DEVELOPMENT OF A SOLAR POWERED POULTRY INCUBATOR SYSTEM

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DECLARATION

I OYUGBO, Eseose Valerie with matriculation number 17/ENG06/072 hereby declare that this project was carried out by me and has been submitted to the Department of Mechanical and Mechatronics Engineering, Afe Babalola University, Ado Ekiti in partial fulfilment of the requirements for award of Bachelor of Engineering (B. Eng.) degree in Mechanical Engineering.

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CERTIFICATION

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DEDICATION

This project is dedicated to my parents Mr. and Mrs. Oyugbo for their never-ending love, care and support.

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ABSTRACT

An incubator is an insulated casing where the natural conditions for the growth, reproduction or hatching of organisms can occur. The efficiency of natural incubation is low because the production level of a brooding hen is limited but the artificial incubation process requires sustainable energy supply to maximize efficiency. A solar powered incubator can provide this.

The incubator design was done using solid works after careful calculations. The incubator chamber was made using MDF board. It gives a good finish. Inside the incubator was insulated using styrofoam. The egg trays were made with mild steel wire mesh. The materials were selected based on durability and cost effectiveness before they were sourced from the local market.

The assembling of the incubator casing was done using dry wall screws and a hand drill, reinforced with aluminum angles. After assembling and electrical coupling, 10 eggs were placed in the incubator for performance evaluation. Hourly readings were taken for the temperature and humidity level and recorded for 2 days to show the temperature and humidity range.

Out of the 10 fertile eggs placed inside the incubator, 9 of them successfully hatched. This gave a hatchability of 90%. Therefore, the solar incubator is a better replacement for the existing ones especially in the rural areas.

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INTRODUCTION

1.1 Background of the Study

Factory farming is a method of rearing fast-growing animals in close quarters with limited movement. Industrial agriculture is a group of procedures that is aimed to generate the most yield with minimal expenses by utilizing economies of scale, modern medicine and machinery for finance and sales. Factory farming is a part of industrial agriculture(ABU MUSA BIN MOHD ADID, 2008). The Long-term availability of energy sources that are affordable, accessible, and ecologically benign is essential for industrial agriculture's economic success.

Energy, on the other hand, is a critical component of every sector of a country's economy. Nigeria has an excessive amount of various energy resources. The sun is considered the best alternative source of energy because it’s renewable, clean, and free of charge. The amount of solar energy accessible is affected by the sun's position, the weather, particularly clouds, and the location. Nigeria has ample resources for both traditional and modern energy needs but because of insufficient development and ineffective management of the energy sector, a supply and demand gap exists. Electricity, the country’s most extensively utilized energy source, has proven undependable.

Rural communities have limited access to conventional sources of energy such as electricity and petroleum products as a result of poor road networks. They are the best places for solar energy since they have tough topography and no quick fossil fuel energy access. By harnessing solar radiation in the agricultural sector, the effective harnessing of solar radiation using solar energy technology will increase the availability of energy for socio-economic activities and improve the standard of living of the people. (Oyedepo, 2012). The application of energy in poultry production has received less attention, particularly in developing nations. The global population is rapidly increasing, as is the demand for protein, particularly in rural regions.

Poultry is a tremendous source of protein. Natural incubation limits production since the number of eggs laid by a female bird in a year range from 0 to 365, or one every day. Nonetheless, a broody hen (a hen that wants to lay eggs, hatch them, and rear its chicks) may hatch 10-12 eggs at once in 21 days. An artificial incubation technique became essential. The fertilized eggs of chickens are kept warm in poultry incubators until they are ready to hatch.

1.2 Problem Statement

A hen hatches her eggs at low efficiency. The production level is limited as a brooding hen can only hatch about 12 eggs in the 3weeks. The artificial incubation process requires a sustainable energy supply for efficient performance and profitability. This is a challenge in the rural areas and some urban areas because of the Nigerian Government’s inability to supply reliable and adequate energy supply. The solar-powered incubator can be used to avoid power failure thereby increasing production level and maximum efficiency.

1.3 Aim and Objectives

The project aims to develop a poultry incubator that is powered by solar energy. The objectives of this project include:

i. Design of a solar-powered egg incubator using Solid works.

ii. Source for materials locally

iii. Fabricate the incubator with locally sourced materials according to the design.

iv. Carry out performance evaluation of the fabricated incubator.

1.4 Justification

The purpose of this project is to fabricate an incubator for poultry that is powered by energy from the sun harnessed by a solar panel. The intention is to improve the hatching process of eggs and create a safe environment free from pollution. This project will assist small-scale and large-scale farmers in achieving a high production level as a large number of eggs can be hatched at the same time, and there will be no disruption of power supply thus maximizing efficiency.

1.5 Scope of Work

The scope of work covers the design, fabrication, and assembly of various components to create the incubator.

CHAPTER TWO

LITERATURE REVIEW

2.1 Solar Energy

The Sun is a primarily hydrogen-based gaseous body. Gravity creates a lot of pressure and heat in the core, which starts nuclear fusion reactions. This means that atoms of lighter elements are combined into atoms of heavier elements, which release enormous quantities of energy (Bhatia & Gupta, 2017). The sun provides more for our world than merely giving light during the day; each particle of sunlight (called a photon) that reaches Earth carries energy that powers our globe. Solar energy is the ultimate source responsible for all of our weather systems and energy sources on Earth, and enough solar radiation reaches the planet's surface each hour to theoretically meet our global energy needs for nearly an entire year. Photovoltaics and solar thermal collectors can be used to harness solar power and convert it to usable energy. Although solar energy contributes to a small portion of total worldwide energy consumption, the decreasing cost of installing solar panels implies that more people in more regions can benefit from solar energy. Solar is a clean, renewable energy source that is expected to play a significant role in the global energy future (Marshall, 2019). Solar radiation is absorbed, scattered, and reflected by components of the atmosphere. The atmospheric effects of solar radiation are shown in Figure 2.1.

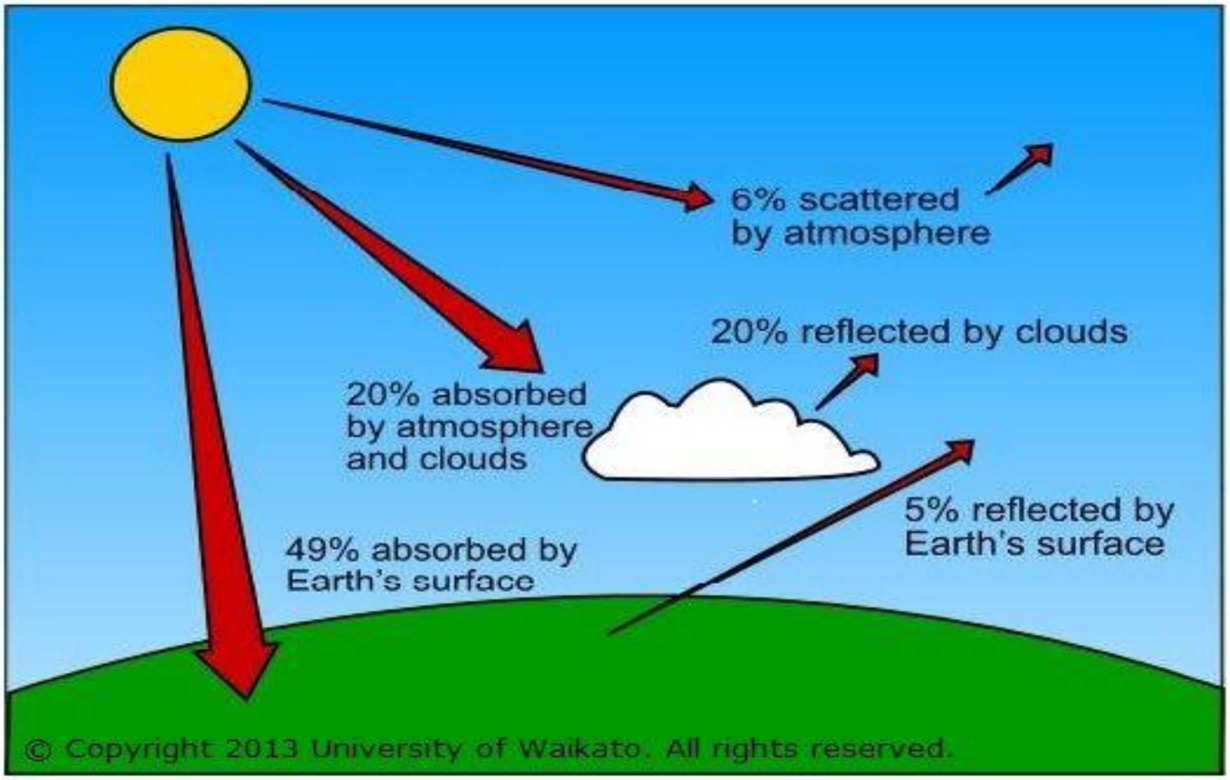


Figure 2. 1: Atmospheric effects of solar radiation

(source: googleimages.com)

