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Abstract:

Poultry farms located in hot and dry regions like El Oued in southeastern Algeria are faced with great difficulties in achieving a suitable indoor climate for poultry. Both high temperature and humidity can be harmful to poultry health and productivity. Further, the utilization of conventional energy sources i.e., electricity or fossil fuels, leads to both high energy consumption and increased environmental pollution. To find solutions to these issues, this study examined the usage of geothermal energy as an alternative poultry house heating and cooling system. A ground heat exchanger system was used with the purpose of indoor temperature and humidity stabilization and reduced consumption of traditional energy resources. Therefore, the geothermal poultry house was evaluated against a conventional setup to determine its effectiveness. The results presented that the geothermal house had more regular temperature and humidity values, and it had significantly lower CO₂ and CO emissions, leading to improved air quality indoors. The findings confirm the benefits of using geothermal energy to create a better environment for poultry, improve energy use, and support cleaner, more sustainable farming.

Keywords:

Poultry farms; temperature; humidity; geothermal energy; CO₂ and CO emissions.

المخلص

تواجه مزارع الدواجن في المناطق الجافة والحارة مثل ولاية الوادي جنوب شرق الجزائر، صعوبات كبيرة في الحفاظ على مناخ داخلي مناسب للدواجن، حيث تؤثر درجات الحرارة المرتفعة والرطوبة سلبًا على صحة الدواجن وإنتاجيتها. كما أن الاعتماد على الطاقة التقليدية سواء كانت كهربائية أو وقود أحفوري يؤدي إلى استهلاك مرتفع للطاقة وزيادة في الانبعاثات الضارة بالبيئة. ولهذا لجأ هذا العمل إلى استخدام الطاقة الجيوحرارية كحل بديل للتدفئة والتبريد في بيت الدواجن، وذلك من خلال نظام تبادل حراري أرضي يهدف إلى تحقيق استقرار في درجة الحرارة والرطوبة مع تقليل الاعتماد على مصادر الطاقة التقليدية. وقد تمت مقارنة الأداء بين بيت دواجن يستخدم هذا النظام وآخر تقليدي. أظهرت النتائج أن الحظيرة المزودة بالنظام الجيوحراري سجلت درجات حرارة ورطوبة أكثر استقرارًا، مع انخفاض ملحوظ في انبعاثات ثاني أكسيد الكربون CO_2 وأول أكسيد الكربون CO ، مما أدى إلى تحسين جودة الهواء داخل الحظيرة. أكدت هذه النتائج الدور الفعال للطاقة الجيوحرارية في خلق بيئة أفضل لتربية الدواجن وتحقيق كفاءة طاغوية أعلى والمساهمة في إنتاج أكثر استدامة وصديق للبيئة.

الكلمات المفتاحية:

- مزارع الدواجن; درجة الحرارة; الرطوبة; الطاقة الجيوحرارية; انبعاثات CO_2 و CO .
- استخدام الطاقة المتجددة لتحسين بيئة الدواجن.

إهداء

الحمد لله على لذه الإنجاز والحمد لله عند البدء وعند الختام

اهدي هذا العمل المتواضع وثمره جهدي إلى والدي الذي أضاء دربي وطريقي وقدوتي في كل خطوة اخطوها إلى أمي الغالية الحضان الدافئ وسمائي التي لم تتركني يوما ولا يكتمل يومي بدونها إلى اخواني وأخواتي الذين وقفو معي دائما وساندوني خلال مسيرتي التعليمية إلى جميع دكاترتي الاعزاء الذين علموني وأرشدوني ووجهوني تحياتي لكل دون فرق والله ولي التوفيق.

شكر وعرّفان

بعد أن منّ الله علينا هذا العمل، فإننا نتوجه إليه سبحانه، ونتعالى أولاً وآخرًا بجميع ألوان الحمد والشكر على فضله وكرمه الذي أغرقنا به، فوفقنا إلى ما نحن فيه، راجين منه دوام نعمه وكرمه، وانطلاقًا من قوله صلى الله عليه وسلم: "من لا يشكر الناس لا يشكر الله"، فإننا نتقدم بالشكر والتقدير والعرّفان إلى الأستاذة الفاضلة نجاة غرايسة والاستاذ الفاضل عطيه عبد المالك على إشرافهما على هذه المذكرة، وعلى الجهد الكبير الذي بذلاه معنا، وعلى ضمائرهما اليقظة التي عمدت لنا الطريق لإنجاز هذه الدراسة، فلهما منا فائق التقدير والاحترام ونشكر أصدقائي أيضا الذين ساعدوني في هذا العمل.

كما نتوجه في هذا المقام لأساتذتنا الذين رافقونا طيلة المشوار الدراسي.

وفي الختام نشكر كل من ساعدنا وساهم في هذا العمل سواء من قريب أو بعيد، حتى ولو بكلمة طيبة أو ابتسامة عطرة.

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General Introduction

The global population is steadily increasing and is expected to reach 9.2 billion by 2050, creating growing pressure on food production systems [1], food sustainability is a growing social issue across the globe. One agricultural sector that contributes to the international food supply system is poultry. In fact, poultry production accounts for one of the largest agriculture/farming sectors in the world because it provides an inexpensive, readily available stable source for animal protein. However, this critical industry is at risk. Due to erratic weather patterns and the extensive energy usage for necessary heating, cooling, lighting and ventilation, poultry farms require much more energy to maintain operations; thus, they are increasingly reliant upon fossil fuels. This creates not only increased costs to production but also pollutants to the surrounding environment.

To tackle these issues, there has been a stronger focus on using renewable energy sources that help reduce the reliance on fossil fuels, which in turn lowers the impact on the environment. Renewable energy, especially when produced locally, can improve energy use and support eco-friendly farming [2]. Poultry farming plays an important role in both food production and the economy of Algeria. Recently, the government has been promoting the use of renewable energy to save energy and reduce pollution [3]. One possible solution being tested is geothermal energy, especially systems like Earth-to-Air Heat Exchangers (EAHE), which could help make heating and cooling in poultry houses more efficient. However, this technology is still being tested and is not yet widely used.

This study looks at how geothermal energy, particularly Earth-to-Air Heat Exchanger (EAHE) systems, can improve the environment inside poultry farms. It examines how these systems control temperature and humidity, reduce harmful gas emissions, and if they can help cut down on energy costs. To do this, the research includes both a review of existing studies and a practical test done in El Oued, a dry and hot area in southeastern Algeria. The work involves measuring things like temperature, humidity, and air quality inside the poultry house, before and after the geothermal system was installed, to see if this solution works well in such harsh weather.

The thesis is organized as follows:

Chapter I:

First, we discuss the impact of poultry houses on the environment.

Chapter II:

Next, we present the benefits of using geothermal energy in poultry houses.

Chapter III:

Finally, we describe the experiment and present the results by comparing the measurements of the poultry house with the one using geothermal energy.

**Chapter I Impact of poultry houses on
the environment.**

I.1. Introduction

Poultry farming is one of the key agricultural activities that provides an important source of protein and plays a major role in supporting the local economy. As the sector grows, so does the need for energy to run heating, cooling, ventilation, and lighting systems in poultry houses. This causes high costs and more pollution because most of this energy comes from burning fuel. As energy prices rise and pollution becomes a bigger problem, it's now important to look for better, cleaner ways to use energy. In this chapter, we will talk about how poultry farms affect the environment, especially in terms of energy use and gas emissions.



Figure 1: Poultry houses[4].

