duct can all be used to further categorize the systems. [28]

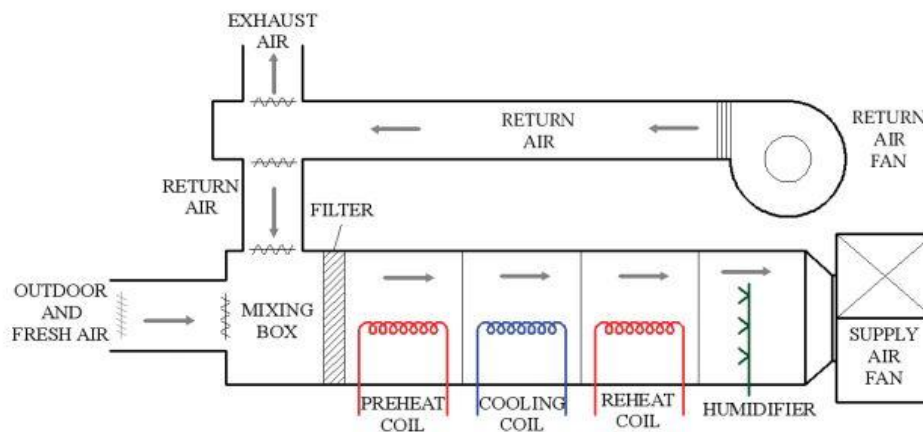


Figure II.3 The configuration of the central HVAC system's equipment. [28]

II.2.6. All-air HVAC system for single zone:

A single zone system comprises an air handling unit, a heat source, a cooling source, distribution ducting, and appropriate delivery devices. The air handling systems can either integrate heat and cooling sources or keep them separate. Typically, this integrated package is a rooftop unit connected to ductwork, distributing conditioned air to multiple locations within the same thermal zone. The primary benefits of single zone systems are their simplicity in design and maintenance, as well as their low initial cost compared to alternative systems. However, their main drawback is that they only serve one thermal zone, which can be a limitation if not used appropriately. [28]

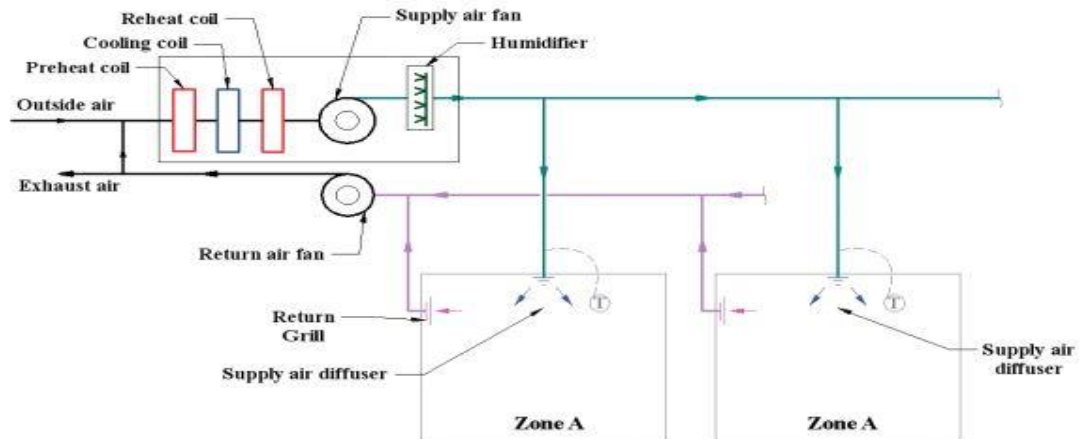


Figure II.4 A digram All-air HVAC system for single zone. [28]

In a single zone all-air HVAC system, one control device such as thermostat located in the zone controls the operation of the system, as shown in Figure 4. Control may be either modulating or on-off to meet the required thermal load of the single zone. This can be achieved by adjusting the output of heating and cooling source within the packaged unit.