The amount of radiation reaching the Earth is less than what entered the top of the atmosphere. According to (Bhatia & Gupta, 2017), we classify it into two categories :

1. Direct radiation: that is radiation that gets to the earth without scattering.

2. Diffuse radiation: that is radiation scattered by the atmosphere and clouds.

2.1.1 Harnessing solar energy

The sun does not distribute energy to all places evenly therefore solar energy needs to be harnessed. Photovoltaic cells and panels, concentrated solar energy, and solar architecture are all examples of solar energy technology. Capturing solar radiation and transforming it into useable energy may be done in a variety of ways. These ways use either active solar energy or passive solar energy. Active solar technologies involve the use of electrical or mechanical systems to transform solar energy into another kind of energy, most often heat or electricity while no external equipment are used in passive solar technology(Morse & Turgeon, 2012). Active solar technologies include photovoltaic cells and solar panels, concentrated solar power, solar thermal collector systems (concentrating solar electricity), and various methods of converting sunlight. Passive solar systems and approaches include orienting a structure toward the sun, selecting appropriate materials, and developing spaces that naturally and favorably regulate airflow.(Hediu, 2021) Let's take a look at five cutting-edge solar energy harvesting systems: (Wendt, 2020)

i. Photovoltaic solar panels: Photovoltaic (PV) solar panels generate electricity by harnessing the power of the sun. Today, this is the most extensively used way of gathering solar energy. These panels, which range in size from a few square centimeters to a few square meters, are made up of a complex matrix of PV cells. Intuitively, the greater the surface area available for sunlight to permeate the PV cells, the greater the amount of solar energy harvested. Each PV solar cell is composed of a compound semiconductor wafer structure, which can be monocrystalline or polycrystalline. Two thin semiconductor wafers, one P-type and one N-type, are developed separately in the structure. The two wafers are stacked on top of each other, and the natural reaction between the two types of semiconductors creates a depletion zone that achieves an equilibrium point without generating any electricity. A single photon interaction generates electricity that is replicated throughout the whole surface of the PV cell. It's combined into an entire panel of solar cells, which is then combined into a massive PV panel array. This little contact in the depletion zone can be repeated and compounded to produce a large amount of electricity. PV solar panels, on the other hand, generate direct current (DC). This DC energy must be converted to AC power via an inverter before it can be integrated with modern power transmission technologies, such as the outlets in your home. An example is shown in Figure 2.2

ii. Thermal energy harvesting (Energy of electromagnetic radiation): The sun emits a wide range of light at various wavelengths, including infrared. This spectrum efficiently transfers thermal energy to absorbable substances. Elements that can successfully absorb this thermal electromagnetic energy are known as 'black bodies,' because the color black absorbs all visible wavelengths of radiation.

Figure 2. 2: Solar panels

(source: googleimages.com)

All wavelengths of the electromagnetic radiation spectrum can be accurately absorbed and emitted by an ideal black substance. Electromagnetic radiation has long been employed for heating in numerous passive heating systems, such as egg boiling, Roman bathhouses, and Ancient Egyptian homes, as well as modern alternatives like thermal solar panels and thermosiphons. These thermal solar energy collecting systems rely significantly on the physics of black body radiation and their ability to absorb and transfer electromagnetic radiation. Thermal energy is most commonly collected in the home for use in water heating systems. These technologies, however, are less suitable for industrial-scale energy generation.

iii. Solar water heater: A solar water heater is an excellent example of a thermal solar energy harvesting application that is widely used in sunny locations around the world. A pump circulates chilled water through a black body panel in the most basic variant of a solar water heater system. This appears to be a PV solar panel, with the black surface efficiently absorbing thermal energy, which is then cooled by the cycled water, heating the water. Throughout the sun activity, water is constantly pumped via this loop, producing warm water. Some systems can avoid the need for a pump by leveraging the buoyancy caused by the heated water. This warmer water 'floats,' while the cooler water sinks, resulting in low quantities of flow in the system and the formation of a thermosiphon. These methods necessitate placing the storage tank above the solar absorption source. It can be shown in Figure 2.3

iv. Vacuum tube solar water heater: Vacuum tubes and self-contained heat pipes are used in more complex and efficient solar water heating systems to transport thermal energy to a secondary tank. The vacuum tube allows radiant energy to enter the system, but all energy that is converted to thermal energy is confined within the tube. This energy is absorbed by the heat pipe and then transferred to the huge water tank. These systems are far more efficient at heating water during the winter because just a small amount of thermal energy escapes the vacuum tube, allowing practically all radiant energy to be transformed into thermal energy.

v. Molten salt solar power: Recent advances in molten salt systems are pushing the frontiers of solar energy power generation. Molten salt power plants, like the previously proposed solar-powered water heating systems, use electromagnetic radiation to melt salt. This molten salt is then moved to a heat exchanger, which converts water into steam, which is subsequently used to generate energy via a steam turbine. Molten salt power systems, such as the Ivanpah Solar Plant, rely on a vast network of heliostat mirrors to focus sunlight to a single location, which is commonly referred to as a power tower or central tower. This tower absorbs the energy from all of the heliostats around it, which is enough to melt the salt at over 1500°F. This molten salt is then kept in insulated tanks, where it may be used even when the sun is not shining.

2.1.2 Advantages of solar power

The advantages of solar power and reasons its mostly sought after include:(Gaille, 2020)

i. Solar power increases sustainability.

ii. It has a lower environmental impact than other forms of energy generation. It decreases pollution.

Figure 2. 3: Solar Water Heater

(source: googleimages.com)

iii. It can reduce the emission of greenhouse gases thus reduces global warming

iv. Solar energy can reduce your carbon footprint.

v. Solar energy allows for global energy independence.

2.1.3 Photovoltaic systems

Photovoltaic conversion is the direct conversion of sunlight into electricity that does not require the use of a heat engine. Photovoltaic devices are rugged and simple in design, requiring very little maintenance, and their fundamental advantage is that they can be built as stand-alone systems with outputs ranging from microwatts to megawatts. As a result, they are employed in power generation, water pumping, remote buildings, solar home systems, communications, satellites, and space vehicles, reverse osmosis plants, and even megawatt-scale power plants. The light from the Sun, made up of packets of energy called photons, falls onto a solar panel and creates an electric current through a process called the photovoltaic effect. Each panel produces a relatively small amount of energy but can be linked together with other panels to produce higher amounts of energy as a solar array. The light from the Sun, made up of packets of energy called photons, falls onto a solar panel and creates an electric current through a process called the photovoltaic effect. Each panel produces a relatively small amount of energy but can be linked together with other panels to produce higher amounts of energy as a solar array. The electricity produced from a solar panel (or array) is in the form of direct current (DC). Although many electronic devices use DC electricity, including your phone or laptop, they are designed to operate using the electrical utility grid which provides (and requires) alternating current (AC). Therefore, for the solar electricity to be useful it must first be converted from DC to AC using an inverter. This AC electricity from the inverter can then be used to power electronics locally, or be sent on to the electrical grid for use elsewhere.(Afework et al., 2018). A typical residential grid-tied solar PV system diagram can be seen in Figure 2.4

2.2 Incubators

An incubator is an insulated casing where the natural conditions for the growth, reproduction or hatching of organisms can occur. (Jacob, 2021)

2.2.1 History of poultry incubator

Early Egyptian incubators were made up of a big mud-brick house with a number of little rooms (ovens) on each side of a central passageway around 3,000 years ago. There were shelves in the upper section of these "little incubation rooms" where straw, camel manure, or charcoal could be burned to provide radiant heat to the eggs below. These chambers had vents in the roofs that allowed smoke and gases from the flames to escape while also providing some light. A little manhole served as the entrance to each incubator room from the hallway. Thousands of eggs were laid out on the floor of each incubator room and turned twice a day. Temperature management was accomplished by adjusting the fire's intensity, opening the manholes, and opening vents in the ovens' and passageway's roofs on a regular basis. When necessary, moist jute was put over the eggs to manage humidity. The temperature, humidity, and ventilation were examined and managed in this basic incubation system by having the hatchery manager and hatchery staff actually live within the structure. They would learn to estimate humidity, temperature, and air freshness based on their own feelings and sense of touch by living there. They were able to detect any deviation from the standard. They used to assess the temperature of the egg by holding it against their eye lids.(Paniago M., 2005) Humidity requirements and air cell size were judged by the sound made by rolling two eggs together in one hand.