I.2. Greenhouse Gas Emissions from Poultry Houses

Chicken droppings can release some bad-smelling and harmful gases like ammonia, carbon dioxide, methane, and hydrogen sulfide. These gases can make it hard for the chickens to breathe and can also affect the air and the building inside the poultry house. Too much ammonia in the air can bother the chickens' breathing, and high carbon dioxide levels aren't good for them either. That's why cleaning out the waste regularly is important. To keep the chickens in good shape, it's best to keep ammonia below 25 ppm and carbon dioxide under 2,500 ppm [4, 5].



Figure 2 : Air installation in poultry houses[5].

The air inside a poultry house can get worse if there isn't good airflow. Bad smells and gases like ammonia and carbon dioxide can stay in the air and harm both the chickens and the workers. To avoid this, it's important to let fresh air in and push the dirty air out. Table 1 shows how much of these gases is still safe. A good ventilation system helps keep the air fresh, brings in oxygen, and lowers the number of germs [5].

Table 1 : Typical gas concentrations in chicken barns[6].

Gas	Symbol	Lethal	Desirable
Carbon Dioxide	CO₂	Above 30%	Below 1%
Methane	CH₄	Above 5%	Below 1%
Ammonia	NH₃	Above 500 ppm	Below 40 ppm
Hydrogen Sulfide	H₂S	Above 500 ppm	Below 40 ppm
Oxygen	O₂	Below 6%	Above 16%

Ventilation also helps keep things dry. If the air doesn't move, water can stay in the air or collect on the walls and equipment. This can damage the building or make the chickens sick. When the weather gets warmer, the air can hold more water. For example, if the air gets 20°C hotter, it can take in a lot more moisture [7, 8].

I.3. Energy Consumption in Poultry Farms

In poultry farming, a substantial amount of energy is needed to create and sustain indoor conditions that favor the well-being and productivity of the birds. Farmers must regulate factors like temperature, airflow, and lighting to keep the environment comfortable and stable. This requires strong energy systems, including machines for feeding and watering, lighting setups, fans for ventilation, and equipment for heating and cooling. Without these kinds of systems, maintaining a healthy and productive flock would be challenging. Because of this, energy use becomes one of the major operational concerns in modern poultry facilities.

I.3.1. Sources of Energy Consumption Sources in Traditional Poultry Farms

I.3.1.1. Heating System

Heating systems play a crucial role in maintaining optimal indoor conditions for poultry farming, particularly during colder seasons. Various heating methods are employed depending on farm size, operational costs, and regional climatic conditions. Electric heaters are commonly used due to their ease of installation and ability to provide rapid heat. However, they are associated with high energy consumption and elevated operating costs. Alternatively, gas-powered heaters offer a more cost-effective solution; nevertheless, their reliance on fossil fuels significantly contributes to greenhouse gas emissions. Similarly, diesel-fueled heating systems are widely utilized in large-scale farms, but they are major sources of carbon dioxide emissions, thereby exacerbating environmental degradation. In contrast, solar heating systems have gained popularity in modern poultry farming practices. They provide a renewable and environmentally friendly solution, which not only reduces operational expenses but also minimizes the environmental footprint

Maintaining warmth inside poultry farms is especially important when temperatures drop, and farmers use different types of heaters depending on their budget, farm size, and local weather. Electric heaters are easy to set up and give off quick heat, but they tend to use a lot of electricity, which makes them expensive to run. Usually, Gas heaters cost less to run, which is why many farmers like them, but since they burn fuel, they're not exactly eco-friendly. Diesel heaters are pretty common too, especially in bigger farms, but they give off a lot of smoke and fumes. These days, some farmers are switching to solar setups. They might be expensive at first, but they save money in the long run and don't mess with the environment as much [9, 10].



Figure 3 : Heating Systems[10].

I.3.1.2. Cooling and Ventilation Systems

Maintaining poultry houses cool enough for the birds becomes extremely difficult in hot climates. Their growth may be slowed and their health may be severely impacted if the interior temperature rises too high. For this reason, farmers employ a variety of techniques to regulate the temperature. Using fans is a popular trick. Fans help reduce the heat and make the space more comfortable for the hens by keeping air movement [10]. Evaporative cooling is an additional technique that cools the air by using water. In hot, dry climates, this system is extremely beneficial [5]. Furthermore, some farms use natural ventilation techniques, depending on vents placed in strategic locations to promote air exchange; however, in extremely hot or cold climates, the efficiency of this strategy can be greatly diminished. Low-energy ventilation technologies have recently surfaced as a viable substitute. By reducing electricity use and preserving sufficient air quality within poultry facilities, these systems support modern poultry farming's overall sustainability initiatives [11].

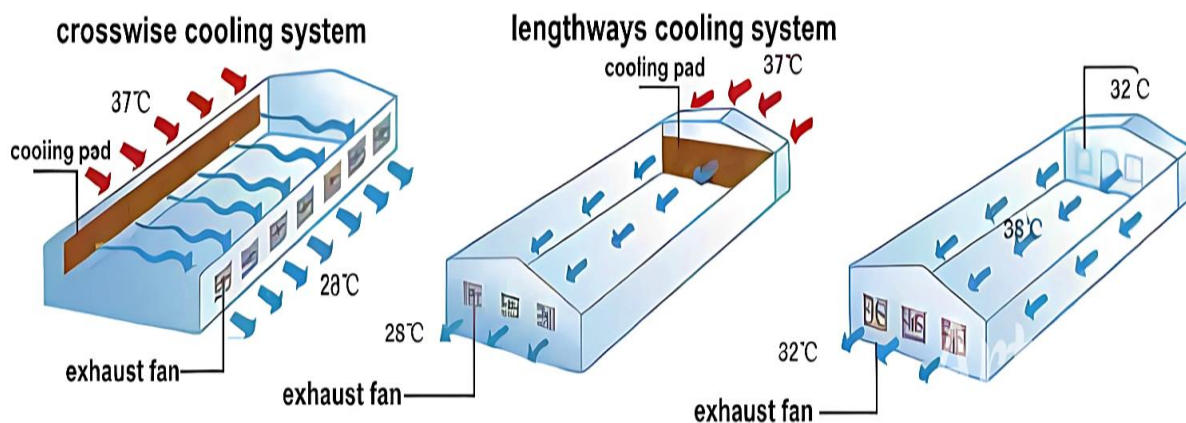


Figure 4: Cooling and ventilation systems[10].

I.3.1.3. Lighting System

- **Incandescent and Fluorescent Lamps**

Incandescent and fluorescent lighting have been the most common types of lighting used in poultry houses, providing the light required that regulates the behavior of birds and promotes productivity [12]. But both lamps are beset by high energy consumption and, therefore, high operating costs and a greater carbon footprint for farms [13]. Additionally, incandescent bulbs give off plenty of excess heat that may disrupt barn temperature control and necessitate the use of additional cooling devices, especially in hot climates. Although fluorescent bulbs are more energy efficient than halogen or incandescent bulbs, they contain mercury, which poses serious environmental threats if not disposed of properly. As a result of these issues, a large number of poultry farms are progressively embracing environmentally friendly lighting options, like LED systems, to conserve energy and lower their ecological footprint [14].

- **LED Lighting**

LED lighting is a viable and sustainable option for chicken farms since it consumes a lot less energy than traditional lighting systems like fluorescent and incandescent lights, which reduces operating expenses. In addition to its exceptional energy efficiency, LED lighting has a longer lifespan, which lessens the need for regular maintenance and replacement. It also provides consistent and even lighting, which reduces stress in birds and promotes healthier growth patterns. Poultry houses require fewer additional cooling systems because LEDs produce significantly less heat and consume up to 75% less energy than conventional lamps. Another significant advantage is the ability to adjust light intensity to the birds' developmental needs, which improves behavior and overall productivity. Furthermore, programmable LED systems can better optimize energy use and support poultry circadian rhythms by mimicking natural day-night cycles [15].



Figure 5 : LED Lighting[15].

