DESIGN AND DEVELOPMENT OF AN AUTOMATIC TURNING MECHANISM INCUBATOR

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JANUARY, 2011

DECLARATION

ıereby declare that this projec work is a record of a research work that was undertaken and itten by me. It has not been presented before for any degree or diploma or certificate at any iversity or institution. Information derived from personal communications, published and published work were duly referenced in the text.

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CERTIFICATION

; is to certify that the project entitled "Design and Development of an Automatic Turning :hanism Incubator" by Owa, Gbenga James meets the regulations governing the award of the ree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This project work is dedicated to Almighty God, who was, who is, and who is to come my Lord and saviour Jesus Christ. Who saw me throughout my years of study.

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ABSTRACT

A twenty-five (25) egg capacity automatic egg turning incubator with forced air convention was designed and developed. This was done in order to provide proper circulation of heated air and also prevent the eggs embryos from sticking to the cell membranes of the eggs. It basically consists of the incubating cabinet, fan, heating element, an egg tray, a shaft with bearings, electric motor with gear, sensor, transformers, relays, thermostat, and other electrical components. All materials used for constructions were locally sourced. An electric heating element of 0.5kW was installed in the heating unit to provide the required heat energy to incubate the eggs. The thermostat regulates the temperature of the incubator. The turning mechanism is composed of an electric motor with gear, shaft and bearings at both ends which turns an egg tray at angle of 45^0 to the horizontal at every six hours that is four times in each day for a period of twenty-one (21) days. Test results of the incubator shows that the percentage fertility of the eggs is 60% and the percentage hatchability of 33%. These can be improved by providing a stable source of power supply.

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H Height (m)

ρ_a Density of air (kg/m^3)

M_a Mass of air (kg)

M_p Mass of plywood (kg)

ρ_p Density of plywood (kg/m^3)

Q Amount of heat energy (J)

C_{pp} Specific heat capacity of plywood (J/kgk)

C_{pa} Specific heat capacity of air (J/kgk)

T_1 Initial temperature (^0C)

T_2 Final temperature (^0C)

P	Power (W)
t	Time (s)
Q_v	Heat lost per time (J/s)
V_c	Ventilation rate (m^3/s)
A	Area (m^2)
S	Velocity (m/s)
Π	Pie
Θ	Angle (^{0})
r	Radius (m)
q	Rate of heat (W)
K	Thermal conductivity (W mk)
A_g	Area of glass (m^2)
L_g	Length of glass (m)
B_g	Breadth of glass (m)
q_g	Rate of heat lost by glass (W)
K_g	Thermal conductivity of glass (W/mk)
n	The number of eggs

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

An egg incubator is very essential in the production of poultry and its products for commercial purposes. Incubation is the management of fertilized eggs to ensure the satisfactory development of the embryos into chicks. Incubation may be achieved by natural and artificial methods.

An incubator is a machine which provides suitable conditions such as temperature, humidity, ventilation regulation as well as means of turning of eggs for embryos development into chicks. Four factors are of major importance in incubating eggs artificially: temperature, humidity, air supply, and turning of eggs. Natural egg incubation involves keeping of eggs warm to allow proper development of the embryos into chicks which last for a specific period of about 21 days (Thear and Fraser, 198( ).

Artificial incubation is a man-made heated container for hatching eggs. It stimulates the broody bird by means of regulating the temperature, humidity, and ventilation. Artificial incubation nowadays is carried out with incubators heated with different forms of fuels such as paraffin, ethane, butane gas, electricity, and solar.

There are basically two types of artificial incubators; forced-air and still-air incubators. Forced air incubators have fans that provide internal air circulation whereas still-air incubators are usually small in size and capacity which have no fans for air circulation, and 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.

1.2 Statement of the Problem

Poultry farming is a branch of animal husbandry in animal production which involves rearing and management of birds for optimum production for man's use. The purposes for birds' production may be for meat, eggs, and other commercial purposes. Large scale production of poultry and its products face a lot of environmental factors such as temperature etc.

Natural incubation by the birds involves giving the required warmth conditions and turning of the eggs to hatch into chicks. Artificial incubation is a type of incubation that involves a machine known as incubator. It faces a lot of problems and environmental factors which affect hatchability of eggs. Some of these factors include: improper circulation of heat in the incubator cabinet, lack of the proper turning of eggs on the egg tray of an incubator and lack of maintaining the required relative humidity. As a result of these, an automatic turning mechanism incubator with forced air convention is designed and constructed.

1.3 Objectives of the Study.

1. To design and construct an automatic egg turning incubator.

2. To test the constructed egg incubator.

1.4 Justification of the Study

It has been observed that commercial production and management of poultry and poultry products by artificial incubation method has often times resulted to low hatchability of eggs into chicks due to uneven circulation of heated or warm air at the required psychometric conditions. As a result of the design and development of an automatic egg turning mechanism incubator using an electric system, will enhance and facilitate proper distribution of warm air and regular turning of eggs which is expected to have higher and even hatchability of eggs into chicks. It also eliminates the fatigue involved in manual turning of the eggs.

1.5 Scope of the Study

This research work is limited to the design, construction, testing, and determination of the efficiency of the egg incubator and also assesses the machine of its hatchability efficiency.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General Background

The chicken (*Gallus gall us domestic us*) is a domesticated fowl, a subspecies of the red jungle fowl. One of the most common and widespread birds, with a population of more than 24 billion in 2003, (Vleck, 2003). There are more chickens in the world than any other species of birds. Humans keep chickens primarily as a source of food, consuming both their meat and their eggs. Conventional wisdom has held that the chicken was domesticated in India, but recent evidence suggests that domestication of the chicken was already underway in Vietnam over 10,000 years ago. From India the domesticated fowl made its way to the kingdom of Lydia in western Asia Minor, and domestic fowl were imported to Greece by the fifth century BC. Fowl had been known in Egypt since the 18^{th} dynasty, with the bird that lays every day having come to Egypt from the land between Syria and Shinar, Babylonia, according to the annals of Tutmose III, (Turner, 2002). In the UK and Ireland adult male chickens are primarily known as cocks, whereas in America, Canada and Australia they are more commonly called roosters. Males under a year old are cockerels. Castrated roosters are called capons (though both surgical and chemical castration is now illegal in some parts of the world). Females over a year old are known as hens, and younger females are pullets.

2.1.1 Origin of Chicken

The domestic chicken is descended primarily from the red jungle fowl (*Gallus gall us*) and is scientifically classified as the same species. As such it can and does freely interbreed with populations of red jungle fowl. Recent genetic analysis has revealed that at least the gene for yellow skin was incorporated into domestic birds through hybridization with the grey jungle fowl (*Gallus sonneratii*), (Turner, c2002).

Bones of domestic chickens from about 6000-4000 BC have been found in Yangshao and Peiligan, China, from a time when the Holocene climate was not naturally suitable for the *Gallus* species.