A single thermal zone can be effectively utilized in many applications, including poultry housing. While different types of poultry structures may require varied thermal energy based on occupancy and specific needs, a single-zone system is often ideal for chicken coops. This system ensures consistent temperature control throughout the entire space, which is crucial for the health and productivity of the chickens. The simplicity of design and maintenance, coupled with lower initial costs, makes single-zone systems particularly advantageous for poultry housing. [28]

II.2.7. All-air HVAC system for multiple zones:

Each zone in a building has its own supply air duct in a multi-zone all-air system. At the air handling unit, hot (or return) air and cold air are combined to meet each zone's thermal needs. **Figure II.5** illustrates how distinct supply ducts are needed for each zone with varying thermal requirements. A zone's conditioned air cannot be combined with that of another zone. A multi-zone all-air system consists of an air handling unit with parallel flow channels through heating and cooling coils, along with internal mixing dampers. A single multi-zone unit should only service up to 12 zones due to physical limitations on damper size and duct connections. More air handlers can be employed if additional zones are needed. The primary benefit of the multi-zone system is its ability to condition multiple zones efficiently without wasting energy on a terminal reheat mechanism. However, leakage between the air handler's decks can reduce energy efficiency. The main drawback is the requirement for various supply air ducts to service multiple zones. [27,28]

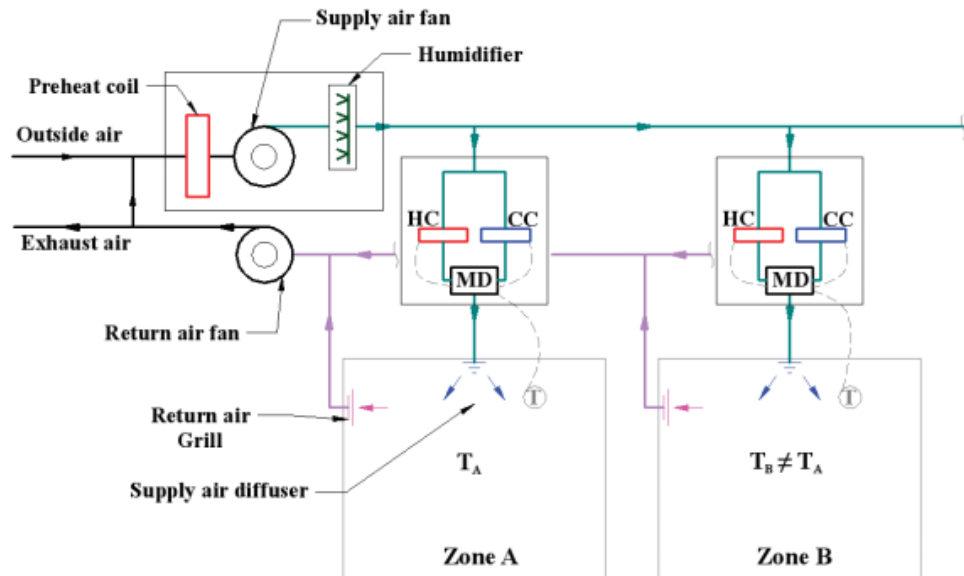


Figure II.5 A digram All-air HVAC system for multiple zones. [28]

II.2.8 Water-source heat pumps:

With water-source heat pumps, poultry buildings can save a significant amount of electricity in extremely cold temperatures. A poultry structure with several zones can be conditioned by multiple separate heat pumps, as each heat pump can be adjusted according to the specific needs of each zone. These heat pumps can be powered by a centralized water circulation loop that serves as both a heat source and a heat sink. If the building needs to simultaneously heat certain zones and cool others, the heat pump can transfer heat from one area to another without the need for a boiler or cooling system. [29]

II .2.9 Heating and cooling panels

Wherever there is a potential source of heating and cooling, heating and cooling panels are mounted on the floors, walls, or ceilings. It also goes by the name "radiant panels." This kind of system can be built using pipes or tubes obstructed inside the surface, with cooling or heating material circulating within the tubes to adjust the surface's temperature.

Heat transfer between the air and panels occurs through natural convection, and between the poultry and the radiant panels through radiation. To ensure thermal comfort for poultry, the temperature of the radiant panels should be adjusted according to their needs. Maintaining a temperature range of 70-75°F (21-24°C) is recommended to create an optimal environment, promoting the health and productivity of the poultry. [30].

II.3. Geothermal Energy :

The first step before beginning the extraction process is to search for possible geothermal reserves. Although there are various types of geothermal resources, the best

traditional Water, permeability, and heat are required for geothermal systems. as shown in **Figure II.6**

Heat from the earth's core constantly radiates, often remaining below the crust but occasionally surfacing as lava or magma, with temperatures reaching several hundred degrees Celsius. A geothermal aquifer forms when hot water or steam, heated by the earth's heat, is trapped in permeable rocks beneath an impermeable layer. While some geothermal water appears as hot springs, most is trapped in rock pores and cracks below the surface, forming a geothermal reservoir.. [31]