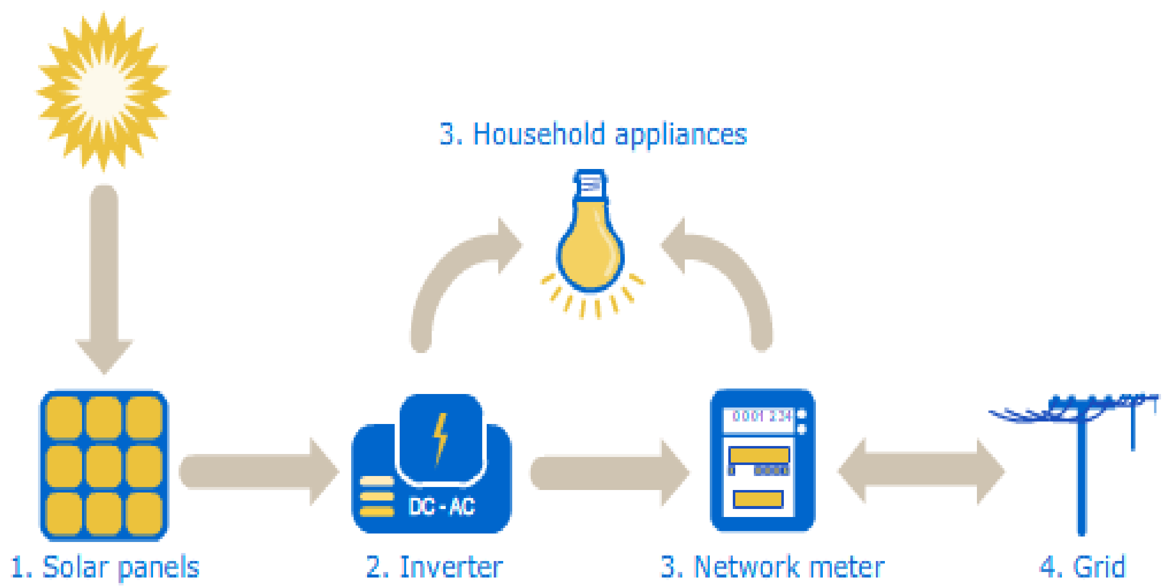


Figure 2. 4: Residential grid-tied solar PV system diagram

(source: googleimages.com)

Ancient records tell us that they custom hatched, returning two chicks for every three eggs brought in. their profit was all the hatch above 70%. The Egyptians did not, however, have a monopoly on egg hatching. Their Chinese counterparts had developed two very successful methods by at least 1,000 B.C. The first, and simplest, used the heat of rotting manure. The eggs were placed in a mixture of chopped straw and rice hulls on top of the manure; it appears to have been moderately successful. The second method, more widely used and still functional today, was just as ingenious as the Egyptian hatchery (seen in Figure 2.5 below). The basic structure was again a cylindrical building, but the fire was on the floor, with the eggs contained in an inverted cone above it, partially filled with ashes. Placed on the ashes were egg baskets made of woven straw. The eggs were contained in muslin bags, the whole being covered in an insulating layer of rice hulls. A straw thatch roof, shaped like the traditional coolie's hat, completed the insulation, and kept out the rain. Every seven days a fresh bag of eggs was added to each basket, and the bags were continually moved about to turn the eggs. After the first three weeks of the hatching season, the fire was allowed to go out; the self-generative heat of the eggs kept the process going. They had also developed the art of candling, for clear eggs were removed on the third day and sold for normal consumption.(Pleysier, 2009)

Aristotle, the Greek philosopher, writing about poultry at around 400BC, describes a similar method to Egyptian incubators, but the necessary heat to the eggs was provided by burying them in piles of decomposing manure. Several records exist of high-born Roman ladies foretelling the sex of their offspring by hatching an egg tucked under their breasts.(Pleysier, 2009)

Figure 2. 5: Ancient egg hatchery of Egypt

(source: googleimages.com)

2.2.1.1 The development of modern incubators

Egyptian professionals were requited to Europe in the mid- 1600s to develop and operate an Egyptian style hatchery, but the project was abandoned due to their failure. This failure was most likely due to the harsh weather conditions in Europe throughout the winter, as opposed to the mild and relatively stable temperatures in Egypt, which aided the success of their strategy. Following the failure of the Egyptian incubators in Europe, the goal shifted to the development of more sophisticated mechanical equipment. In 1750, a French scientist, de Beaumur, published "The art of hatching and bringing up domestic fowls of all kinds, at any time of the year, either by means of hotbeds or that of common fire". This author employed fermentation as well as a simple thermometer to heat the incubator. Over the following 100 years, more experimental incubators were produced, some using hot water, some heated by charcoal and others by steam. However, very few of these machines were successful as they were unable to regulate the range of temperature within the narrow range which was required. (Paniago M., 2005)

In the second half of nineteenth century, the advent of thermostats to regulate temperature accurately allowed the development of more efficient incubators. From this point on, several models of small machines were developed and sold mainly to small poultry producers. Incubators were developed in the United States throughout the first decades of the twentieth century. Electric "forced-draught" devices changed day-old chick production, not just in terms of hatchability but also in terms of chick quality. These huge "forced-draught" incubators enabled for bulk production of chicks with far less labor, lowering production costs. The modern-day commercial poultry business was on its way. From 1960 onwards, the poultry sector progressed at a breakneck pace over the world, with two notable changes. One factor was the growing size of chicken farms with large flocks being grown in a single shed, necessitating an increase in incubator capacity to support this development. The technology was the source of the second major breakthrough. Since then, hatcheries have evolved into a technological marvel, complete with electronic controls to regulate temperature within 0.1℃ of variation, automatic humidifiers to control moisture, automatic egg turning 24 times a day, alarm systems to alert for any problems in the machines, all necessary information displayed on a digital display outside of the machines, and the entire operation can be monitored and controlled through a central computerized system.(Paniago M., 2005)

2.2.2 Incubator types

There are three types of incubators:(Jacob, 2021)

a) Poultry incubator: They are used for keeping the fertilized eggs of birds warm until they're ready to hatch. Large commercial incubators can hold up to 75000 eggs at one time. An example is shown in Figure 2.6

b) Infant incubators: The infant incubator shown in Figure 2.7 can be used for a number of things asides from providing a warm environment for premature babies. These uses include:

i. to protect the preemie (premature baby) from infection, allergens, or excessive noise or light levels that can cause harm.

ii. to control the concentration of oxygen inside the incubator if the infants have oxygen deprivation, hypoglycemia (low blood glucose levels), metabolic acidosis, and rapid depletion of glycogen stores.

iii. providing special lights to help reduce jaundice in newborns.