- **Smart Lighting Systems**

Poultry farms are increasingly using smart lighting systems to increase lighting efficiency and reduce energy consumption. Depending on the needs of the chickens at various stages of their lives, these systems modify the brightness of the lights. They use tools like timers and sensors to do this automatically. By gradually altering the light, these systems help avoid sudden changes that could frighten or stress the birds. In this more tranquil setting, the hens will sleep better and develop faster. Farmers also find it easier because they can use their phone or computer to control the lights. In the end, smart lighting lowers electricity costs while improving farm operations [16].

I.3.2. Energy Challenges in the Poultry Industry

In the poultry industry, energy consumption poses a serious problem that affects production efficiency, environmental sustainability, and operating costs. The goal of poultry producers is to minimize energy consumption while fostering an environment that promotes bird growth. These problems need creative answers.

I.3.2.1. Rising energy costs and their impact on production

Since the birds must always be kept warm, cool, and comfortable, poultry farms consume a lot of energy. This implies that the ventilation, heating, and cooling systems operate virtually constantly. Farmers are unable to turn a profit as a result of having to spend more money due to rising fuel and electricity prices. Several farms are beginning to employ smart energy management systems and improved insulation materials to help address this issue. By maintaining the proper temperature inside the poultry house, these technologies also help save energy. In this way, farms can reduce expenses without compromising the quality of their output or the health of the birds.[17, 18].

I.3.2.2. Fossil fuel price variations and their influence on farm stability

Chicken farms significantly dependent on fossil fuel as the major source of energy are at risk to shifts in world gasoline prices. These could cause abrupt rises in operation costs that would reflect on product pricing and farm profitability in the end. Farmers might be inclined to explore alternative energy like solar and geothermal systems to boost economic resistance to future changes in world gasoline prices. These renewable options offer greater cost predictability over time and help reduce dependency on conventional fossil fuels [18].

I.3.2.3. The effects of conventional energy use on the environment

Conventional fossil fuels especially during periods of peak demand place a further strain on national grids. Apart from massive greenhouse gas emissions, which drive environmental degradation and global warming, it also results in poultry farms can use a wide range of green technologies to reduce these effects, including heat recovery systems from heating processes, efficient lighting, and incorporating solar or geothermal power sources. These measures support the shift towards a more sustainable agriculture sector and help decrease the environmental impact of chicken production [18].

I.4. Strategies for mitigating environmental impacts

Poultry farming can considerably minimize its environmental impact by embracing sustainable practices. First, organic manure and anaerobic digestion to improve waste handling reduce pollution and generate biogas and other renewable energy. Nutritionally, the environmental impact of traditional feed production is minimized when sustainable substitutes, like insect proteins or crop residues, take the place of traditional feed. The employment of clean energy sources such as geothermal, wind, and solar also reduces carbon emissions and fossil fuel consumption. Recycling practices and effective irrigation systems help to conserve water and preserve natural resources in the utilization of water. All of these measures ensure the establishment of sustainable and eco-friendly poultry rearing systems [18, 19].

I.5. Conclusion

Poultry farming requires a high amount of energy for heating, ventilation, and lighting, which results in increased operating costs and environmental concerns. The use of conventional heating systems based on fossil fuels contributes to greenhouse gas emissions and negatively affects both farm sustainability and the surrounding ecosystem. To defeat these difficulties, it is necessary to seek clean and renewable energy sources. One of the most environmental and efficient alternatives among them is geothermal energy. It supplies poultry houses with continuous and low-cost heating with minimal effect on the environment. The use of geothermal energy for improving energy efficiency and environmental practice in poultry farming will be examined in the following chapter.

**Chapter II Benefits of Using Geothermal
Energy in Poultry Houses**

II.1. Introduction

With the growing interest in sustainable and more energy saving options in the agricultural sector, greater focus has begun to shift toward renewable energy sources in farms. In this context, geothermal energy stands out as a promising option for heating poultry houses, due to its efficiency, reliability, and low environmental impact. This chapter provides an overview of the role of geothermal energy in poultry farms and outlines its main benefits compared to traditional energy systems.

II.2. Geothermal Energy Systems in Poultry Houses

II.2.1. Definition and Principles of Geothermal Energy

Geothermal energy is stored underground at a temperature. This heat is primarily produced from the decomposition of certain naturally occurring radioactive elements in the earth, such as uranium, thorium, and potassium, in addition to the residual heat from the elective process. To obtain this energy, wells are drilled to depths ranging from 1 to 5 meters, depending on the humidity and temperature of the site [20].

In areas rich in geothermal energy resources, temperatures at depth are often high, estimated at between 30 and 40 degrees Celsius. This can persist continuously for applications that do not require high-temperature heating, such as heating and recycling in various fields, including agriculture. This energy is extracted from hot water vapor or even from the hot ground [20].

II.2.2. Why Geothermal Energy is Suitable for Poultry Production?

Demand for diverse commercial applications is increasing, reaching a widespread use of energy technologies in all available areas. Of these options, geothermal energy is a reliable and environmentally friendly solution for providing warm water for poultry, especially in areas with high geothermal resources [21].

Maintaining stable indoor environmental conditions is essential for bird health and high productivity. However, **traditional heating systems that rely on fossil fuels often** result in high operating costs and release harmful emissions such as carbon dioxide (CO₂) and nitrogen oxides (NO_x), which negatively impact both the environment and animal welfare[22, 23].

In contrast, geothermal energy systems provide a clean, continuous heat source that operates independently of weather fluctuations.

Unlike solar or wind energy, geothermal energy is not affected by intermittency. This is particularly suitable for poultry farms that require precise thermal regulation to ensure production is monitored. Scientific studies have begun to show that the use of geothermal energy for climate control can increase feed conversion efficiency (FCE), maximize feed efficiency, and improve overall farm performance [24].

In addition, the advantages of regional energy provide long-term benefits. However, while significant installation costs may be delayed, operational savings do not reduce reliance on unstable fossil fuels, contributing to the long-term investment [25].

II.2.3. How Geothermal Energy Works?

Geothermal energy production involves extracting heat from underground reservoirs of hot water and steam. Wells are drilled into these reservoirs to bring the steam or hot water to the surface, where it is used to drive turbines connected to electricity generators. Afterward, the cooled water is re-injected into the Earth, maintaining the pressure and temperature of the reservoir, thus creating a sustainable energy cycle [26].

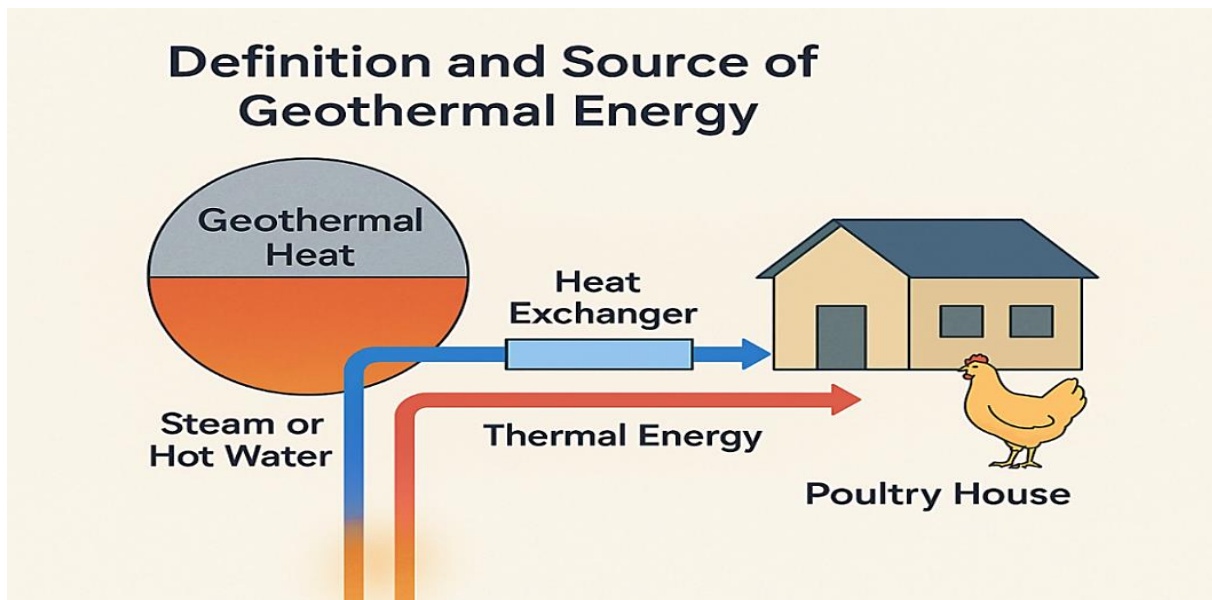


Figure6 : A schematic diagram simply explaining how geothermal energy is used to heat poultry houses.