The extraction of geothermal energy is currently limited to specific depths from the Earth's surface due to technological and financial constraints. Geothermal reservoirs have been drilled to depths of less than five kilometers. Research methodologies for geothermal sources must be planned similarly to other natural resources. After identifying a specific geothermal zone, various study techniques are applied to pinpoint potential geothermal areas. Additionally, factors such as temperature, reservoir capacity, depth, and permeability need to be calculated. Estimating the chemical composition of the generated fluid is also essential. [32]

-To obtain these varied pieces of information, there are several different investigating methods available: [33]

- Surface manifestation inventory and survey
- Geological and hydrogeological survey
- Geo-chemical survey
- Geo-physical survey

Suggested steps for a successful search for effective geothermal locations are as follows. The extraction procedures are put into effect after the exploration process is finished. The many methods for extracting geothermal energy are the subject of the following section.

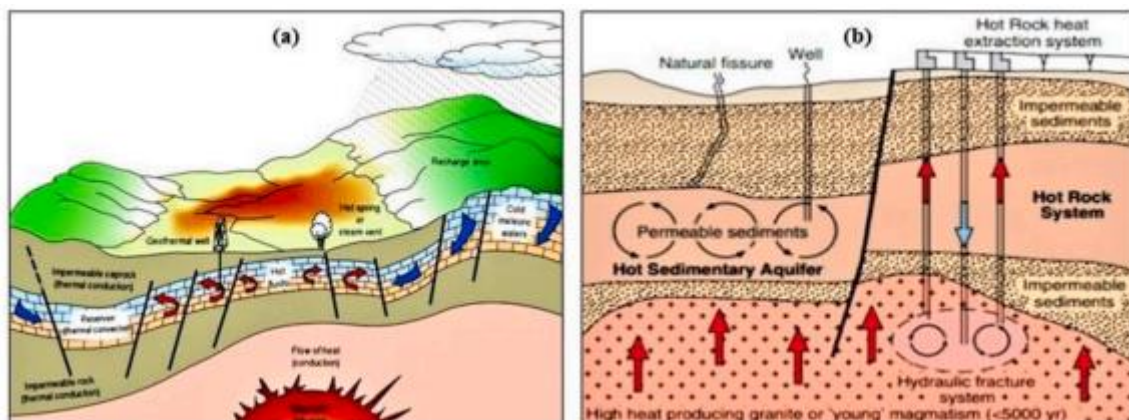


Figure II.6 (a) Diagram showing the optimal geothermal system and (b) The hot sedimentary aquifer system and hot rock [31]

II.3.1. Extraction of geothermal energy

Thermal energy reservoirs known as geothermal resources may one day be tapped into for comparable prices. Heat is concentrated in the higher crust by geothermal sources, which heats water in porous rocks. The resources with the highest energy density are typically found close to plate borders, where there is frequently a discernible geothermal gradient. [33]

When the underlying rocks in a particular place are hotter than the mean value, a geothermal gradient is almost always the first sign of this. The localized heat source may be a magma that penetrates the crust within a few kilometers and has a temperature of 600–1000°C. Nevertheless, geothermal fields can develop in areas that have not recently seen superficial magmatic intrusions. [34]

Certain conditions, such as weakening continental crust, which allows the crust-mantle boundary to up-well and raises temperatures at shallower depths, may be to blame for the abnormally enhanced heat flow. Still, more is needed for a geothermal resource to be sustainable than just a thermal anomaly. Additionally, there must be a reservoir or a sizable enough body of porous rock that can be accessed by drilling at a specific depth. [35]

II.3.2. Advanced or engineered extraction method

Geothermal energy is also utilised with the aid of some sophisticated techniques. One such technique is enhanced geothermal systems (EGS). **Figure II.7** illustrates how an EGS plant is made up of both subsurface and aboveground infrastructure.

In order to create new fractures or widen existing ones, cold fracturing fluid must be injected deep below during the development of an EGS reservoir. [36,37]

After that, a working fluid is rerouted in order to extract the geothermal energy. Before being removed from yet another well, the fluid might be heated to a greater temperature by pumping it through the fractured network of the geothermal reservoir. [38,39,40]