Later traces are found about 3000-2000 BC in Harappa and Mohenjo-Daro, Pakistan, and - according to linguistic researchers- in Austronesia populations travelling across Southeast Asia and Oceania. A northern road spread chicken to the Tarim basin of central Asia, modern day Iran. The chicken reached Europe (Romania, Turkey, Greece, Ukraine) about 3000BC, and the Indus Valley about 2500 BC. Introduction into Western Europe came far later, about the 1st millennium BC. Phoenicians spread chickens along the Mediterranean coasts, to Iberia. Breeding increased under the Roman Empire, and was reduced in the middle Ages. Middle East traces of chicken go back to a little earlier than 2000 BC, in Syria; chicken went southward only in the 1st millennium BC. The chicken reached Egypt for purposes of cock fighting about 1400BC, and became widely bred only in Ptolemaic Egypt (about 300 BC). Little is known about the chicken's introduction into Africa. Three possible ways of introduction in about the early first millennium AD could have been through the Egyptian Nile Valley, the East Africa Roman-Greek or Indian trade, or from Carthage and the Berbers, across the Sahara. The earliest known remains are from

Mali, Nubia, East Coast, and South Africa and date back to the middle of the first millennium AD. Domestic chicken in the Americas before Western conquest is still an ongoing discussion, but blue-egged chicken, found only in the Americas and Asia, suggest an Asian origin for early American chickens.

A lack of data from Thailand, Russia, the Indian subcontinent, Southeast Asia and Sub-Saharan Africa makes it difficult to lay out a clear map of the spread of chickens in these areas; better description and genetic analysis of local breeds threatened by extinction may also help with research into this area.

2.2 Poultry Farming

Wilson (2002), discovered that more than 50 billion chickens are reared annually as a source of food, for both their meat and their eggs. Chickens farmed for meat are called broiler chickens, while those farmed for eggs are called egg-laying hens. In total, the UK alone consumes over 29 million eggs per day. Some hens can produce over 300 eggs a year. Chickens will naturally live for 6 or more years, but broiler chickens typically take less than six weeks to reach slaughter size. For laying hens, they are slaughtered after about 12 months, when the hens' productivity starts to decline. The vast majority of poultry are raised using intensive farming techniques. According to the World watch Institute, 74 percent of the world's poultry meat, and 68 percent of eggs are produced this way. One alternative to intensive poultry farming is free range farming. Friction between these two main methods has led to long term issues of ethical consumerism. Opponents of intensive farming argue that it harms the environment, creates human health risks and is inhumane. Advocates of intensive farming say that their highly efficient systems save land and food resources due to increased productivity, stating that the animals are looked after in state-of-the-art environmentally controlled facilities.

2.2.1 Fertile Eggs

A fertile egg is one capable of developing into a chick. Eggs for hatching should ideally come from hens which have laying rates well above the mean average figure for the flock and have been mated to cockerels which record the faster growth rates and healthiest records of their hatch.

To obtain a realistic hatchability of 95% both cock and pullets (hens) should be at least six months old. However, hatchability holds reasonably well up to seven days, but declines rapidly. Therefore, eggs should not be stored more than seven days before incubating. After three weeks of storage, hatchability drops to almost zero.

For lighter breeds, one active rooster is capable of fertilising up to 15 hens, but for the heavier meat-type breeds, the ratio should be one-twelve maximum. Maximum egg fertility requires a 72 hours period to elapse after putting male and female birds together. And while hens will continue to lay fertile eggs for 30 days after the cockerels have been removed, egg fertility will fall away.

2.3 Incubation

Incubation is the management of a fertilized egg to ensure the satisfactory development of the embryo inside it to chick. Incubation may be achieved by natural method or using special machines known as incubators. Egg incubation by nature, involves keeping of eggs warm to allow proper development of the embryos into chicks, which last for a period of 21days, (Thear and Fraser, 1986). Improvement in the design and construction of incubators have made artificial incubation so reliable that have completely replaced poultry hens on most farms for large scale production of poultry and its products.

Temperature, humidity, ventilation, and turning of eggs are important factors which influence hatching quality. The optimum temperature for hatching is 37.7^0C (100^0F). A hygrometer will give the relative humidity reading. Eggs need to be turned at least three times a day. The optimum relative humidity for incubation during the first 19 days is between 50-60%. Natural hatching egg should lose about 10.5% of their weight before at 19 days. The humidity in the Hatcher should gradually increase to a relative humidity of 75% at the peak of hatching.

2.3.1 Selection of Hatching Eggs

Hatching eggs should be gathered three to five times daily to prevent the eggs from broken by the hens and the hens from becoming broody. Hatching eggs are selected and sorted commercially as they are gathered on the breeder farm. Eggs laid on the floor are obviously dirty eggs as well as cracked and miss-happen eggs are eliminated for use as hatching eggs.

2.3.2 Egg Size

Uniformity of size is also important criteria in selecting of hatching eggs. Neither small sized egg nor very big sized should be selected. It is always desirable to select eggs before incubation in order to achieve maximum hatchability of viable and strong chicks. Generally, the larger the egg the longer the incubation periods, large eggs compare to other eggs produced in the same flock will take 12 hours longer to hatch than smaller ones. Hence, eggs with abnormal size do not hatch well.

Table2.1: Optimum Size of Hatching Eggs.

Species	Weight (g)
Chicken	55-58
Duck	75-80
Turkey	80-85
Quail	10-17

Source: Poultry eggs.

2.3.3 Composition of an Egg

The egg o f a bird is complex structure, comprising the shell, the albumen (egg white), the yolk, chalazas of supporting tissue and the fertile region, which is called germinal disc or blastoderm, and embryonesis begins before laying, but stop and only commences on incubation.

The Shell

The eggshell is about 350μm thick and is composed of radiating crystals of almost pure calcite (calcium carbonate). Checking through the shell are pores that allows gases to pass. The shell apart from pores is impervious to most substances and forms a physical barrier to substances that might adversely affect the microenvironment of the embryo. It also provides mechanical strength and rigid support to main the orientation of the heterogeneous internal components. The shell's strength is determined mainly by its curvature and thickness, though other factors are involved. It also provides calcium for the developing embryo. The outer covering of the egg, the proteinaceous cuticle, reduces water loss and bacterial contamination.

In chicken and many other species, the eggs are remarkably conical, pointed at one end and enlarged at the other and when disturbed and set in motion they do not roll in a straight line but in small circles. This simply insignificant fact is an important survival factor that has evolved in birds, the egg rolls only in a circular pattern. Thus ensuring that it does not roll far from where it was laid, perhaps of little consequences in straw nest, but vital in the wild for eggs laid on ledges.

The Shell Membranes

The shell membranes are two tough, slightly elastic, whitish layers surrounding the albumen and together are about 70μm thick. The membranes form about one or two percent of the egg mass, although generally their thickness is inversely proportional to the shell thickness.