II.2.4. Types of Geothermal Systems

- **Closed Loop Systems**

In these systems, the fluid typically circulates in a loop that does not interact with the external environment, ensuring that the system remains closed and controlled. This makes them suitable for areas where groundwater quality is not suitable for direct use[21, 26].

- **Open Loop Systems**

These systems require a steady and clean supply of groundwater, which means they are often used in areas where natural water resources are abundant and easily accessible. They are highly efficient but depend on local water availability and quality[21, 26].

II.3. Geothermal Heating and Cooling Applications in Poultry Houses

Geothermal energy systems are used in poultry houses not only for heating in winter but also for cooling during hot summer months. These systems take advantage of the Earth's relatively constant underground temperature to regulate indoor conditions efficiently throughout the year.

II.3.1. Geothermal Heat Pump Systems (GHP)

Geothermal heat pump systems (GHP) utilize the stable temperatures beneath the Earth's surface to provide efficient heating for poultry houses. These systems work by extracting heat from the ground through a network of underground pipes connected to heat pumps. Thermal fluids or groundwater are pumped from wells to the heat pump units, where the heat is transferred to air or water that circulates within the poultry house to maintain optimal indoor temperatures[21].

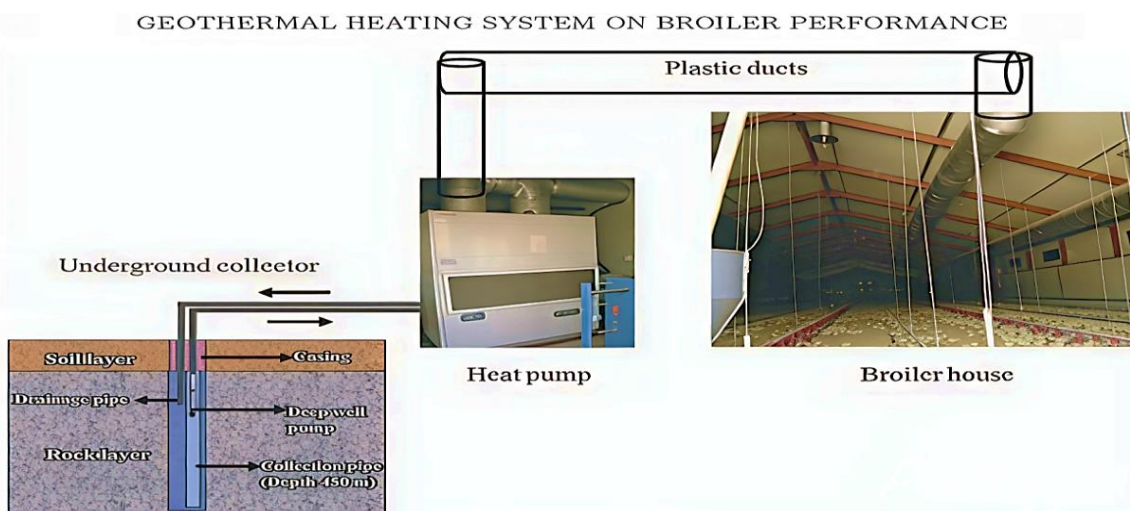


Figure 7 : Schematic diagram of the geothermal heat pump (GHP) system for the broiler house[27].

II.3.2. Ventilation and Air Management Systems

Geothermal energy can be used to pre-condition incoming air in poultry houses. In cold seasons, it helps warm the air, while in hot seasons, it cools the incoming air through ground-cooled ventilation. This process improves indoor air quality and helps reduce concentrations of harmful gases such as ammonia (NH_3) and carbon dioxide (CO_2), creating a healthier living environment for poultry[27].

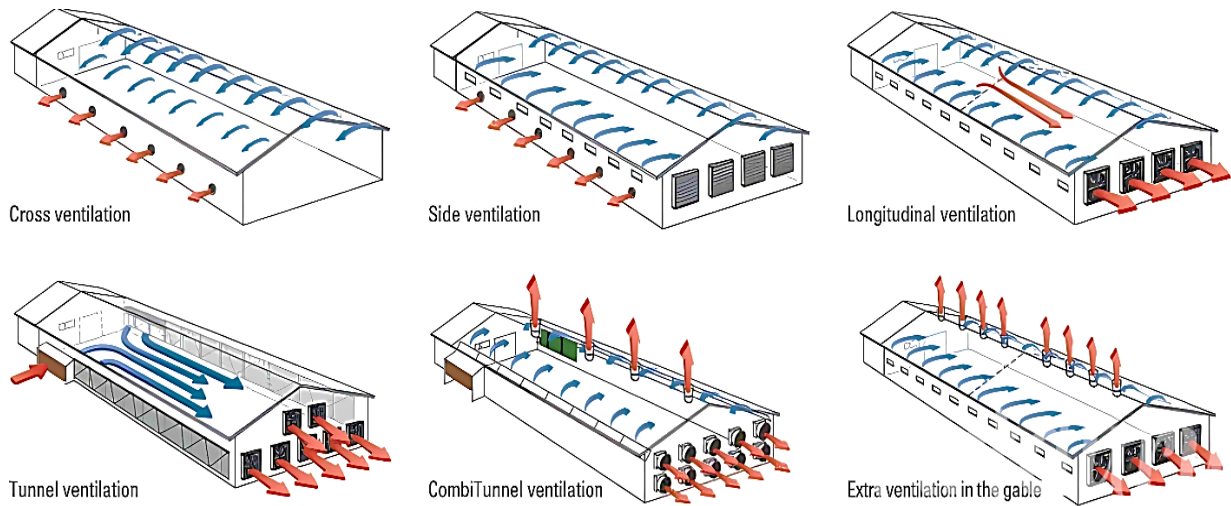


Figure 8: Poultry farmhouse ventilation system.

II.3.3. Direct Heating and Cooling Systems

In some poultry houses, hot water from geothermal wells is used directly in floor or wall heating systems during winter. Similarly, cool groundwater may be circulated through radiant floor systems or air exchangers during summer to reduce indoor temperatures naturally FIGURE 9.

These applications provide a consistent and efficient indoor climate that supports bird health and reduces thermal stress in all seasons[28].