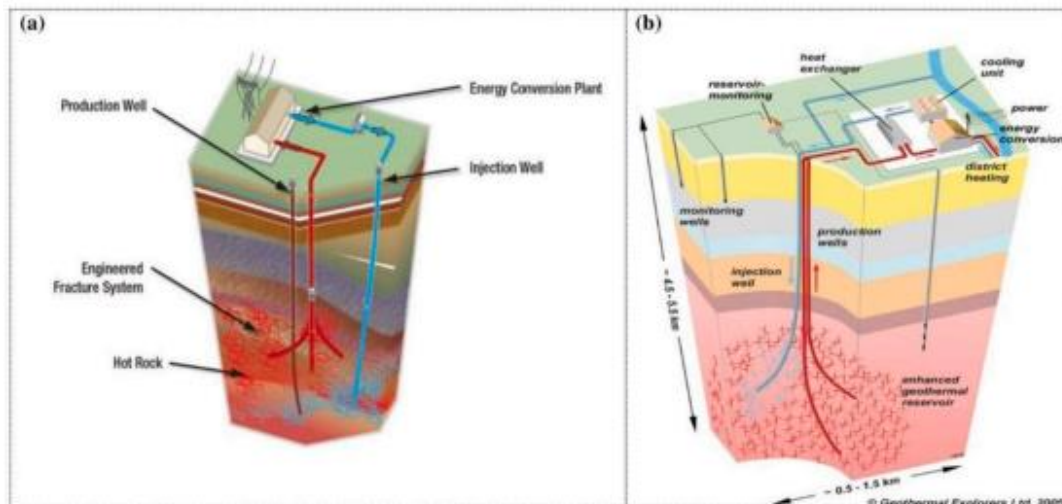


Figure II.7 (a) Plant layout in general using the EGS concept[41] and (b) An EGS plant's subsurface and aboveground infrastructure [42]

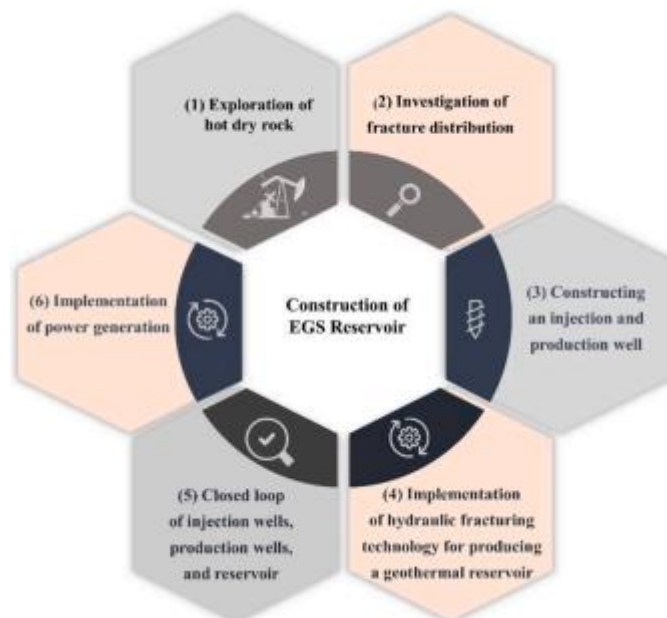


Figure II.8 depicts the building of a standard geothermal reservoir. [38,39,40]

II.3.3. Application of geothermal heat in the Algerian desert used in poultry houses

The El-Oued region is known for its harsh winters and scorching, dry summers. Fossil fuels and gas are the primary energy sources in poultry farms there, and they account for a sizable portion of farm owners' expenses, particularly during the the wintry months [43]

Poultry farmers pay roughly 6% of their overall production costs in the winter and 4% in the summer due to the need for heating. The research states that a diesel boiler and heat lamps provided the barns' heating, and that the idea of Fan-powered evaporative cooling system [44]



Figure II.9 Installing a geothermal system in an area (Reguiba-El Oued)

II.4. Conclusion

geothermal heating and HVAC systems play a crucial role in maintaining optimal conditions within poultry houses. By leveraging the earth's consistent underground temperature, geothermal systems provide an energy-efficient solution for heating, thereby reducing operational costs and minimizing environmental impact. The integration of HVAC systems ensures that temperature, humidity, and ventilation are meticulously controlled, fostering a healthy and productive environment for poultry. This combination not only enhances the well-being and growth rates of the birds but also aligns with sustainable agricultural practices, highlighting the significance of adopting advanced technologies in modern poultry farming.

Chapter III: Results and Discussion

III.1. Introduction:

The Heating, Ventilation, and Air Conditioning that are called HVAC systems which are one of the largest energy consumers in poultry farming, this system is defined as the simultaneous control of temperature, humidity, radiant energy, air motion and air quality within a space to meet requirements of comfort. They are the many methods for transferring air between indoor and outdoor spaces, with along cooling and heating. These systems participate to keep poultry house cool and fresh in the summer, warm in the winter and filter indoor air to keep proilers healthy and maintain appropriate humidity levels at ideal comfort levels.