Immediately after laying, as the egg cools, the membranes at the blunt end of the egg separate to form the air sack. Later during the embryonesis, the head comes to lie near this space. The size of the air sack is related to that of the egg. The air space increases in size as the chicks, thus maintaining an adequate supply of air for the chick while it is in the shell, use up the contents of the eggs. Indeed, it is into this air space that the chick first penetrates when it is point of hatching. The air sack also increases in size with the age of the egg irrespective of whether it is fertile or non- fertile, and therefore, is used as a measure of freshness and suitability for incubation. This increase is exacerbated in dry atmosphere, especially in tropical climates and is why old eggs float in water while newly laid ones sink.

The Yolk

Yolk has a definite structural organisation, though at first sight its appearance may suggest otherwise. The latebra, a small ball of white York, is visible at the centre of the central yolk mass. It is about 5mm in diameter and represents the remains of the highly proteinaceous material laid down in the early stages of maturation of the egg coyote. Its mass is about 2% of the total yolk.

Yolk is composed of just over 50% solids, 99% of which are proteins. It is also rich in lipoproteins, 30% of the yolk being formed of lipo and phosphoproteins. The yolk is formed in the ovary of laying birds and very little is used up during incubation. The material absorbed by the chicks' abdomen just before hatching, act as a food reserve for the first few days of the chick existence outside the egg. This is why day-old chicks can survive for several days without food after hatching, and why they can be successfully transported.

The blastoderm, the site of potential development of the embryo, and by fertilization of the female sex cell, and is located on the surface of the yolk. Pullets which are young hens coming into lay for the first time, produce eggs with smaller yolk- proportionally more albumen and water and therefore, proportionally less protein and lipid.

The Albumen

Albumen (egg white) forms about 65% of the mass of the egg in precocial species and rather more in others. It is almost exclusively composed of protein and water. Unlike the yolk, albumen has little intrinsic structure, though it is divided into compartment. It is made up of three layers which are easy to see when the egg is fresh, and thus is another way of assessing the suitability of a batch of eggs for incubation. Albumen has at least three important roles. First, it forms a thick aqueous environment for embryo development, which, because of its high protein content, does not dry out easily. Many of its proteins have anti-bacterial properties particularly lycozyme and ovotrasferrin, and therefore it forms the last defence against bacterial invasion. Finally in many, if not all birds, it provides some additional nutritional material for the embryo.

The Chalazas

The chalazas are coils of thick albumen which are formed during rotation in the oviduct. Two strands occur at the pointed end of the egg and one strand at the blunt end, with supporting function to hold the yolk in its pivotal rotating position in the centre of the egg. This is achieved by particular arrangements of the fibres (threads), which are coiled in opposite direction. Failure to ensure the yolk is not maintained in its central position, but settled to one side instead, will prevent the egg from developing to hatching. However, in the incubator, eggs must not be continually turned in the same direction. Considering the nature of threads comprising the chalazas, turning continually in one direction only will coil one chalaza increasable tighter, while slackening the other, preventing the yolk from rotating freely. At the same time eggs must be turned slowly and with care to avoid damage to the developing embryo.

The percentage of several parts of the egg of chicken, duck, turkey, and quail are shown in the table 2.2. It is evident from the table that percentage composition of egg varies among different species of birds. It is made up of yolk, albumen, and the shell.

Table 2.2: Composition of an egg

Species	Albumen (%)	Yolk (%)	Shell (%)
Chicken	55.8	31.9	12.3
Duck	52.5	35.4	12.1
Turkey	55.9	32.3	11.8
Quail	55.8	29.5	14.7

Source: Poultry eggs.

Nutritive Value of Egg

The eggs of the birds are composed of substances that form the basis of all animal life. Eggs are composed of proteins, fats, carbon hydrates, minerals and vitamins. All these chemicals constituents are distributed among the egg component structures in a very specific manner.

Proteins

The proteins are present in every part of the egg. The main source of protein is albumen, and yolk with only small amount is present in the shell membranes. The various parts of the average chicken egg contain the following.

Table 2.3: Amount of protein of the various parts of chicken egg

Egg parts	Amount of protein in weight (g)	Percentage content (%)
Yolk	3.10	44.30
Albumen	3.50	50.00
Shell	0.15	02.10
Shell membrane	0.25	03.60

Source: Poultry eggs.

Fats

In the egg, a variety of fats are present which are of high energy value. Fats of an egg are of four main types:

Glycerides (62.3%)

Phospholipids (32.8%)

Sterols (4.9%)

Cerebro sides (traces)

Carbon hydrates

The egg contains only 1% of carbon hydrates of the total egg content. The energy value of egg varies with the species of egg size.

Minerals

Minerals are essential to life and only small quantities are needed. Eggs offer an excellent source of many major, and trace minerals. Major minerals include: calcium, phosphorous, magnesium, potassium, chlorine, sodium, sulphur, and iron. Trace minerals are: zinc, copper, bromine, manganese, and iodine.

Vitamins

Eggs are especially valuable for many vitamins which are grouped as:

Fat soluble vitamins: these are vitamins A, D, E, and K.

Water soluble vitamins: the nine water soluble vitamins namely; thiamine, riboflavin, niacin, pantothenia, inositol, pyridoxine, biotin, folic acid, and chlorine.

2.3.4 Storage of Hatching Eggs

Hatching eggs are stored with the larger end upwards. Storage times of over one week cause a decline in hatchability. Generally, an egg room temperature of 16^0C (60^0F) is ideal for hatching eggs to be stored for one week. Eggs stored for 10-14 days at 10-13^0C (50-55^0F) hatch better than those stored at high temperatures. In any case hatching eggs should not be stored at temperature under 10^0C (50^0F) and the relative humidity should be kept at 80-85% during storage.

2.3.5 Transportation of Hatching Eggs

Excessive shaking or jerking of hatching egg should be avoided during collection and transportation which sometimes lead to a condition called tremulous air cells. This condition tends to lower hatchability.

2.3.6 Cleanliness of Eggs

Clean eggs hatch better than soiled eggs. The effect of shell, contamination of floor egg is significantly reflected in hatchability which may be reduced by twenty percent (20%) as compared to the nest egg. Soiled eggs are washed with warm water at most five degrees (5^0C) warmer than normal egg, compatible, odourless, germicidal, colourless, and non toxic detergent sanitizer.

2.3.7 Incubation Periods of Hatching Eggs

The incubation periods of a number of species of poultry vary as shown in the table 2.4 below.

Table 2.4: Incubation periods of Hatching Eggs

Species	Incubation periods (Days)
Cortunix	17-18
Pigeon	17-19
Bobwhite quail	22-24
Chicken	20-21
Guinea fowl	26-28
Pheasant	23-28
Turkey	26-28
Duck	28-33
Geese	28-34
Ostrich	40-42
Quail	21-23
Chukar	21-23

Source: poultry production in warm wet climates

2.4 Methods of Incubation

2.4.1 Natural Incubation

Naturally, local breeds of poultry are good incubators and mothers. They should be provided with a straw nest, a small box or clay pot with enough shape and size which has been disinfected before the beginning of incubation. Hatching can be successful, if specific poultry breeds with a good record of hatch are selected and provided with all that is required to enhance the hatching capabilities.