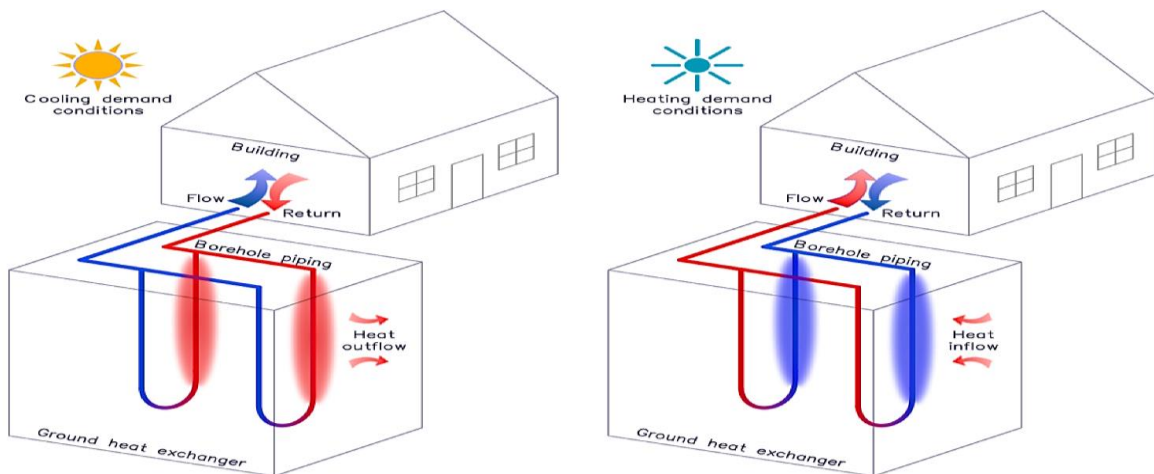


Figure 9: Principle of Direct Geothermal Heating and Cooling in Poultry House[29].

II.4. Impact of Geothermal Energy in Poultry Farming

Poultry houses are specialized structures designed to create an optimal environment for raising domestic birds, such as chickens, ducks, geese, and turkeys. These facilities are built to regulate temperature, humidity, ventilation, and air quality to promote bird health and productivity.

Integrating geothermal systems into poultry houses can significantly improve indoor climate control by reducing thermal stress and stabilizing environmental conditions.

These systems minimize the use of fossil fuels, thereby lowering harmful emissions such as CO₂ and NH₃. In turn, this improves air quality, reduces the risk of respiratory diseases, and enhances overall bird welfare and productivity[30].

II.5. Benefits of Using Geothermal Energy in Poultry Houses

II.5.1. Improved Energy Efficiency and Cost Savings

Geothermal energy systems provide significantly higher efficiency and lower operational costs compared to conventional heating methods used in poultry houses (TABLE 2). Their ability to maintain a stable indoor temperature throughout the year results in substantial reductions in energy consumption and better economic performance. A study published in *Energy and Buildings* found that geothermal heating can reduce energy consumption by up to **74%** compared to conventional systems, thanks to its ability to maintain a stable indoor temperature throughout the year[31].

Table 2 : Comparison of Geothermal Energy with Other Energy Sources in Poultry Houses.

Criteria	Geothermal Energy	LPG (Gas)	Diesel	Electric Heating
Energy Efficiency	Very high (90-95%)	Moderate (70-80%)	Moderate (60-75%)	Low (50-70%)
Operating Cost	Low	High (fluctuations)	Very high	High (electricity cost)
Carbon Emissions	Very low (136,571 kg CO ₂)	High	Very high (133,798 kg CO ₂)	Low
Environmental Impact	Eco-friendly	Air pollution	High pollution	Depends on source

❖ Low Operational Costs

Although the initial installation cost of geothermal systems may be high, their running costs are much lower than fossil fuel-based systems. A study conducted in Korea showed that geothermal energy reduced heating costs by 92% compared to diesel-based systems[27].

❖ **High Thermal Efficiency**

Geothermal systems operate with high efficiency by consistently converting underground heat into usable energy. This is particularly beneficial in cold regions where solar systems tend to underperform due to limited sunlight[31].

❖ **Reduced Maintenance Requirements**

Compared to traditional systems, geothermal heating requires less maintenance, which leads to long-term cost savings and improved financial sustainability for poultry farmers.

II.5.2. Environmental Sustainability and Emission Reduction

One of the most important environmental advantages of geothermal energy is its minimal environmental impact. Unlike fossil fuels, geothermal systems do not emit carbon dioxide (CO₂) or nitrogen oxides (NO_x) during operation, which are major contributors to air pollution and climate change. Moreover, reducing the use of traditional fuel sources lowers ammonia (NH₃) emissions inside poultry houses, improving indoor air quality and reducing the risk of respiratory diseases among birds. Geothermal energy is also a renewable and weather-independent resource, offering a reliable year-round energy supply that enhances energy security and reduces dependency on volatile fossil fuel markets[27].

II.5.3. Enhanced Poultry Health and Productivity

Stable indoor conditions are essential for maintaining poultry health and maximizing productivity. Geothermal systems help ensure consistent temperatures and clean air, reducing thermal stress that negatively affects bird growth and well-being. By minimizing harmful gases and providing optimal environmental conditions, geothermal energy supports better feed conversion efficiency (FCE), lowers mortality rates, and improves overall flock performance. Birds can use more energy for growth instead of adjusting to temperature fluctuations[31].

II.5.4. Clear Advantage Over Conventional Energy Sources

Compared to fossil fuels like diesel or natural gas, geothermal energy systems offer numerous advantages[31]:

- ❖ Lower operational costs and long-term savings.
- ❖ No direct greenhouse gas emissions, reducing environmental impact.
- ❖ High thermal efficiency, especially in cold regions where solar systems are less effective.
- ❖ Stable year-round operation, unlike solar or wind systems that depend on weather conditions.

- ❖ These factors make geothermal energy a reliable, efficient, and sustainable alternative for poultry farming.

II.6. Challenges in Applying Geothermal Energy in Poultry Farming

Although geothermal energy offers numerous benefits, several technical and financial challenges may hinder its widespread adoption in poultry farming. These include high initial investment, site-specific feasibility, and the need for specialized installation and maintenance expertise. Overcoming these challenges requires supportive policies, training programs, and pilot projects to demonstrate effectiveness.

II.7. Conclusion

Geothermal energy is a simple and reliable solution for keeping the poultry houses warm in winter and cool in summer. It keeps the indoor temperature at the same level throughout the year, thus making the birds more comfortable and less stressed. When the chickens are healthier, they grow and eat better, which increases their productivity and health in general. Using geothermal systems instead of fuel-based heaters can lower energy use, reduce costs, and cut down on harmful gases released into the air. Unlike solar or wind power, geothermal energy works well no matter the weather, which makes it more dependable. Geothermal systems keep the air in poultry houses clean by dehumidifying. It implies the air stays healthier for the birds. Sure, the installation might cost more up front, but it doesn't need as much maintenance and saves on energy costs down the line. In the long run, though, it's not just saving money — it's also a smart and sustainable way to run a poultry farm.

Chapter III Results and Discussion

III.1. Introduction

The use of geothermal energy is an alternative and sustainable solution to naturally improve the internal climatic conditions of poultry farms. This system exchanges temperature between the ground and the barns, helping to maintain moderate and stable conditions, reduce conventional energy consumption, and lower greenhouse gas emissions. This chapter aims to study and analyze the impact of integrating a geothermal energy system into poultry farms by evaluating changes in humidity, temperature, and gas emissions such as carbon dioxide (CO₂) and carbon monoxide (CO). This is part of a field experiment conducted in the region Reguiba – El Oued during the period from January – February 2025.

III.2. Importance of Indoor Climate for Chickens

The indoor climate has a major effect on chickens. Temperature and humidity are crucial factors that influence their health and production. Therefore, these need to be controlled indoors in the chicken house to allow for effective poultry farming.

III.2.1. El Oued area

El Oued is located in the southeastern region of Algeria and is known for its dry desert climate. The area experiences extremely high summer temperatures, occasionally over 45°C, and moderately cold winters. Relative humidity is low, especially during the hot season. The precipitation is extremely rare, usually less than 100 mm annually, and thus El Oued is one of the driest regions in the country. These extreme climatic conditions, in turn, directly affect agricultural operations, particularly poultry farming, where temperature and humidity control inside poultry houses become vital for the health of birds and stable production.