This chapter presents the effect of geothermal energy system (Figure III-1) integration on indoor environment (humidity, Temperature and CO emission) of poultry house located in Reguiba – El Oued during the period of January – February 2024.



Figure III-1 ventilation system for geothermal system inside Poultry Houses (Reguiba-El Oued)

III.2. Effect of Geothermal energy on internal humidity

A strong relationship between the indoor temperature and humidity and the efficiency of poultry production has been reported in the literature. Figure III. 2 compared the results obtained from the preliminary analysis of humidity between two poultry houses, one of them is integrated with geothermal between two poultry houses, one of them is integrated with geothermal energy exchanger. What stands out in this figure is the difference between the two

poultry house in terms of indoor humidity. Several factors could explain this observation. Firstly, the ventilated air by geothermal system is ambient air with it has low humidity compared with internal poultry environment this study confirmed to her that geothermal energy has a role in stabilizing moisture in poultry houses.

Here are some reasons why humidity is important for poultry production:

- ✓ Respiratory Health: High humidity can help prevent respiratory problems in chickens, such as bronchitis and tracheitis.
- ✓ Egg Quality: Eggshell quality can be affected by moisture levels. Low humidity can result in thinner, more brittle shells.
- ✓ Feed Conversion: Feed conversion is a measure of how efficiently chickens convert feed into meat. Higher humidity levels can result in better nutrition

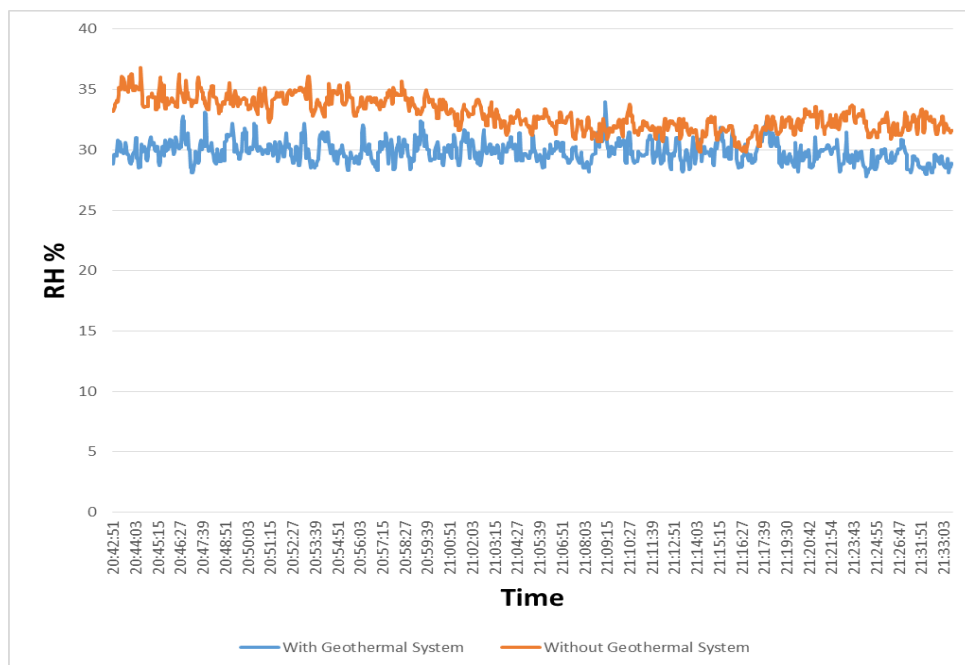


Figure III-2 Impact of geothermal energy on humidity inside Poultry Houses



Figure III-3. The device in the picture is a digital scale. It is used to measure temperature and humidity.

III.3. Temperature of internal environment of poultry house

Temperature plays a fundamental role in the efficiency and production of poultry. It should be controlled during the whole broiler production process under a strict temperature program. The figure III.4 depicts the comparison between two poultry houses, one connected to geothermal energy. What stands out in this in this figure is the difference of temperature between the two poultry houses. This study has been unable to demonstrate that the geothermal energy contributes positively on internal temperature. A possible explanation for this might be the continuous injection of warm air via the geothermal heat exchanger. The present results have confirmed the significance of geothermal energy integration in poultry house for reducing the fuel consumption and the contribution in foot carbon mitigation.