Figure 2. 6: Poultry incubator

(source: googleimages.com)

Figure 2. 7: Infant incubator

(source: googleimages.com)

c) Bacteriological incubators: They are used in microbiology, biochemistry, dairy, and other food-processing industries, as well as water and sewage treatment plans. They are used for promoting the growth of bacteria or other microorganisms in various culture media. They are also used for identifying the type of microorganisms in the sample of a patient's blood, mucus or other secretions. An example is seen in Figure 2.8

2.2.3 Incubator classes

Incubators are divided into two classes namely:

a) Natural Incubators: The full incubation period for an egg, from laying to hatching, is 20 to 21 days. During this time, a hen sits on her egg(s) and maintains a temperature of around 37.78℃. This temperature is needed to ensure proper embryonic development. Eggs usually become fertile about four days after the rooster has been introduced to the hens. A maximum of 14 to 16 eggs may be brooded in one nest, but hatchability often declines with more than ten eggs, depending on the size of the hen. Feed and water are usually provided in close proximity to the hen so as to keep her in better condition and reduce embryo damage due to the cooling of the eggs if she has to leave the nest to scavenge for food. The hen maintains the proper humidity level in the eggs by sprinkling water on them with her beak. Another reason to give her easy access to water is because of this. In extremely arid areas, slightly wet soil can be put under the nesting material to help the hen maintain the proper humidity level (60-80%) (King'ori, 2011).

Figure 2. 8: Bacteriological incubator

(source: googleimages.com)

Factors to consider for successful natural incubation include the following:(Sonaiya & Swan, 2004)

i. Feed and water should be close to the hen.

ii. The broody hen should be examined to ensure that she has no external parasites.

iii. Any egg stored for incubation should be kept at a temperature between 12 and 14 °C, at a high humidity of between 75 to 85 percent, and stored for no longer than seven days.

iv. Extra fertile eggs introduced under the hen from elsewhere should be introduced at dusk.

v. The eggs are tested for fertility after one week by holding them up to a bright light (a candling box works best. If there is a dark shape inside the egg (the developing embryo), then it is fertile. A completely clear (translucent) egg is infertile.

vi. A hatchability of 80 percent (of eggs set) from natural incubation is normal, but a range of 75 to 80 percent is considered satisfactory.

b) **Artificial Incubators:** They are further classified as forced-air and still-air incubators. Forced-air incubators have fans that provide internal air circulation. The capacity of these units may be very large. The still-air incubators are usually small without fans for air circulation. Air exchange is attained by the rise and escape of warm, stale air and the entry of cooler fresh air near the base of the incubator. (Okeoma, 2016) There are many commercial artificial incubators of varying capacities. Most depend on electricity, but some use gas or kerosene for heating. All use a thermostatic switching device to keep the temperature constant within one Celsius degree. The correct humidity is usually maintained by having a pre-determined surface area of water appropriate for each incubator chamber. (Sonaiya & Swan, 2004)

2.2.4 Incubating conditions

Inaccurate temperature and/or humidity regulation is the most typical cause of poor performance. The temperature or humidity is too high or too low for an extended period of time, interfering with the embryo's natural growth and development. Inadequate ventilation, egg turning, and machine or egg cleanliness can all contribute to poor outcomes. (Smith, 2004) According to (Smith, 2004), when utilizing a forced-air incubator, keep the temperature at 100 degrees F for the whole incubation period for the best hatch. Minor temperature changes (less than ½ degree) above or below 100 degrees are acceptable, but temperatures should not vary by more than 1 degree. Long durations of extreme heat or cold will affect hatching success. Extreme heat is very dangerous. Early hatches are more likely in a forced-air incubator that is too warm. Late hatches are more likely to occur when the temperature is persistently colder. The overall number of chicks hatched will be lowered in both circumstances. He claimed that to compensate for temperature layering within a still-air incubator, keep the temperature at 102 degrees F. When the eggs are laying horizontally, raise the bulb of the thermometer to the same height as the top of the eggs to get the correct temperature reading. Elevate the thermometer bulb to a point about ¼ to ½ inches below the top of the egg if the eggs are stacked vertically. The temperature is taken at the point that the embryos are forming (at the top of the egg). Allow the bulb of the thermometer to not come into contact with the eggs or incubator. As a result, incorrect readings will occur.

To avoid unwanted egg moisture loss, the humidity is carefully managed. The relative humidity in the incubator should maintain at 58-60% or 84-86 degrees F (wet-bulb), between setting and three days before hatching. When hatching, the relative humidity is raised to at least 65%. To check correct humidity, candle the eggs at various stages of incubation. For a chicken egg, the usual size of the air cell after 7, 14, and 21 days of incubation is depicted. This can be seen in Figure 2.9. Necessary humidity adjustments can be made as a result of the candling inspection. The egg's weight

must decrease by 12% during incubation if good hatches are expected. (Smith, 2004)

Proper ventilation is also critical. During embryo development, oxygen enters the egg through the shell, and carbon dioxide exits in the same way. As the chicks hatch, they demand a greater amount of oxygen. As the embryos grow, the air vent openings are gradually opened to satisfy increased embryonic oxygen demand. It is important to maintain humidity at this stage. Proper air exchange requires unobstructed ventilation openings both above and below the eggs. (Smith, 2004)

2.2.5 Incubator terminologies

Some important terms include:

i. Air cell: The pocket of air inside the egg at the large end. The air cell gets larger as incubation progresses.
ii. Candling: The visual examination of egg by holding it in between the eye and source of light to test internal quality and freshness of egg.
iii. Hatchability: The percentage of fertile eggs that hatch when incubated. It is affected by the temperature & humidity control, condition of the egg, turning frequency and air supply & ventilation.
iv. Pip: The first little break a chick makes through the membrane and shell. The first step in hatching.
v. Infertile: An egg that is not fertilized and therefore will not hatch.

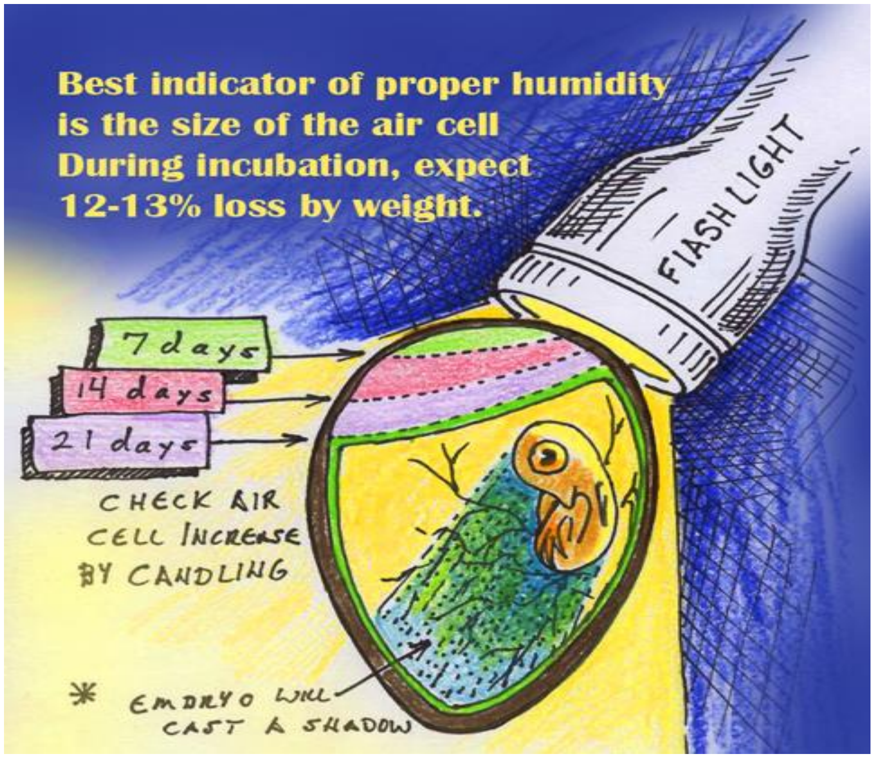


Figure 2. 9: Size of the Air Cell on the 7th, 14th and 21st day

(source: googleimages.com)

2.3 Solar Poultry Incubator System

The incubator is made of different parts to help maintain optimal conditions for the eggs. The main components of a solar poultry incubator system are the incubating chamber, the control system and the solar power system.

2.3.1 The incubating chamber

The incubating chamber is the part of the system that houses the eggs during the incubation period. It includes:

i. **The incubator walls:** these are insulating thus reduce heat losses to the environment. It also protects the eggs from external dangers.
ii. **The eggs tray:** they are in direct contact with the eggs. The eggs are placed on them throughout the incubation period.
iii. **The bulb:** these provide the heat the eggs require to effectively hatch.
iv. **The water bowl:** this helps to control humidity.