III.2.2. Temperature

To keep chickens well, the ideal temperature is debatable and might depend on other conditions like humidity. Chicks need warm temperatures of about 30-32°C for the first week, and this needs to decrease gradually each week. For growing chickens, a cold range of between 18-22°C will usually be appropriate. In hot regions like the El-Oued region, keeping proper temperature inside poultry houses is very important. If heat is not regulated properly, it will affect the growth of chickens and reduce production. Therefore, the design of the poultry house must take very seriously how to deal with a high temperature.

III.2.3. Relative humidity

Humidity significantly affects poultry farming, especially in hot and dry regions like El Oued, Algeria, where it interacts with temperature to influence bird health and growth. When humidity is high along with high temperatures, it can lower feed efficiency and increase disease risk. On the other hand, moderate humidity can be beneficial to the comfort of birds in cold climates. As birds grow, the moisture they release raises indoor humidity, promoting the spread of pathogens like Salmonella. Proper management of humidity is thus necessary to attain healthy and consistent poultry production.

III.3. Description of the Experimental Setup

III.3.1. Poultry House Dimensions

- **Area:** The size of the poultry house is calculated by the number of chickens. On average, 1 m² space holds 10 to 12 birds. In our experience, a single poultry house can hold a maximum of 8000 chickens. (For example, if you have 1000 chickens, you will need about 80 to 100 square meters of space).
- **Height:** It should be around 2.5 to 3 meters. It provides proper ventilation and proper airflow.

III.3.2. Geothermal Pipe System

- **Quantity of Pipes:** 15 durable PVC pipes.
- **Pipe diameter:** 110 mm to provide enough air movement.
- **Burial Depth:** Pipes are buried 2 to 4 meters underground, where the temperature remains stable year-round.
- **Pipe Length:** All pipes are 50 meters long.
- **Slope:** Pipes are provided with a smooth slope (1–2%) for the disposal of any water condensed.

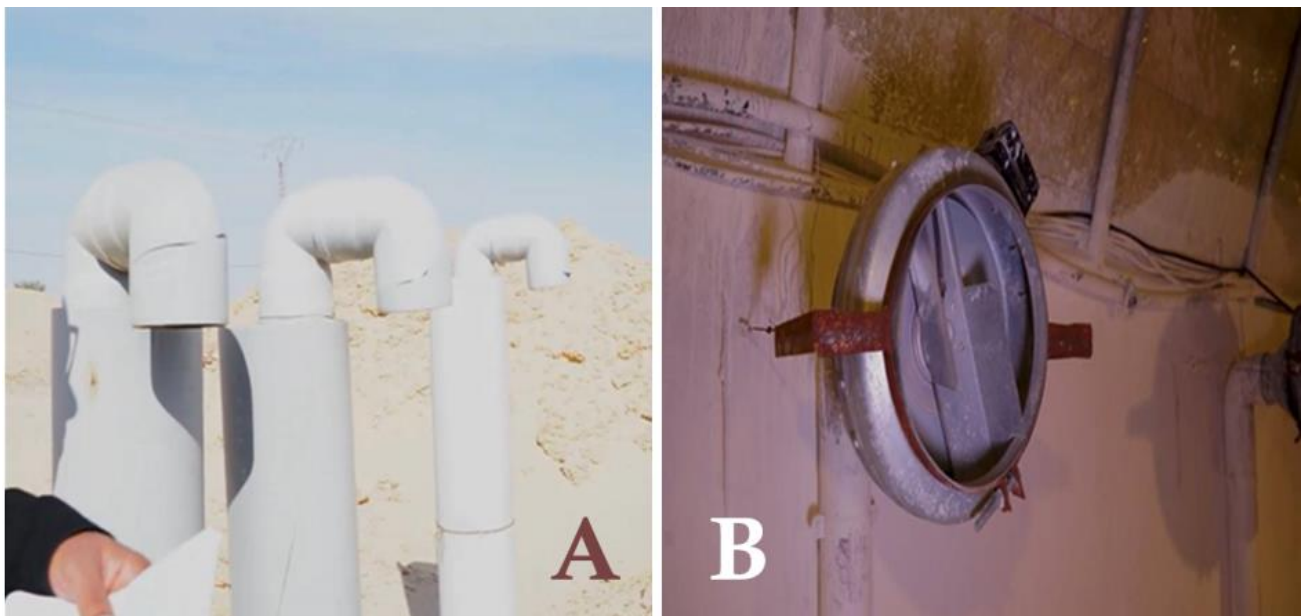


Figure 10 : Geothermal Energy System (Reguiba -El Oued) Inlet (B) Outlet(A).

III.3.3. Ventilation System

- **Exhaust Fan:** It uses a fan with 0.5 to 1 horsepower to pull air from underground tubes and force it into the chicken house. This supplies an ongoing amount of fresh air from the ground.
- **Air Distribution Outlets:** Vents are set up across the poultry house in a balanced way to keep the air moving equally in every part.

III.3.4. Temperature and Humidity Control

Summer (Cooling)

- **How It Works:** Hot outside air is cooled as it passes through underground pipes at around 20°C.
- **Inside Temperature:** Can be reduced to 25–28°C, which is ideal for poultry comfort and performance.
- **Relative Humidity:** Maintained at 20–50%, controlled by adjusting airflow speed.

Winter (Heating)

- **How It Works:** Cold air is slightly warmed while moving through the buried pipes before entering the poultry house.
- **Inside Temperature:** Maintained between 25–28°C to support healthy growth.
- **Relative Humidity:** Ranges from 20–50%, helping to reduce bedding dryness and support bird welfare.



Figure 11 : The device in the picture is used to measure temperature and air velocity.



Figure 12 : The device in the picture is used to measure temperature and humidity and transmit data via 4G internet.

III.4. Results and discussion

In this section, we will report and discuss the findings regarding the indoor state of both the TEM poultry house and the geothermal one. The main focus will be given to three parameters: temperature, humidity and gas emissions, measured using special devices (Figure13). Firstly, we will compare the capacity of each system to maintain a stable indoor temperature. Secondly, we will consider humidity in both environments. Finally, but not least, we will analyze gas emissions of carbon dioxide (CO₂) and carbon monoxide (CO), important indicators of air quality and ventilation performance.

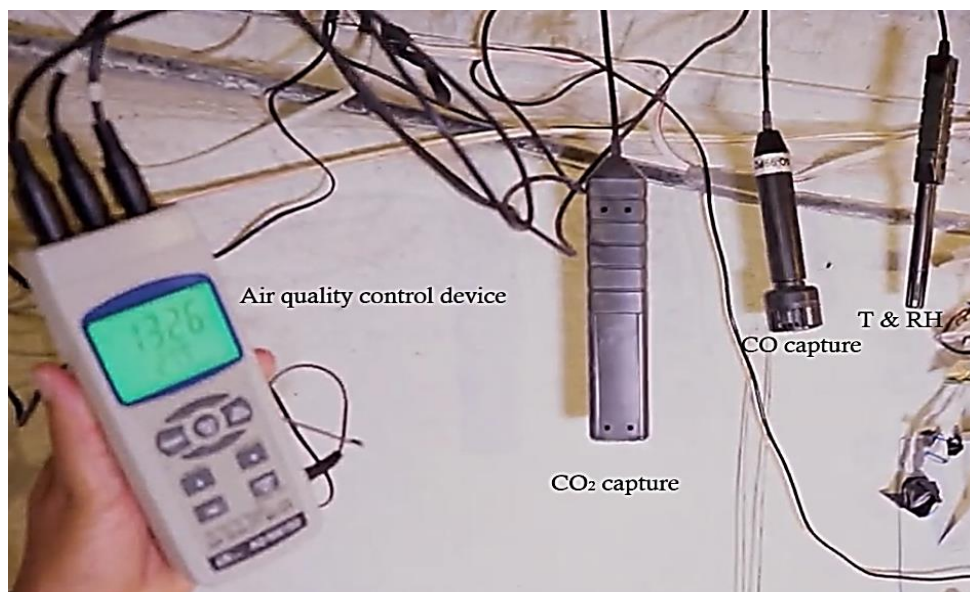


Figure 13 : The devices are used to measure different parameters.