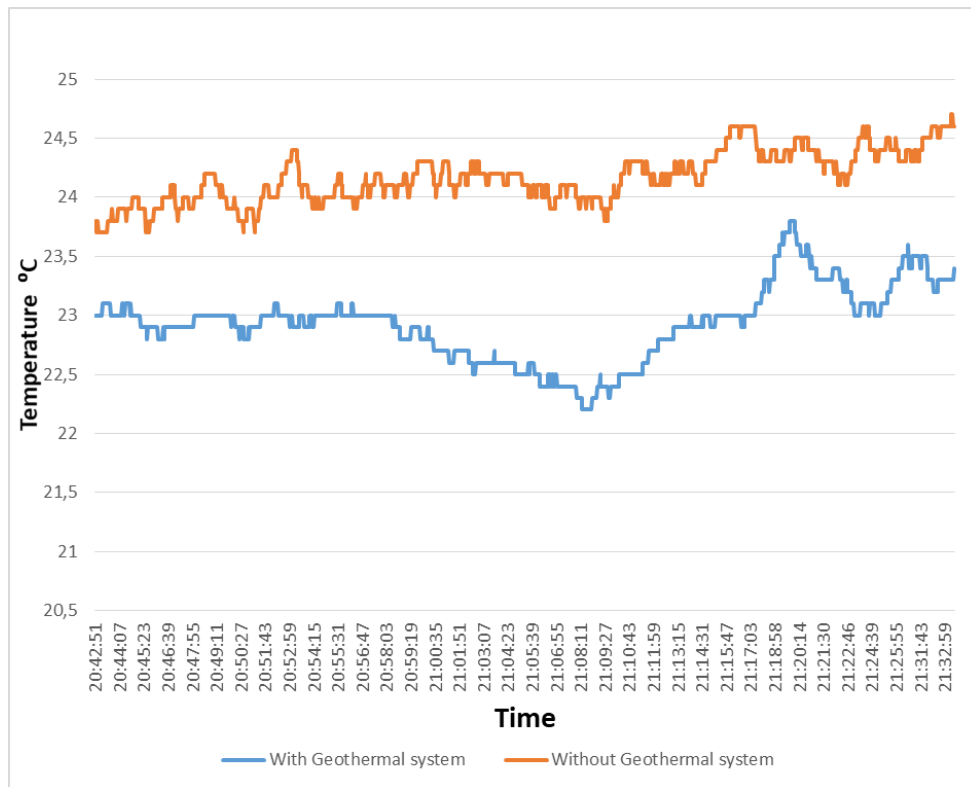


Figure III-4 Impact of geothermal energy on temperature inside Poultry Houses

III.3. 1. The device is used

To measure the internal temperature, we used multi-channel digital thermometer with data logger.

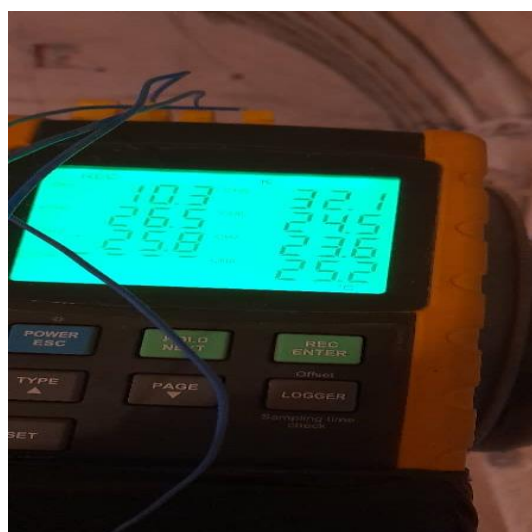


Figure III.5. multi-channel digital thermometer with data logger.

III.4. Interpreting the results of CO₂ emission inside the poultry house

Carbon dioxide production per unit heat increased as body mass increased carbon dioxide production is associated with increased respiratory rate Respiratory quotient increases as body mass increases, understanding temperature and carbon dioxide (CO₂) in poultry housing systems is critical to poultry health, welfare and productivity. In this study, it has an increase in the level of carbon dioxide in two houses, the first contains a geothermal system and the second without this system. Figure III.6 shows the impact of CO₂ PPM (parts per million) emission with time inside poultry house. The curves shows that the emissions of CO₂ are increased in system without geothermal compared with other system due to the system based on geothermal energy ventilates the interior atmosphere of the house, which leads to changing the amount of air to a pure amount