2.3.2 The control system

This is made up of:

i. **Temperature controller:** this is an instrument used to control temperatures, mainly without extensive operator involvement. A controller in a temperature control system will accept a temperature sensor such as a thermocouple or RTD as input and compare the actual temperature to the desired control temperature, or setpoint. It will then provide an output to a control element.

ii. **Solar charge controller:** This is a small box positioned between the incoming wiring from the solar panels and the batteries. The charge controller acts as a moderator between your panels, or PV array, and your energy-storage system to prevent the overcharging of the batteries. It also prevents discharge when the system is not in use, such as at night.

2.3.3 The solar power system

This includes the solar panels, battery and the charge controller. It is used to convert sunlight to electricity to provide power to run the incubator.

2.4 Review on Related Works

(Adegbulugbe et al., 2013) developed an electric egg incubator using a forced draft principle. The aim was to produce an inexpensive incubator and increase the production of day old chicks for small and medium scale poultry farmers. An electric gear motor (0.5 h p) was employed to power the tray turning mechanism. The humidity was 55%, temperature was 37℃ the first 18 days and then maintained at 37.5℃ till hatching. The result gave 84.06% hatchability. (Agidi et al., 2014) designed and constructed an electric powered egg incubator. The results from the test showed that out of the total 25 eggs, 5 eggs hatched after operating the machine. This gave 33% hatchability.

(Radhakrishnan et al., 2007) designed and implemented a fully automated egg incubator. A ATmega16 microcontroller was used. The system included a temperature sensor that could measure the temperature inside and outside the incubator and send the data to the microcontroller. The microcontroller used relays to operate an incandescent lamp and an air circulating fan to keep the egg temperature between 37 and 38.5°C. (Jimoh N. Olasunkanmi & Lawrence O. Kehinde, 2015)developed a low cost, battery powered, low energy, and remotely monitored (GSM based) bird egg hatching system. The incubator system was tested with quail eggs for 17 days. It was able to keep the temperature within the desired range of 37°C and 38°C. During incubation, humidity was kept between 32% and 35%, and during hatching, it was kept between 60% and 75%. The incubator had a hatchability rate of 94%.

(Okpagu & Nwosu, 2016) developed a smart egg incubator for various types of eggs. The project attempted to model, construct, and create an egg incubator system capable of incubating various types of eggs at temperatures ranging from 35 to 40°C. The technology used temperature and humidity sensors to monitor the status of the incubator and automatically adjust to the appropriate temperature for the specific egg. Four relays were utilized to control the incandescent lighting, fan motor, and DC motor. The weight of the egg in the incubator was monitored using a weight sensor. The temperature of the system is controlled by the PID controller implemented in the microcontroller. The simulation was performed by altering the temperature parameters of the PID controller in order to get a set of parameters that, when implemented in a microcontroller, maintain temperature stability at the incubator. (Kyeremeh & Peprah, 2017) developed an Arduino microcontroller-based egg incubator. Through relays, the Arduino microcontroller controlled the heaters, air circulation fans, and the mechanism for turning the trays. It could hold 14000 quail eggs (approximately 4500 chicken eggs).

CHAPTER THREE

METHODOLOGY

This chapter focuses on the procedure explored in this project. It includes the material selection and the assembling of the various components of the incubator. This chapter provides an introduction to the project design and implementation.

3.1 Materials

The material selection is a critical in engineering considering the materials' best cost, machinability, and serviceability, as well as other mechanical and chemical properties. The materials utilized in the development of the solar incubator system are shown in Table 3.1.

3.2 Methods

This relates to a detailed explanation of all of the methods and phases involved in the production of the solar poultry incubator, from procurement to finishing.

3.2.1 Description and operation of the incubator

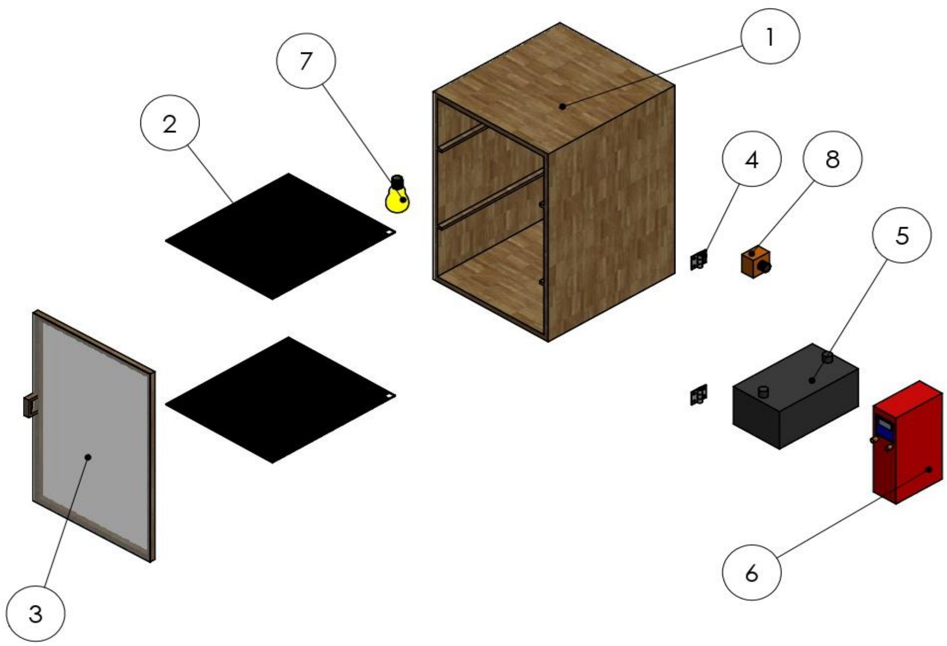
The incubator is powered by electricity generated from the sun. The solar panel takes the sunlight, converts it to power to be stored in the battery and also supplies it directly to the incubator. The incubator operates on the principle of thermo-electricity which according to (The Editors of Encyclopedia Britannica, 2009) is the direct conversion of heat into electricity or electricity into heat through two related mechanisms, the Seebeck effect and the Peltier effect. The eggs are kept on the wire mesh egg tray (labelled as part 2 in Figure 3.1**)** The switch is located at the side of the incubator which controls the power supply to it.

Table 3.1: Materials

S/N	MATERIAL	LENGTH/SIZE	REASON FOR SELECTION
1	MDF board	3fts	Cheaper, surface is smooth and gives a good finish, durable.
2	Quarter plywood	3fts	Comparatively lighter in weight.
3	Dry wall screws	6×1-⅛"	Have deeper threads which prevent them dislodging easily. Require low power screwdriver to drill them.
4	Tire tube	mtc	Its rubbery material creates an impervious seal to prevent heat from escaping the incubator.
5	Tack nails	½"	High quality and low price.
6	Polystyrene (Styrofoam)	6ft	Easy to handle. Gives high insulation
7	Wire mesh net	3ft	To create a base for the egg tray
8	Heat lamp	sm	Provides safe heat
9	Transparent glass	2ft by 1.5ft	Allows for checking the eggs without opening the door.
10	Battery	100 ah	To store excess electricity generated by the solar panels
11	Solar charge controller	120 ah	To keep the battery from overcharging. To regulate the voltage and current from the solar panels to the battery.
12	Temperature controller	-	To regulate the temperature of the incubator environment
13	Solar panel	150 w	Collects sunlight to power the incubator
14	Chicken eggs		Has high demand as a source of protein in Nigeria