2.4.2 Artificial Incubation

Chicken egg incubation can successfully occur artificially as well. Nearly all fertilized chicken eggs will hatch after 21 days of good conditions 37.5 °C (99.5 °F) and around 55% relative humidity (increase to 70% in the last three days of incubation to help soften egg shell). Eggs must be turned regularly (usually three to eight times each week) during the first part of the incubation. If the eggs aren't turned, the embryo inside will stick to the shell and may hatch with physical defects. Some incubators turn the eggs automatically. This turning mimics the natural process. An incubating hen will stand up several times a day and shift the eggs around with her beak. However, if the egg is turned during the last week of incubation the chick may have difficulty settling in the correct hatching position.

Many commercial incubators are industrial-sized with shelves holding tens of thousands of eggs at a time, with rotation of the eggs a fully automated process. Home incubators are boxes holding from half a dozen to 75 eggs; they are usually electrically powered, but in the past some were heated with an oil or paraffin lamp.

An artificial incubator is a man-made heated container for hatching eggs. It simulates the broody birds by means of regulating the temperature, humidity, and ventilation. Artificial incubation nowadays is carried out with incubators heated with fuel as diverse as paraffin, ethane, butane gas, solar, and electricity.

The incubator and hatchers units should be located indoors to protect them from weather changes. It is essential that the room has a good ventilation system to provide enough circulation of fresh air. Keeping the units indoors makes it easier to maintain uniform temperature and humidity. There are basically two types of artificial incubators available which include; forced-air incubators and still-air incubators.

2.4.2.1 Forced-Air Artificial Incubators

Forced-air artificial incubators have fans that provide internal circulation. When using a forced air incubator the best hatch is obtained by keeping the temperature at 37.5^0C throughout the entire incubation periods. Minor fluctuation (less than-17.5^0C) above or below 37.5^0C are tolerated, but the temperature should not be allowed to vary more than a total of -17.2^0C, (Ferguson, 1994). Prolonged periods of high or low temperature will alter hatching success. High temperatures are especially more serious. A forced-air incubator that is too warm tends to produce early hatches. One that runs consistently cooler tends to produce later hatches. In both cases the total chicks hatched will be reduced.

The relative humidity in the incubator between setting and three days prior to hatching should remain at 55-60% and 28.9^0C-30^0C of wet bulb thermometer. When hatching, the relative humidity in the incubator increased to 65% or more. The capacity of the forced air incubators may be very large.

Ventilation is very important during the incubation process. While the embryo is developing, oxygen enters the egg through the shell and carbon dioxide escapes in the same manner. The eggs must be turned at least three to six times daily during the incubation period. The eggs should not be turned during the last three days before hatching.

2.4.2.2 Still-Air Artificial Incubators

The still-air artificial 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. A still-air artificial incubator is maintained at an optimum temperature of 37.5^0C. The relative humidity, egg turning and ventilation are maintained at the level as in the forced air incubators. They capacity of the still air incubators is usually small.

2.5 The Effects of Incubator Design

Most poultry species have an optimum incubation temperature of 37 to 39^0 C and small deviations from this optimum can have a major impact on hatching success and embryo development (Wilson, 1991). The vast majority of poultry hatching eggs are artificially incubated in incubators that must be designed to accurately control the temperature inside the machine to ensure that the temperature of the developing embryo does not deviate from this optimum. The temperature experienced by the developing embryo is dependent on three factors: the incubator temperature, the ability of heat to pass between the incubator and the embryo, and the metabolic heat production of the embryo itself. The purpose of this review is to use a simple thermal energetic model of the artificial incubation process to describe the interrelationships among the three factors that determine embryo temperature and discuss some of the implications for the design of incubators.

2.6 Temperatures in Incubators

The use of thermal conductance (K), has assumed a simple incubator that is an egg surrounded by warm air. However, in commercial incubators the situation is much more complicated, as each egg will be surrounded by many other eggs that may (in a single stage incubator) or may not (in a multi-stage incubator) be at the same developmental stage. Owen, (1991), the design of an incubator will have an effect on the transfer of heat between the egg and the incubator air. Incubators require an air conditioning unit to provide heat or cooling and humidification and a fan to circulate the conditioned air through the eggs before being returned to the conditioning unit. The volume of air that passes the eggs to transfer heat can be estimated using (Owen, 1991) (T off – Ton) = F. Heggs/Veggs where; (Toff – Ton) = the temperature rise in air flowing over the eggs (Celsius); F = factor, approximately 3.25 for incubator air at 37.5^0 C and 50% RH; Heggs = heat production of eggs in flow path (Watts); and Veggs =flow rate of air over eggs (cubic meters per hour). The rise in air temperature as it passes over the eggs is inversely proportional to air volume flow and therefore uniform control of egg temperature within the incubator depends on uniform air movement around the eggs. As air flow has a negligible effect on water loss from the eggs (Kaltofen, 1969; Spotila *et al.*, 1981) there appears to be no limit to increasing air flow to control temperature(Owen, 1991).The uniformity of air flow within an incubator will depend on how easy it is for the air to pass between the trays of eggs. This may be the path of greatest resistance to air movement and air may pass around the mass of eggs, through spaces next to machine walls or between