III.4.1. Temperature of internal environment of poultry house

This figure shows how indoor temperatures vary in two poultry houses over specific period (3 days from 28/02/2025 to 30/02/2025). The blue curve (TEM_T) refers to the control house without any special heating, while the orange curve (GTH_T) represents the house using a geothermal heating system. From the chart, we can see that the geothermal-heated house keeps a more stable temperature, especially during colder periods when the control house shows sudden drops. Inside the geothermal home, the temperature is more stable, thus enabling the chickens to stay comfortable and keep growing at a stable rate. In comparison, there is a bigger fluctuation of temperatures in the control home, which could make the chickens uncomfortable and even stress. Among the key benefits of using geothermal energy in poultry houses are the reduction of energy consumption, both fuel and electricity, and its environmentally friendly nature through the significant decrease in harmful gas emissions.

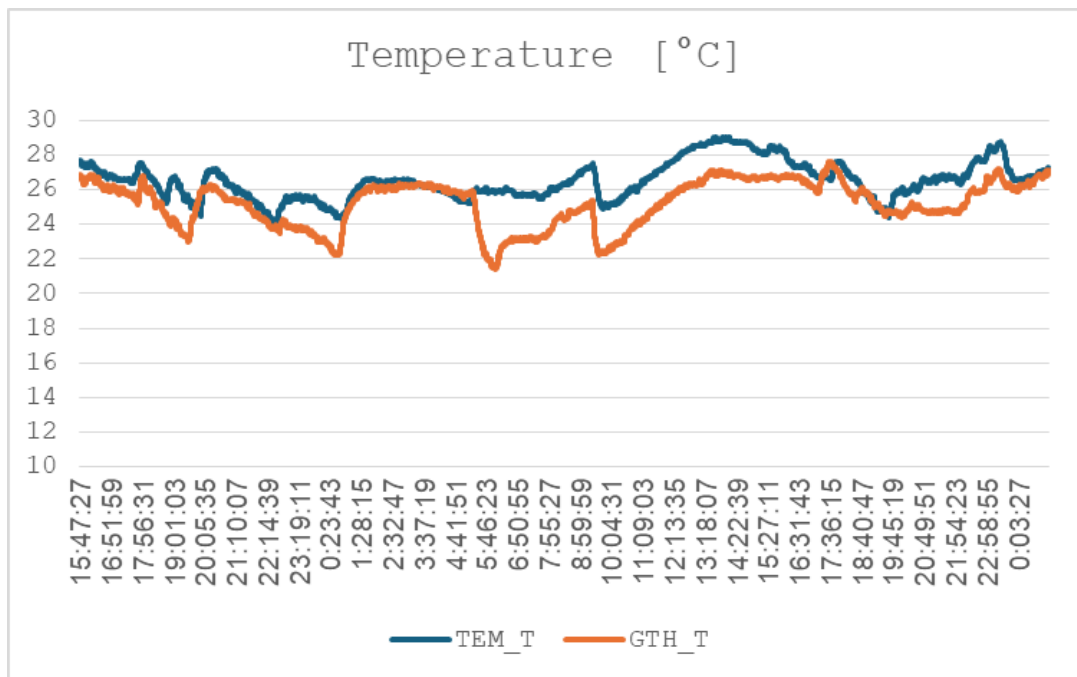


Figure 14: Effect of Geothermal Energy on Indoor Temperature in Poultry Houses.

III.4.2. Impact of Geothermal Energy on Indoor Humidity Levels

The graph illustrates the effect of using geothermal energy on the relative humidity inside poultry houses over the specific period. The blue line (TEM_RH) represents the relative humidity in the control poultry house, where values generally range between 25% and 47% and show noticeable fluctuations. In the case of the poultry house using geothermal heating, shown by the orange line (GTH_RH), the relative humidity stays mostly between 13% and 35%. These values remain steady during the observation period, with very little change.

This suggests that the geothermal system helps keep humidity at lower and more consistent levels, which results in a drier indoor environment compared to the control house. Overall, maintaining moderate humidity in poultry houses is important for efficient poultry production. It avoids respiratory disease and increases egg yield and egg quality. Therefore, the constancy of humidity provided by geothermal energy not only supports a better health environment but also improves the overall health and productivity of the chickens.

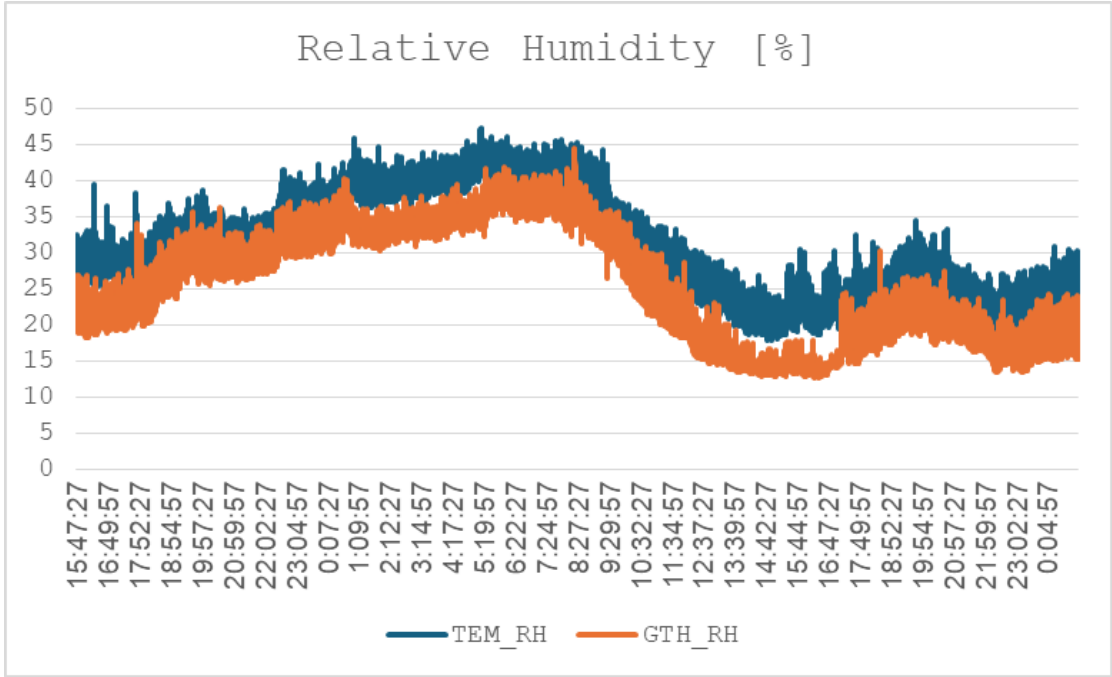


Figure 15: Impact of geothermal energy on humidity inside Poultry Houses.