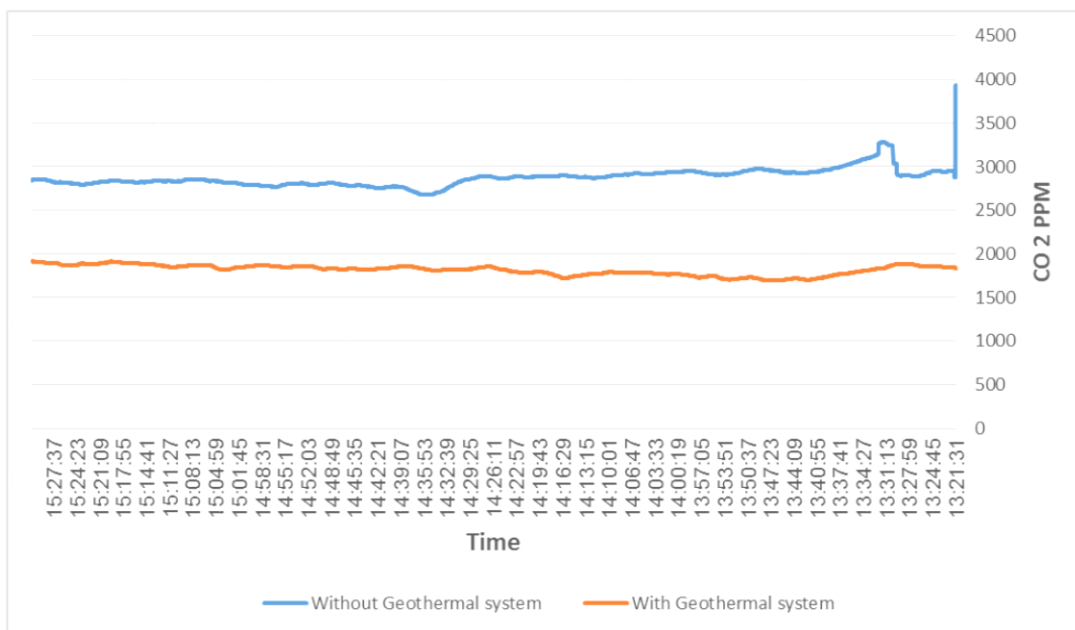


Figure III-6 Impact of geothermal system on CO₂ emissions inside poultry house

III.5. Emission of CO inside of poultry house

The figure III.7 shows a change in carbon monoxide emissions inside the poultry house. The results obtained show that the effect of the percentage of carbon emissions is almost negligible in both systems, because the percentage of this gas in the atmosphere is small.

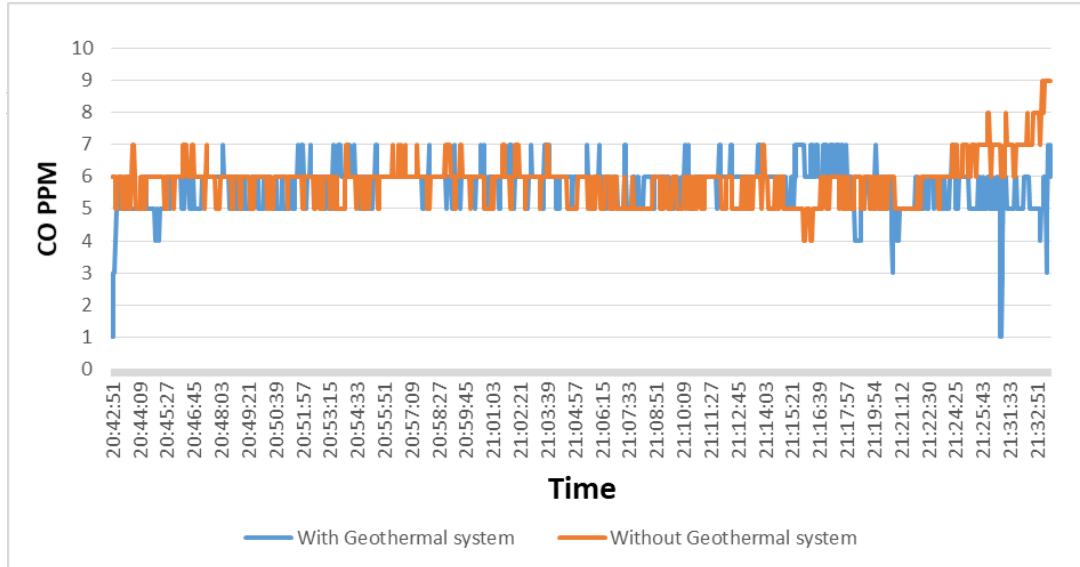


figure III-7 Impact of geothermal system on CO emissions inside poultry house

III.6. Temperature of injected air from geothermal heat exchanger

Thermal energy in poultry houses is important to maintain the life of poultry and provide comfort. The figure III.8 expresses the change in air temperature in three specific places. The results showed that a system based on internal thermal energy can provide the heat needed by poultry houses. We notice from the results that there is an increase in temperature between the external location and the internal location.