egg trolleys (Owen, 1991). Eggs must be turned through 45° every hour for normal embryo development to take place (Tullett and Deeming, 1987) and this is achieved in an incubator by tilting the egg trays at 45° from horizontal, the direction changing every hour. In most incubators, turning is achieved by pivoting the individual trays around a fulcrum at the centre of the tray. The effect of the turning is to reduce the space between the trays significantly from the spacing when the trays are horizontal. It is possible to estimate the effect of tray spacing on the air speed required over 18 days for chicken eggs to obtain an acceptable air temperature rise (for calculation purposes 0.5 C). Assumptions made in the calculations were: height of tray and eggs = 60 mm; tray dimensions = 0.9 m ′ 0.31 m, air assumed to pass across the width of the egg tray; heat output per egg =120 mW; and tray capacity = 132 eggs, of which 22 are exposed to open air when tray is turned and therefore excluded from the calculation. The relationship between tray spacing and required air speed to maintain egg temperature, two estimates are given, one assuming that both trays contain eggs at 18 days of incubation and one assuming that one tray contains eggs that are less than midway through incubation and therefore producing no heat. The spacing between the trays increases, there is an exponential decline in required air speed. Although actual spacing between trays in commercial incubators is highly variable, with many of the newer machine designs incorporating greater tray spacing, it is not uncommon to see trays that are sufficiently close together that large eggs on the tray are damaged by the tray above. There are little reported data on air speeds between trays in incubators, but values between 0.1 and 3.0 m/s have been observed in chicken incubators (Kaltofen,1969), less than 0.1 m/s in duck incubators (Kashkin,1961) and between 0.2 and 2.2 m/s in a turkey incubator(French, unpublished observations). The considerable variation in air speed between different locations within chicken and turkey incubators would suggest that temperature variation would be observed in these machines. Kaltofen, (1969), investigated the relationship between air speed over the eggs, temperature of the air surrounding the eggs and subsequent hatchability at different locations within a commercial incubator (700egg drum type, make not specified, operated single stage). As part of the study, incubator fan speeds were changed to give different air speeds over the eggs. Increasing the incubator fan speed resulted in faster airspeeds over the eggs and lower air temperatures; supporting the predictions of Sotherland *et al.* (1987) and Meijerhof and van Beek (1993) that air speed has a major influence on thermal conductivity. Air speed also varied between tray locations within the machine, although only at the lowest fan speed did this result in a temperature difference between the trays. The increase in temperature at the lowest fan speed was also sufficient to depress hatchability. Mauldin and Buhr (1995) measured temperatures on top of eggs in a multi-stage chicken incubator and observed that temperature was on average 1^0C warmer on the trays than at the temperature controller of the incubator. Temperature on the trays also changed with time depending on the age of the eggs within the incubator. Every 3 or 4 days, 18-day-old eggs were moved out of the incubator to be transferred into a hatcher and they were replaced with fresh eggs. The initial effect of the movement of eggs was to lower temperature just after the transfer. An increase of approximately 0.5^0C over the following 3 or 4 days was then observed, until temperature fell again at the next transfer. The study illustrates the effect that the presence and management of other eggs within the incubator can have on the temperature experienced by an individual egg. The observation of Kaltofen (1969) and Mauldin and Buhr (1995) that temperatures recorded among the eggs can differ markedly from the operating temperature of

the incubator has also been observed in a wide range of turkey incubators. Maximum temperatures were recorded normally on eggs at the end of incubation and were between 0.4 to 3.1^0 C the machine operation temperature. It is clear from these studies that many commercial incubators are not able to maintain a uniform temperature surrounding the incubating egg, principally due to uneven air flow within the machine. Improving incubator design by improving air flows within the machines is an important goal for incubator manufacturers. Techniques to directly measure K within incubators have been described by Meijerhof and van Beek (1994).

2.7 Optimum Incubation Temperature

Optimum incubation temperature is normally defined as that required to achieve maximum hatchability. However, Decuypere and Michels (1992) have argued that the quality of the hatchling should also be considered. The effect of temperature on length of incubation has been observed in several studies (Romanoff *et al.*, 1938; Michels *et al.*, 1974; French, 1994) and on the rate of embryo growth (Romanoff et al., 1938; Decuypere *et al.*, 1979). Incubation temperature has been found to affect the hatchling's thermo-regulatory ability, hormone levels, and post hatching growth rate (Wilson, 1991; Decuypere, 1994). Of potentially greater commercial importance, Ferguson (1994) has suggested that temperature may be able to alter the sex ratio by altering the phenotypic sex of a proportion of chick embryos. Wilson (1991), Several broad conclusions were drawn in these reviews: optimum continuous incubation temperature for poultry species is between $37^0$to 38^0C, although hatchability is possible between 35^0 to 40.5^0 C; embryos are more sensitive to high temperature than to low temperature; the effect of a suboptimal temperature will depend, on both the degree of deviation from optimum and the length of time applied; embryos appear to be more sensitive to suboptimal temperatures at the beginning of incubation that at the end of incubation. Recent studies suggest that optimum temperature may differ between poultry strains (Decuypere, 1994; Christensen *et al.*, 1994) or eggs of different sizes (French, 1994).

Interpretation of incubator temperature studies is difficult because they use incubator operation temperature as the temperature treatment applied to the egg. The data from both chicken and turkey incubators show that the temperature indicated on the incubator control may be significantly different from the temperature of the air surrounding the egg. The embryo inside the egg may be subjected to a different temperature to the air surrounding the egg depending on the thermal conductivity of the boundary layer of air around the egg. It is therefore possible that two studies using different incubation systems can apply the same incubator temperature treatments but for widely different temperature of the embryo results to be observed. The problem is illustrated by the elegant study of Ono et al. (1994). Chicken embryos between 12 and 20 days of incubation were subjected to a temperature of 48^0C and the time taken for the embryos' hearts to stop beating was measured. As the embryos got older their tolerance time decreased from 100 min at 12 days to 56 min at 20 days. From this finding, it could be concluded that older embryos are less tolerant to high temperature. However, internal egg temperatures were also measure in this study and it was found that, at all ages, embryos were dying when their internal egg temperature reached 46.5^0C. Tolerance time became shorter with embryo age because older embryos had higher internal temperatures at the start of the experiment. The important conclusion is that incubator temperature studies should measure the temperature experienced by the embryo if the observations are to have wider relevance than to the particular incubator used in the experiment. Most research work is undertaken in small incubators containing hundreds of eggs, in which the difference between incubator temperature and that experienced by the embryo may not be high. However, commercial incubators contain thousands of eggs and results from research may not be transferable to the practical situation unless a common standard of egg temperature is used. Measuring internal egg temperature is problematic because the structural integrity of the shell becomes damaged, risking bacterial contamination and damage to the developing embryo. An alternative is to measure shell surface temperature, as Kegg (egg thermal conductivity) is high in comparison to Kair (air thermal conductivity), resulting in only small differences between internal and shell surface temperature (Sotherland *et al.*, 1987).

2.8 Temperature and Embryo Metabolism

Studies on the effects of incubation temperature on embryo metabolism have been reviewed Deeming and Ferguson (1991). As temperature changes, so does the oxygen consumption of the embryo and, hence, its heat production, (embryo heat). Avian embryos for the majority of the incubation time are poikilothermic and therefore do not increase their metabolic heat output to maintain Temb (embryo temperature) when Tinc declines. Indeed, the opposite occurs and as Tinc decreases so does oxygen consumption. Tazawa *et al.* (1989) showed that at about 18 days of incubation the chick embryo could maintain oxygen consumption when temperature fell from 38^0 to 35^0C but as temperature decreased further, oxygen consumption then declined. After pipping, an increase in oxygen consumption in response to a decrease in Tinc has been observed in both chickens (Tazawa *et al.*, 1989) and Japanese quail (Nair *et al.*, 1983), but full thermoregulatory response in Galliformes only develops after hatching (Dietz and van Kampen, 1994). Although metabolic responses to short-term changes in incubation temperature have been studied, only limited data are available on responses to long term or continuous alterations to normal incubation temperature. Chicken eggs incubated continuously at 38 or 35.5^0C had different growth rates but oxygen consumption at comparable embryo mass was the same (Tazawa, 1973). Decuypere et al. (1979), incubated chicken eggs at 35.8, 36.8, 37.8, and 38.8^0C for the first 10 days and then at 37.6^0C for the rest of incubation. Although the temperature treatments altered rate of development, embryo heat production remained the same at equivalent developmental stages. Similar results were obtained with turkey embryos incubated at 37.5, 38.5, 39.5, and 40.5^0C for the first 6 days of incubation (Meir and Ar, 1992, Tel-Aviv University, Tel-Aviv, 69978 Israel, personal communication).