III.4.3. Interpreting carbon dioxide levels in the poultry house environment

The chart shows how carbon dioxide (CO₂) levels changed over time in two poultry houses. The TEM_CO₂ line tracks the CO₂ concentration in the control poultry house, where values usually fall between 800 and 1800 ppm, with clear ups and downs, especially during certain peak times. In contrast, the GTH_CO₂ line shows the CO₂ levels in the poultry house that uses geothermal heating, where the values tend to be lower typically between 600 and 1400 ppm and remain more consistent throughout the day. This suggests that the geothermal system helps improve air circulation, which keeps CO₂ from building up inside the poultry house. While both houses show some temporary spikes, the values in the geothermal house rarely go above 1400 ppm, unlike the control house which sometimes reaches 1800 ppm. In general, geothermal energy appears to reduce CO₂ levels by about 200 to 400 ppm in most cases.

This not only helps keep the air cleaner but also supports a healthier indoor space for the birds, which may reduce the chance of breathing problems caused by high CO₂.

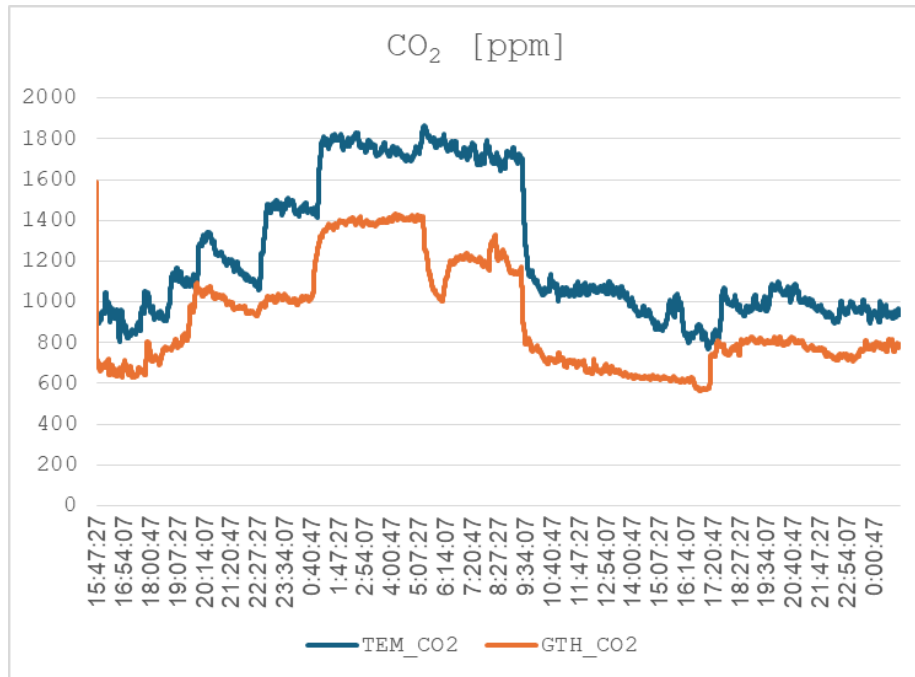


Figure 16 : Impact of geothermal system on CO₂ emissions inside poultry house.

III.4.4. Emission of CO inside of poultry house

The Figure 17 shows how carbon monoxide (CO) levels varied over time in two poultry houses. The TEM_CO line represents the CO values in the control house, while the GTH_CO line present the values in the house equipped with a geothermal heating system. In general, both houses maintained low CO levels, mostly ranging between 0 and 13 ppm, which suggests that the air quality remained within a safe range for poultry. However, the control house sometimes showed brief increases, with CO values rising to about 13 ppm. In contrast, CO values in the poultry house using geothermal energy stayed more stable and usually remained under 5 ppm. This could mean that the geothermal system helps improve air circulation and keeps CO levels low over time. As time progressed, values in both houses gradually settled into similar ranges. This is probably due to the naturally low levels of carbon monoxide in the air. The initial changes might be caused by short-term differences in ventilation, while the later stability suggests that the heating method has little effect on a gas with such low emissions.

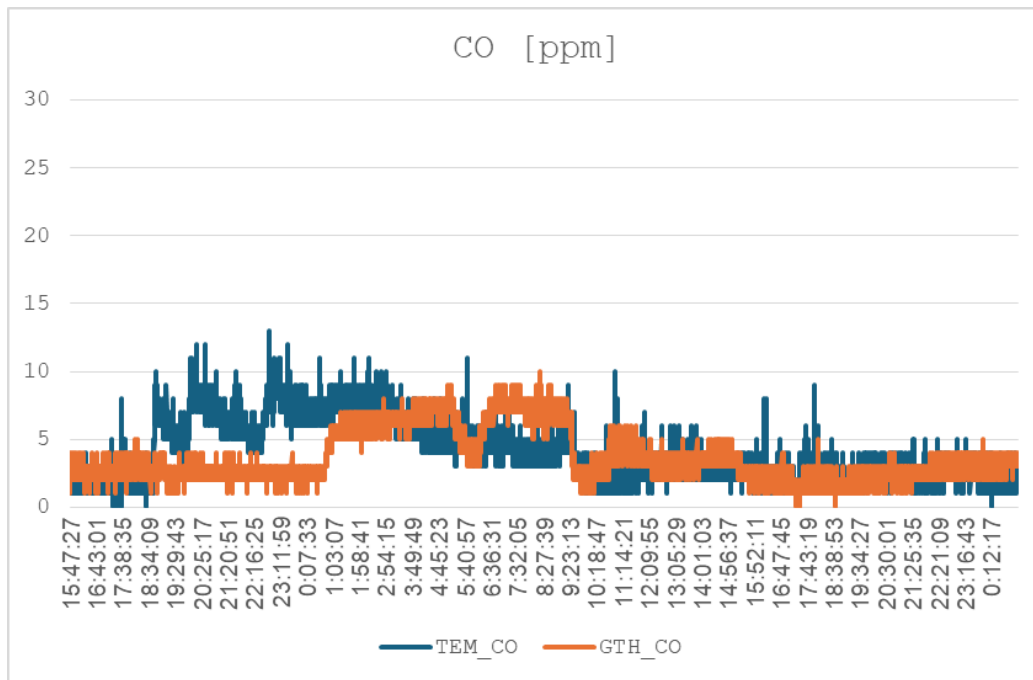


Figure 17: Impact of geothermal system on CO emissions inside poultry house.

III.5. Conclusion

This chapter has outlined the most significant findings related to the indoor environment of poultry houses, with regard to temperature, humidity, and emissions including carbon monoxide (CO) and carbon dioxide (CO₂). The comparison of a control poultry house and a geothermal-heated poultry house showed obvious differences in environmental quality. The results showed that the house with geothermal heating maintained more balanced and stable indoor conditions. Temperature and humidity levels were more controlled, and gas emissions, particularly CO₂ and CO, were noticeably lower. These improvements suggest that geothermal systems can help provide a healthier and more comfortable space for poultry, while also reducing energy needs and environmental impact. This makes geothermal energy a useful option for poultry farming in regions with tough climate

General conclusion

Geothermal energy assists a lot with the quality of air, temperature, and humidity of chicken houses. Through its operation, temperatures are maintained at optimum level so stability is maintained at most desirable level at all times either daytime or nighttime depending on heat trapped below the surface of the earth. It offers a safe and comfortable environment that supports bird growth as well as general health.

In addition, these systems help in maintaining humidity levels within the poultry houses to prevent condensation and mold caused by high moisture levels. This regulation reduces the risk of respiratory diseases and improves the quality of air, making the surrounding healthier for birds. Furthermore, continuous temperature and humidity control leads to the general condition of air being healthier by reducing the amount of toxic gases and dust and enhancing air circulation. That is improved respiratory health for the birds, reduced stress levels, and enhanced productivity.

In general, geothermal energy serves to enhance environmentally friendly conditions inside poultry houses, increase stability and comfort levels among the birds, and increase the efficiency of production with sustainability.

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