The switch is to be kept on throughout the incubation period. After the switch is turned on, the solar panels collect sunlight, convert to electricity and this in turn powers the heat lamp (shown in Figure 3.1, labelled as part 7) in the incubator. The charge controller (labelled as part 6 in Figure 3.1) regulates the voltage and current coming from the solar panels and keeps the battery (labelled as part 5 in Figure 3.1) from overcharging. The heat lamp provides the temperature the eggs need during the incubation process.This temperature is regulated and displayed by the temperature controller (labelled as part 8 in Figure 3.1). Its set for a range of 35-37.5℃ which is an appropriate temperature for chicken egg incubation. When the temperature of the incubator gets higher than the set temperature (37.5℃), the temperature controller alerts the system and power to the heat lamp is cut off. When the temperature drops lower than 35℃, the temperature controller alerts the system and power to the heat lamp is turned back on. The incubator has a constant supply of electricity because it's powered by solar energy so it always on even though the heat lamp is turned off, the charge controller, battery and temperature controller are still receiving power. The design of the incubator using solid works is shown in the exploded view with the part list in Figure 3.1, the 2D and 3D view in Figure 3.2 and the detailed dimension of the wooden frame and the door labelled part 1 and 3 in Figure 3.3.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Frame	Wooden frame	1
2	Mesh	Stainless mesh	2
3	Door	Wooden door and acrylic plastic	1
4	Hinges	Metalic hinges	2
5	Battery	100AH battery	1
6	Controller	Charger controller	1
7	Bulb	100w bulb	1
8	Control	Temperature control	1



AFE BABALOLA UNIVERSITY, ADO EKITI (ABUAD)			
DRAWING TITLE	SOLAR INCUBATOR SYSTEM		
DRAWN BY	OYUGBO ESEOSE VALENE		
MATRIC NO	17/ENG06/072		
DESIGNED BY	ENGR. T. M AZEEZ		
SUPERVISOR	ENGR. T. M. AZEEZ		
SCALE	1: 18	DATE	DECEMBER, 2021
ALL DIMENSIONS IN MM			

Figure 3. 1: Exploded view of the incubator with list of parts.

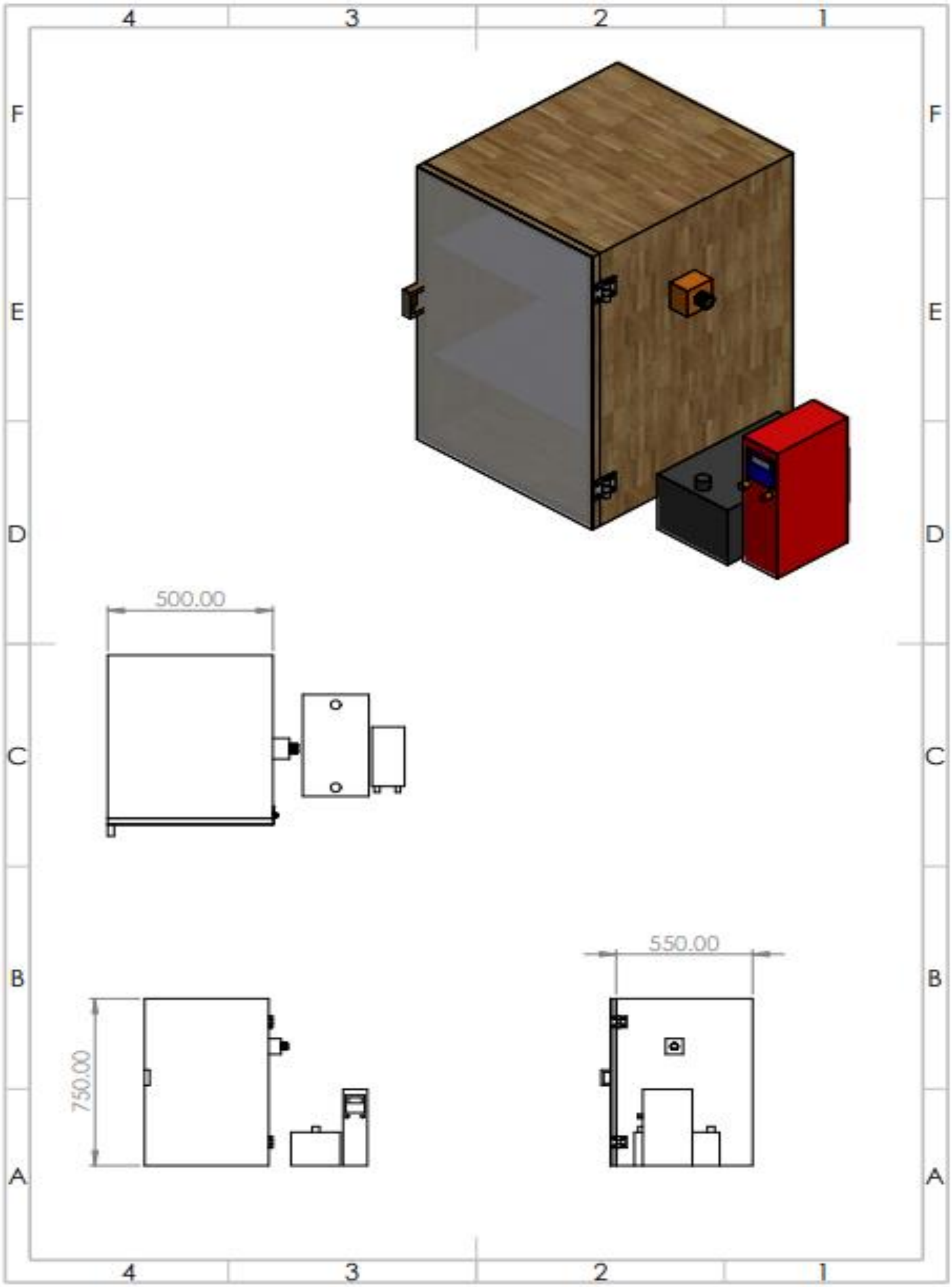


Figure 3. 2: 3D & 2D view of solar incubator with dimensions

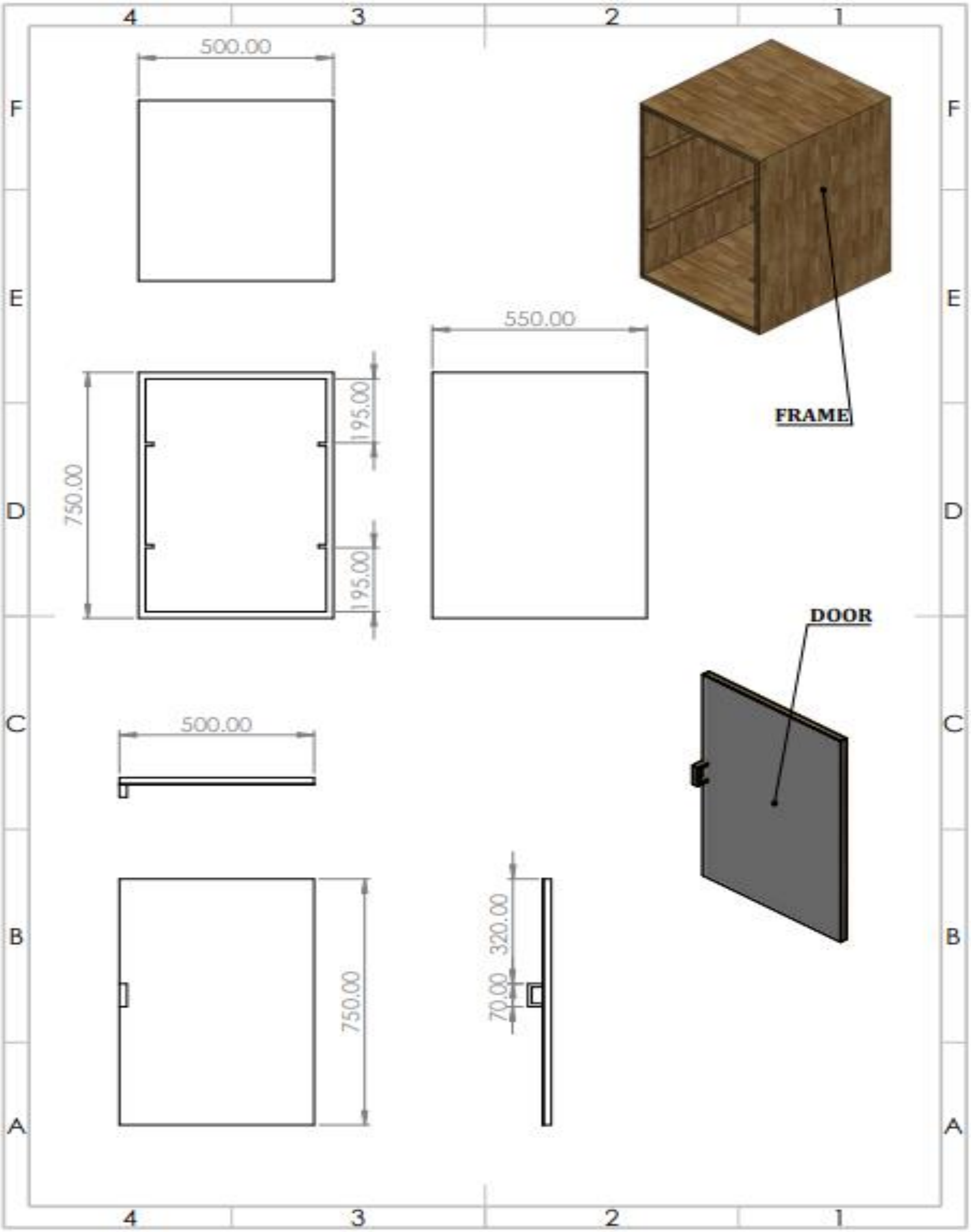


Figure 3. 3: Detailed dimensions of parts 1 & 3 in 2D & 3D views

3.2.2 Sourcing of materials

All the materials used were gotten from the local market.