These workers also investigated the effect on oxygen consumption by varying temperature either during the second and last third of incubation or by using a lowering temperature regimen. Although temperature changed growth rate, oxygen consumption per unit of dry embryo mass remained the same. Contrary to the above observation, a study by Geers *et al.* (1983) showed that temperature could affect oxygen consumption per unit of dry embryo mass. These workers incubated chicken eggs for the first 10 days at either 35.8 or 37.8^{0}C and then subsequently at 37.8^{0}C. Although the cool incubator temperature reduced early embryo growth rate, once the cool embryos were returned to normal temperature at 11 days they grew faster than the controls, confirming observations in an earlier study (Geers *et al.*, 1982) that embryos can exhibit compensatory growth. The faster growth in the cool treated embryos resulted in a higher metabolic heat production per unit dry embryo mass than that of the control group. Hoyt (1987) developed a model that separated embryo metabolism between growth and maintenance and used this model to predict that the pre-internal pipping rate of oxygen consumption would be greater in embryos that grow faster to achieve a given final embryo weight. The model would suggest that altering embryo growth rate by manipulating incubation temperature would affect the rate of oxygen consumption per gram of embryo mass; however, studies to critically test this prediction have not been undertaken and the available evidence is ambiguous.

CHAPTPER THREE

3.0 DESIGN ANALYSIS

The incubator design calculations are based on the conditions required for it to work effectively. Some of the conditions are the temperature of the incubator which is to be maintained, the relative humidity and the turning mechanism to turn the eggs at least three times in a day. It is also based on the design considerations such as material selection, standards, required parameters, and dimensions.

3.1 The Capacity of the Incubator Egg Tray

In order to calculate the capacity of an egg tray of the incubator, it is assumed that the space for an egg is circular in shape on the tray, which is designed to accommodate twenty-five (25) eggs at a time.

Major diameter of an egg is 60mm

Minor diameter of an egg is 46mm

Diameter of egg at the broader end is 30mm

Diameter of egg at the narrow end is 24mm

$$v = \frac{\pi \times D^2 \times H \times n}{4} \tag{3.1}$$

Where;

V is the volume of the egg tray, m^3

D is the minor diameter of an egg, = 0.046m

H is the height of the egg tray or the major diameter of an egg, = 0.06m

n is the number of eggs on an egg tray, = 25

$$V = \frac{n \times \pi \times D^2 \times H}{4}$$

$$= \frac{25 \times \pi \times 0.046^2 \times 0.06}{4}$$

$$= \frac{25 \times \pi \times 0.002116 \times 0.06}{4}$$

$$= \frac{0.00997}{4}$$

$$= 0.0025m^3$$

The egg tray is rectangular in shape with an height of 60mm. The volume of the egg tray can be calculated as;

$$V = L \times B \times H \qquad (3.2)$$

Where,

V is the volume of an egg tray, $0.0025m^3$

L is the length of the egg tray, m

B is the breadth of the egg tray, m

H is the height of the egg tray, 0.06m

Let the length of the egg tray be two times the breadth of the egg tray of the incubator.

$L = 2 \times B$

$V = L \times B \times H$

Substituting for L in the equation

$V = 2 \times B \times B \times H$

$V = 2 \times B^2 \times H$

$$B^2 = \frac{V}{2 \times H}$$

$$B^2 = \frac{0.0025}{2 \times 0.06}$$

$$= \frac{0.0025}{0.12}$$

$B = \sqrt{0.0208}$

$= 0.144m$

$Therefore, L = 2 \times B$

$L = 2 \times 0.144$

$= 0.288m$

The dimension of the egg tray is $0.288 \times 0.144 \times 0.06m$

3.2 Volume of Air in the Incubator

The volume of air in the incubator is the same as the volume of the incubator, since the space will be occupied by air. The volume of the incubator cabinet is calculated by the given design dimensions. The thickness of plywood is taken into consideration which is 15mm.

$$V = L \times B \times H \qquad (3.3)$$

Where;

V is the volume of the incubator cabinet, m^3

L is the length of the incubator, = 0.41m

B is the breadth of the incubator, = 0.32m

H is the height of the incubator, = 0.60m

Therefore, $V = L \times B \times H$

$= 0.41 \times 0.32 \times 0.60$

$= 0.0787m^3$

The volume of air in the incubator is $0.0787m^3$

3.3 The Mass of Air (M_a)

Considering the relationship between volume of air in the incubator cabinet and the density of air, then the mass of air can be calculated.

$$\rho_a = \frac{M_a}{V} \qquad (3.4)$$

Where;

ρ_a is the density of air = 1.23kg/m^3 (Rajput,1998)

M_a is the mass of air, kg

V is the volume of air in the incubator cabinet = 0.0787m^3

$$\rho_a = \frac{M_a}{V}$$

$$M_a = \rho_a \times V$$

$$= 1.23 \times 0.0787$$

$$= 0.097\text{kg}$$

The required mass of air in the incubator is 0.097kg.

3.4 The Mass of Material for Construction

Material selected and used for construction of the incubator is ¾ inches plywood, and to determine the mass of plywood, there is need to relate the relationship between the volume (space) contained by the plywood and its density.

$$\rho_p = \frac{M_p}{V} \qquad (3.5)$$

Where:

M_p is the mass of plywood, kg

ρ_p is the density of plywood, = 540kg/m^3 (Dymola, 2010)

V is the volume contained by the plywood, = 0.0787m^3

$$\rho_p = \frac{M_p}{V}$$

$M_p = \rho_p \times V$

$= 540 \times 0.0787$

$= 42.50$kg

3.5 Determination of the Amount of Heat Energy in the Incubator

This computation is done in order to determine the quantity of electric heat energy suitable to incubate the required number of eggs. This is the sum of the expected heat loss through the walls of the incubator, the insulator and the actual heat required for incubation. It is based on the temperature ranges required by the incubator to be maintained which is from 37-39^{0}C. It is therefore calculated by the difference between the room temperature (25^{0}C) and optimum temperature of the incubator (39^{0}C).

$$Q = M_p \times C_{pp} + M_a \times C_{pa} \times (T_2 - T_1) \qquad (3.6)$$

Where;

Q is the heat required by the incubator, J

M_p is the mass of plywood, = 42.50kg

C_{pp} is the specific heat capacity of the plywood, = 1210J/kgk (Dymola, 2010)

M_p is the mass of air, = 0.097kg

C_{pa} is the specific heat capacity of the air, =1005J/kgk (Eastop, 1993)

T_1 is the room temperature = 25^0C

T_2 is the optimum temperature of the incubator, = 39^0C.

$$Q = M_p \times C_{pp} + M_a \times C_{pa} \times (T_2 - T_1)$$

$= (42.5\times 1210 + 0.097\times 1005) \times (39-25)$

$= (51425 + 97.49) \times 14$

$= 51522.49 \times 14$

$=721314.86J$

3.6 Power Requirement by the Incubator

The power supply by the heating element is determined for a period of 24 hours.

$$Q = P \times t \tag{3.7}$$

Where;

Q is the heat energy required by the incubator, = 721314.86J

P is the electric power to be supplied by the heating element, W

t is the time, = $24 \times 60 \times 60s$

$$Q = P \times t$$

$$P = \frac{Q}{t}$$

$$P = \frac{721314.86}{24 \times 60 \times 60}$$

$$= \frac{721314.86}{86400}$$

$= 8.35W$

$= 8.0W$

The power to be supplied by the heating element every day is 8W for temperature of the incubator to be maintained at 39^0C.