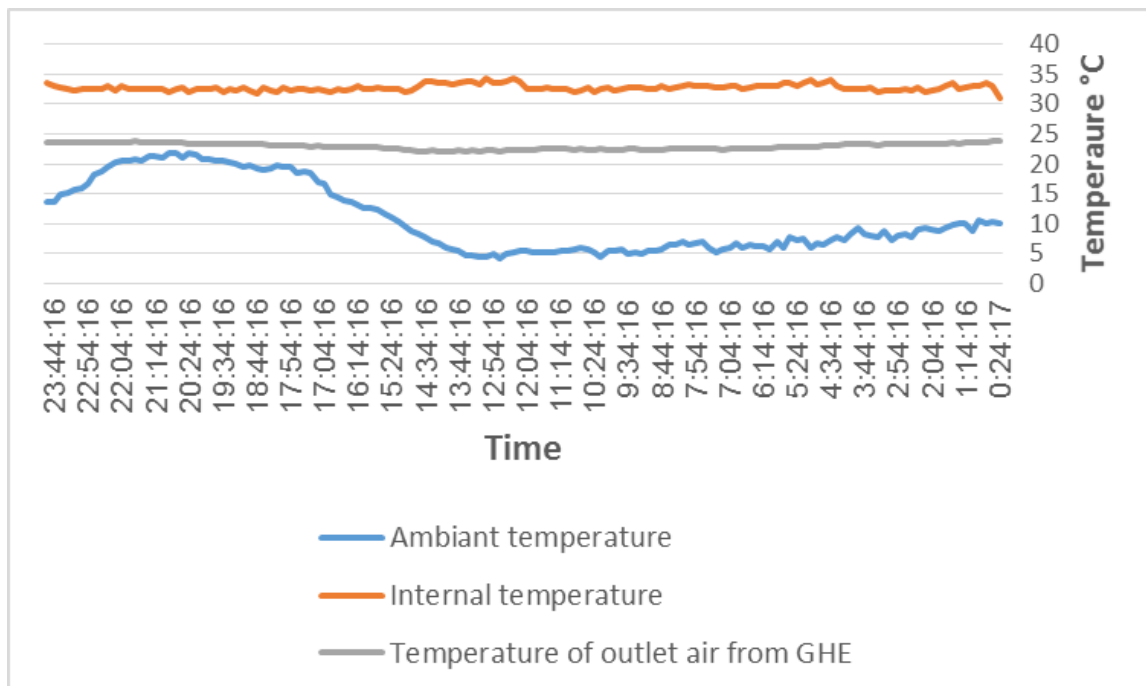


Figure III.8 Evolution of air temperature in and out of Poultry House

III.7. Conclusion:

By concluding this third part of the memorandum on the role of experimental poultry houses, it becomes clear that they play a vital role in improving the performance of poultry production by providing a solid experimental environment. Providing appropriate design and optimal environmental control factors in homes enhances poultry growth and improves production efficiency. Analysis of the results and analyzes from the experiments leads to valuable recommendations for future research in this area. Therefore, the importance of continuing investment in this field can be emphasized to support scientific and economic progress in the poultry industry at the international level.

General Conclusion

As the poultry house is extremely susceptible to rises the consumption of fuel derived from hydrocarbon sources, it needs to reduce oil use and meet the global standard for a friendly environment. In the present study, use of a geothermal system for heating a broiler house was more economical when total energy consumption was considered. Therefore, birds were raised much more economically in the house assisted by geothermal heat exchanger than those in the conventional building. Moreover, energy produced from fossil fuels like crude oil has led to increased carbon foot print in the environment, which in turn, has led to increased environmental pollution and global warming. So, the geothermal energy system proposed in this experiment will be an effective alternative, renewable, and clean energy source for Algeria. From the presented results, it is concluded that the geothermal system could increase the production performance of broiler farming due to increased inside air quality with improved internal housing environment. It is also concluded that the geothermal system has lower CO₂ emissions with lower energy cost than the conventional heating system for broiler chickens. As consequence, the proposed system is very positive for thermal comfort inside poultry house.

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