3.2.3 Fabrication

The fabrication process was divided into two parts; the mechanical coupling and the electrical coupling. The following steps were taken to achieve the mechanical coupling:

i. The dimensions were marked out on the woods.
ii. The woods were cut into their various sizes according to their dimension.
iii. The pieces of the MDF board were screwed together using a hand drill.
iv. The aluminum angles were screwed for reinforcement (Figure 3.4)
v. The quarter plywood was attached to cover the back of the incubator and hammered down with tack nails (Figure 3.5)
vi. The egg tray frame was constructed using wood of appropriate dimension and the hand drill.
vii. The wire mesh net was attached to the tray frame with tack nails to form the egg tray. (Figure 3.6)

Figure 3. 4: Screwing of the aluminum angles

Figure 3. 5: Incubator casing with the plywood back cover

Figure 3. 6: Construction of the egg tray

viii. Glue was applied to the lapping of the woods

ix. Glue was applied to the polystyrene and attached to the inner walls of the incubator

x. The door was attached and insulated with the tire tube

xi. The glass was installed in the door in the space provided for it

xii. The solar panel was installed on the roof of the incubator.

The following steps were taken to achieve the electrical coupling:

i. Holes were drilled on the side of the incubator for the wires to pass through.

ii. The temperature controller was installed passing the wires through hole to place the sensor under the egg tray compartment.

iii. The solar panel was connected to the charge controller and then to the battery.

iv. The 2 heat lamps were connected in parallel and intercepted the positive power line from the battery.

v. A switch was added and all connections were checked before tightening.

3.2.4 Design Calculations

The calculations are shown in roman numeral i-v below.

i. Heating load of the poultry incubator

Some assumptions were made to find the heating load of the solar powered egg incubator based on Fourier's law. They are:

1. Steady state condition exists
2. One dimensional heat flow
3. Incubator material have constant thermal conductivity

4. The incubator is a closed system at constant temperature

The heat balance equation is given by:

$$Qload = Qs + Qegg - Qcond. - Qconv. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Where;

$Qload$ = heat load of the incubator, W

Qs = heat supply by PV panels through the bulb, W

$Qegg$ = heat supply due to activities of eggs, W

$Qcond$ = heat loss by conduction through the incubator wall to the ambient, W

$Qconv$ = heat loss through air convention, W

ii. Heat loss by conduction

Using Fourier heat conduction equation:

$$Qcond = \frac{-KA\Delta T}{\Delta x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where;

ΔT = change in temperature, ^{o}C

A = total area of incubation walls, m^2

K = thermal conductivity of incubator wall, $W/m^{2}\,^{0}C$

Δx = thickness of incubator wall, m

The heat loss through conduction during incubation will be as follow;

$\Delta T = T_{in} - T_s$

T_{in} = temperature of the incubator

T_s = ambient temperature

$$\Delta T = (37.5 - 27) = 10.5°C$$

From equation (2) Heat loss through the glass window, $Qg = -\frac{KgAg(Tin-Ts)}{\Delta x}$

Where K_g = 0.8 W/m^2 ^{0}C, L_g = 0.36m B_g = 0.2m, Δx=0.01m

$$Qg = \frac{0.8 \times 0.072 \times 10.5}{0.01} = -60.48\,W$$

Heat loss through the top section, $Qt = -\frac{KtAt(Tin-Ts)}{\Delta x}$

Heat loss through the bottom section, Qb

Where K_t = 0.05 W/m^2 ^{0}C, L_t = 0.357m, B_t = 0.355m, Δx=0.017m

$$Qt = Qb = \frac{0.05 \times 0.1267 \times 10.5}{0.017} = -3.913\,W$$

Heat loss through the back section, $Qbs = -\frac{KbAb(Tin-Ts)}{\Delta x}$

Where K_{bs} = 0.13 W/m^2 ^{0}C, L_b = 0.629m, B_b = 0.357m, Δx=0.005m

$$Qbs = \frac{0.13 \times 0.2246 \times 10.5}{0.005} = -61.32W$$

Heat loss through the door section (without glass), $Qd = -\frac{KdAd(Tin-Ts)}{\Delta x}$

Where K_d = 0.05 W/m^2 ^{0}C, A_d = 0.1607 m^2, Δx=0.017m

$$Qd = \frac{0.05 \times 0.1607 \times 10.5}{0.017} = -4.963\,W$$

Total heat loss from conduction, $Qcond$;

$$Qg + Qt + Qb + Qbs + Qd = -60.48 + -3.913 + -3.913 + -61.32 + -4.963$$

$$Qcond = -134.589\,W$$

iii. Heat supply by the bulbs

The bulb usage is 35watts that supplies heat to the egg. The total power generated from the two 35 watt's bulb will be 2 x 35 = 70 Watts.

Since it's a still air incubation there's no heat of convection.

$$Qconv = 0$$

$$\therefore Qload = Qs - Qcond$$

$$Qload = 70 - (-134.589) = 204.589W$$

iv. Battery storage size

A battery of 12v 100Ah was used in the design and an operating voltage of 12v was chosen for the design.

For the estimation of the battery storage size, we consider the total load;

2 bulb of 35 watt each = 70 watt

Time require for power supply is 24hrs

8hrs for solar panel (the sun available for roughly 8 hours) and 16hrs for battery

Battery power-hour rating = 12 x 100 = 1200watt-hour

$$Hour = \frac{Power - Hour}{Total\ load} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$Hour = \frac{Ampere - hour}{Load\ current} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (5)$$

$$ID = \frac{QL}{Vop} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where,

I_D = Design current (Load current)

V_{op} = Operating Voltage

Q_L = Total load

Therefore

$$ID = \frac{70}{12} = 5.833A$$

$$Hour = \frac{Ampere - hour}{Load\ current} = \frac{100}{5.833} = 17.1\ hours$$

This means that 12v100ah battery will carry a load of 70W for 17.1hours (17hrs, 6mins). Since the battery can store energy for 17 hours when no power is supplied by the solar panels (at night), the battery capacity is sufficient.

v. PV sizing

In determining the size of photovoltaic panels to be used, consideration was based on heat load of the incubator, hours of usage and the battery size.

This can actually be estimated as;

$$PV = \frac{Battery\ size \times voltage}{Hour\ of\ usage} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (7)$$

Where;

Hour of usage = 8hrs

Voltage rating of the battery = 12v

Battery size = 100AHr.

$$PV = \frac{100 \times 12}{8} = 150W$$

This means a solar panel of 150W is sufficient to charge the 100ah battery for 8 hours.