3.7 Designs for Ventilation Holes

The ventilation heat lost to the environment of the incubator is given by;

$$Q_v = C \times V_e \times (T_2 - T_1) \quad (3.8)$$

Where:

Q_V is heat lost per time, = 8.35J/s

C is the specific heat capacity of air, = 1300J/m^3C (Eastop, 1993)

V_e is the ventilation rate, m^3/s

T_1 is the room temperature, = 25^0C

T_2 is the optimum temperature of the incubator, = 39^0C (Wilson, 1991)

$$Q_v = C \times V_e \times (T_2 - T_1)$$

$$V_e = \frac{Q_v}{C \times (T_2 - T_1)}$$

$$= \frac{8.35}{1300 \times (39 - 25)}$$

$$= \frac{8.35}{1300 \times 14}$$

$$= \frac{8.35}{18200}$$

$= 0.00046 m^3/s$

The ventilation rate is $0.0046 m^3/s$.

$$V_e = A \times S \tag{3.9}$$

Where;

V_e is the ventilation rate (flow rate), $= 0.0046 m^3/s$

A is the area of hole, m^2

S is the air velocity, = 2m/s (Wilson, 1991)

$$V_e = A \times S$$

$$A = \frac{V_e}{S}$$

$$= \frac{0.00046}{2}$$

$= 0.00023m^2$

The area of the ventilation holes is $2.3cm^2$.

3.8 Area of the Egg Tray

The egg tray is rectangular in shape and the area is given by;

$$A = L \times B \qquad (3.10)$$

Where;

A is the area of the tray, m^2

L is the length of the egg tray, = 0.288m

B is the breadth of the egg tray, = 0.144m

$A = L \times B$

$= 0.288 \times 0.144$

$= 0.0415m^2$

3.9 Design of Egg Turning Mechanism

Regular turning of eggs at an angle of 45^0C is crucial for successful hatching of the eggs. Turning prevents embryo from sticking to the shell membranes.

$$L = \frac{\theta \times 2 \times \pi \times r}{360} \qquad (3.11)$$

Where;

L is the length of an arc, m

θ is the angle of turn, = 45^0

r is the radius of the egg tray, $= \frac{0.144}{2} = 0.07m$

$$L = \frac{45 \times 2 \times \pi \times 0.07}{360}$$

$$= \frac{90 \times \pi \times 0.07}{360}$$

$$= \frac{19.79}{360}$$

= 0.05m

3.10 Heat Losses on the Walls of the Incubator.

From the Fourier's law of heat transfer, heat transfer through the wall of an insulated container is given by;

$$q = \frac{(A \times K \times (T_2 - T_1))}{L} \quad (3.12)$$

Where;

Q is the rate of heat, W

K is thermal conductivity of the plywood, = 0.12W/mk (Dymola, 2010)

A is the external surface area of the wall, m^2

T_2 is the internal (normal) temperature of the incubator, $273 + 38^0C = 311^0k$

T_1 is the ambient temperature of the incubator, $273 + 25^0C = 298^0k$

L is the thickness of the insulation, = 0.015m

3.10.1 Heat Lost at both opposite Sides of the Incubator

The heat lost at the opposite sides of the incubator can be calculated because of their equal surface areas and also made up of the same material (plywood).

$$A = L \times B \tag{3.13}$$

Where:

A is the area of the surface, m^2

L is the length of the side, = 0.8m

B is the breadth of the side, = 0.35m

$A = L \times B$

$= 0.8 \times 0.35$

$= 0.28m^2$

Hence, $q = \frac{A \times K \times (T_2 - T_1)}{L}$

$= \frac{0.28 \times 0.12 \times (311 - 298)}{0.015}$

$= \frac{0.4368}{0.015}$

$= 29.12W$

But, it is two opposite surfaces.

$q_T = 29.12 \times 2$

$= 58.24W$

3.10.2 Heat Lost at the Top and Bottom Surfaces of the Incubator

The top and bottom surfaces of the incubator are equal areas and opposite. They are made up of the same material.

$$A = L \times B \qquad (3.14)$$

Where;

A is the area of the surface, m^2

L is the length of the surface, = 0.44m

B is the breadth of the surface, = 0.35m

$A = L \times B$

$= 0.44 \times 0.35$

$= 0.154m^2$

Since there are two equal surfaces, $A = 2 \times 0.154 = 0.308m^2$

Then, $q = \frac{A \times K \times (T_2 - T_1)}{L}$

$= \frac{0.308 \times 0.12 \times (311 - 298)}{0.015}$

$$= \frac{0.308 \times 0.12 \times 13}{0.015}$$

$$= \frac{0.48048}{0.015}$$

$= 32.03W$

3.10.3 Heat Lost at the Front and Back of the Incubator.

Area of the back of the incubator is calculated with its dimensions provided.

$$A = L \times B \qquad (3.15)$$

Where;

A is the area of the surfaces, m^2

L is the length of the surfaces, = 0.8m

B is the breadth of the surfaces,=0.44m

$A = L \times B$

$= 0.8 \times 0.44$

$=0.352m^2$

$$q = \frac{A \times K \times (T_2 - T_1)}{L}$$

$$= \frac{0.352 \times 0.12 \times (311 - 298)}{0.015}$$

$$= \frac{0.352 \times 0.12 \times 13}{0.015}$$

$$= \frac{0.54912}{0.015}$$

$$= 36.61\text{W}$$

The area of the front of the incubator made up of plywood is equal to the surface area of the front of the incubator minus the area covered by glass (A_g).

$$A_g = L_g \times B_g \qquad (3.16)$$

Where;

A_g is the area of the glass,m^2

L_g is the length of the glass, = 0.40m

B_g is the breadth of the glass, = 0.10m

$$A_g = L_g \times B_g$$

$$= 0.40 \times 0.10$$

$$= 0.04\text{m}^2$$

$$q_g = \frac{A_g \times K_g \times (T_2 - T_1)}{L_g}$$

Where;

q_g is the rate of heat lost by glass, W

K_g is thermal conductivity of the glass, = 0.96W/mk

T_2 is the temperature of the incubator, 273 + 38^{0}C = 311^{0}k

T_1 is the room temperature, 273 + 25^{0}C = 298^{0}k

L_g is the thickness of the glass, = 0.015m

$$q_g = \frac{0.04 \times 0.96 \times (311 - 298)}{0.015}$$

$$= \frac{0.04 \times 0.96 \times 13}{0.015}$$

$$= \frac{0.4992}{0.015}$$

= 33.28W

The area of the front of the incubator, $A_T = L \times B$

Where;

A_T is the area of the front, m^2

L is the length of the front surface, = 0.80m

B is the breadth of the front surface, = 0.44m

$A_T = L \times B$

$= 0.8 \times 0.44$

$= 0.352m^2$

The area of plywood is equal to the total area minus the that is made of glass.