3.2.5 Cost Analysis

Costing is essential in the design and construction of engineering equipment because it enables the evaluation of materials, labor, overhead costs, and other costs. The breakdown and total cost of materials acquired are detailed in the material costs. The labor cost indicates the money spent on materials, transportation, and other incidentals throughout the fabrication process. An estimate of the cost of making a typical sample of the designed incubator is given below:

Table 3.2: Bill of Engineering Materials and Evaluation (BEME)

S/N	ITEM	QUANTITY	UNIT COST(N)	AMOUNT(N)
1	MDF board	1	10,000	10,000
2	Quarter Plywood	1	3000	3000
3	Drywall screws	1	5500	5500
4	Wood	4	800	3200
5	Top bond glue	1	3500	3500
6	Tack nails	1	500	500
7	Polystyrene (Styrofoam)	1	6000	6000
8	Wire mesh net	1	2000	2000
9	Aluminum angle	1	3500	3500
10	Tyerod	1	300	300
11	Transparent glass	1	3000	3000
12	Hinges	4	250	1000
13	Tire tube	1	4000	4000
14	12V heat lamp	2	3000	6000

15	Battery terminal clip	2	1500	3000
16	Temperature controller	1	10,000	10,000
17	Angle holder	1	500	500
18	Door locker hinges	1	250	250
19	12V Battery	1	15,000	15,000
20	Charge controller	1	12,000	12,000
21	Solar panel	1	26,000	26,000
	TOTAL			125300

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Result

The incubator was successful constructed. The front, side and end view of the finished work can be seen in Figures 4.1 and 4.2 below. A test was carried out to show the working of the construction, and the following data in Table 4.1 and Table 4.2 was gotten for a period of two (2) days. It took 21 days for the incubation period to be complete and the tests showed that the range of temperature and humidity were the same throughout, so the readings for two days were recorded to show the working of the incubator. The readings for the temperature were taken from the display on the temperature controller as it varied inside the incubator. The humidity level readings were taken using a hygrometer. From the observations and test, the temperature ranged between 35℃ and 38℃. The humidity range was between 45% and 60%.

4.2 Performance Evaluation

The performance of the incubator was evaluated based on the hatchability of the eggs. Since hatchability depends greatly on the temperature and humidity, the values are presented in Tables 4.1 and 4.2 as well as in Figures 4.3 and 4.4 below

(a) (b)

Figure 4. 1: Fabricated incubator (a) front and (b) top view

Figure 4. 2: Side (right) view of the fabricated incubator

Table 4. 1: Temperature and Humidity readings for day one

	TIME	TEMPERATURE (℃)	HUMIDITY (%)
1	9:00	35.3	45
2	10:00	35	45
3	11:00	36.7	50
4	12:00	37.5	55
5	13:00	37	55
6	14:00	37.5	50
7	15:00	36.5	50
8	16:00	37	50

Table 4. 2: Temperature and humidity readings for day two

SN	TIME	TEMPERATURE (℃)	HUMIDITY (%)
1	9:00	36.2	50
2	10:00	37	55
3	11:00	36.7	50
4	12:00	37.5	55
5	13:00	37	50
6	14:00	37.5	47
7	15:00	37.5	45
8	16:00	37	50

The average values for temperature and humidity for day one;

Temperature:

$$35.3 + 35 + 36.7 + 37.5 + 37 + 37.5 + 36.5 + 37 = 292.5$$

$$292.5/8 = 36.56℃$$

For humidity

$$45 + 45 + 50 + 55 + 55 + 50 + 50 + 50 = 400$$

$$400/8 = 50\%$$

The average values for temperature and humidity for day two;

Temperature:

$$36.2 + 37 + 36.7 + 37.5 + 37 + 37.5 + 37.5 + 37 = 296.4$$

$$296.4/8 = 37.05℃$$

For humidity

$$50 + 55 + 50 + 55 + 50 + 47 + 45 + 50 = 402$$

$$402/8 = 50.25\%$$

4.3 Hatchability

At the end of the incubation process, nine (9) eggs hatched successfully out of ten (10).

$$\therefore Hatchability = 9/10 \times 100 = 90\%$$

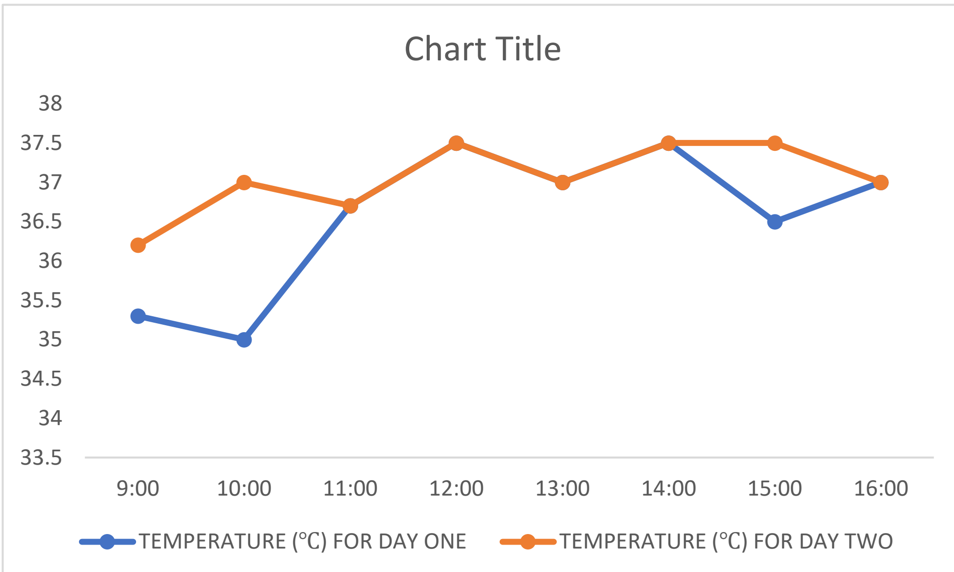


Figure 4. 3: Time-temperature graph for day one and two

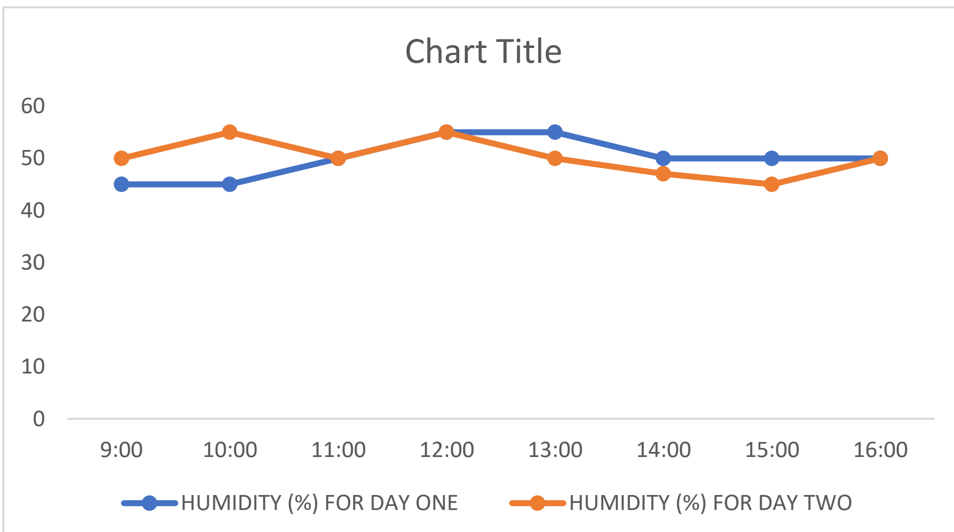


Figure 4. 4: Time-humidity graph for day one and two

CHAPTER FIVE

CONCLUSION, RECOMMENDATION AND CONTRIBUTION TO KNOWLEDGE

5.1 Conclusion

The design and fabrication of the solar poultry incubator was achieved. It was evaluated and found to be capable of incubating 30 chicken eggs. A total of 28 eggs hatch and the hatchability is 93.3%. The temperature controller can be adjusted to the environmental condition for hatching of different other poultry eggs such as duck, turkey, goose and quines fowl among others. The fabrication materials were picked based on cost efficiency, durability and strength. They were locally sourced and could easily be replaced when faulty.

5.2 Recommendation

The following recommendations were made:

i. A hygrometer with display should be introduced to show the amount of humidity in the incubator.

ii. The incubator door should be smaller to reduce the amount of heat loss when opened.

iii. The eggs should not be turned from the 18^{th} day.

5.3 Contribution to knowledge

This research focuses on using solar energy to create a sustainable supply of power for the poultry incubator. As a result, the rural areas can benefit in the agricultural industry.

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