$A_T = 0.352m^2$, $A = , m^2$, and $A_g = 0.04m^2$.

$A = A_T - A_g$

$= 0.352 \times 0.04$

$= 0.312m^2$

$$q = \frac{A \times K \times (T_2 - T_1)}{L}$$

$$= \frac{0.312 \times 0.12 \times (311 - 298)}{0.015}$$

$$= \frac{0.312 \times 0.12 \times 13}{0.015}$$

$$= \frac{0.48672}{0.015}$$

$= 32.45W$

Heat lost is the summation of all the calculated rate of heat around the walls of the incubator.

Total heat lost at both opposite sides of the incubator is 58.24W

Total heat lost at the top and bottom surfaces of the incubator is 32.03W

Heat lost at the back of the incubator is 36.61W

Heat lost from glass at the front is 33.28W

Heat lost from plywood at the front is 32.45W

Therefore, heat losses, = 58.24 + 32.03 + 36.61 + 33.28 + 32.45

= 192.61W

CHAPTER FOUR

4.1 Cost Analysis

In any engineering design, the economic benefit has to be put into consideration through the selection of materials which are very cheap and at the same time meet the specific purpose for which the machine was designed. The essence of costing the design and fabrication is better appreciated when considerations are given to the fact that a product is incomplete unless the cost of designing and fabricating the product are evaluated. The cost of designing and fabricating the automatically turning mechanism incubator with forced air convention system is classified as follows:

1.0 Material cost

2.0 Labour cost

3.0 Overhead cost

4.0 Total cost

4.1.1 Material Cost

This is the cost of all the materials used in the fabrication of the forced air convention incubator. For simplicity and clarity, the summary of the cost of materials used in fabrication are shown in the table below:

Table 4.1: Summary of Material Cost

Material	Number required	Unit Cost (₦)	Amount (₦)
Plywood	$1^1/_2$	4000	6000
Fan	1	1000	1000
Thermostat	1	2500	2500
Heating element	1	1500	1500
Wet and Dry bulb thermometer	1	3000	3000
Relays	3	220	660
Piece of glass	1	200	200
1 inch nails	2kg	50	100
2 inches nails	1kg	100	100
Wires	8 yards	50	400
Shaft	1	1000	1000
Top bond glue	1 tin	250	250
Transformer	1	2500	2500
Bolts and nuts	2	500	100
Bearings	2	500	1000
Brush	1	100	100
Electric motor	1	3000	3000
Hinges	6	100	600
Padlocks	3	100	300
Paint	1 tin	1500	1500

Switches	5	50	250
Timer/Control	3	1000	3000
Temperature sensor	1	500	500
Timer adjuster	1	500	500
Full wave rectifier	1	400	400
Indicators	2	20	40
Capacitors	4	200	800
Resistors	6	10	60
Variable resistors	2	50	100
Regulator	1	50	50
Thermometer	1	2500	2500
Electronic temperature controller	1	4000	4000
Total:	67	31,450	38,010

4.1.2 Labour Cost

Taking a direct labour cost of 25% of the material cost (Olarewaju, 2005)

$$Labour\ cost = \frac{25}{100} \times Material\ cost \quad (4.1)$$

Where;

Material cost is ₦ 38,010

$$Labour\ cost = \frac{25}{100} \times 38010$$

$$= 0.25 \times 38010$$

$= 9502.5$

The labour cost is ₦ 9,502.5

4.1.3 Overhead Cost

This includes all other expenses incurred apart from material and labour cost. Taking an overhead cost of 15% of the material cost (Olarewaju, 2005)

$$Overhead\ cost = \frac{15}{100} \times Material\ cost \qquad (4.2)$$

Where:

Material cost is ₦ 38,010

$$Overhead\ cost = \frac{15}{100} \times material\ cost$$

$$= \frac{15}{100} \times 38{,}010$$

$$= 0.15 \times 38{,}010$$

$$= 5{,}701.5$$

Overhead cost is ₦ 5,701.5

4.1.4 Total Cost

The total cost of fabricating the automatic turning mechanism incubator is the sum of the material cost, labour cost, and overhead cost (Olarewaju, 2005).

Material cost is ₦ 38,010

Labour cost is ₦ 9,502.5

Overhead cost is ₦ 5,701.5

Therefore, Total cost = material cost + Labour cost + Overhead cost

= 38,010 + 9,502.5 + 5,701.5

= 53,214

The Total cost is ₦ 53,214.

4.2 Discussion of Results

Twenty-five eggs were kept inside the incubator over a period of 21 days whereby the relative humidity, temperature of the incubator including the turning of eggs were maintained throughout the incubation period. The following observations were recorded;

Number of fertile eggs is fifteen, 15

Number of eggs, which hatch out, is five, 5

4.2.1 Percentage Fertility

Percentage fertility is the number of fertile eggs after incubation for eighteen (18) days divided by the total number of eggs set in the incubator multiplied by hundred (100).

$$percentage\ fertility = \frac{Number\ of\ fertile\ eggs}{Number\ of\ eggs\ in\ the\ incubator} \times \frac{100}{1}$$

$$= \frac{15 \times 100}{25}$$

$$= \frac{1500}{25}$$

$$= 60\%$$

4.2.2 Percentage Hatchability

Percentage hatchability is the number of fertile eggs which hatch out divided by the total number of fertile eggs multiplied by hundred (100).

$$percentage\ hatchability = \frac{Number\ of\ eggs\ which\ hatch\ out}{Number\ of\ fertile\ eggs} \times \frac{100}{1}$$

$$= \frac{5 \times 100}{15}$$

$$= \frac{500}{15}$$

$= 33\%$

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

An electrically powered automatic egg turning incubator with twenty-five (25) eggs capacity was designed and constructed with local materials. It was tested and also ensured that normal temperature, the required relative humidity, ventilation were maintained and eggs was turned at an angle of 45^0 to the horizontal at every six hours that is four times in a day for twenty-one days of incubation. The percentage fertility of eggs was 60% and the hatchability of eggs was also 33%. The result is due to lack of constant supply of electricity through out the incubation period.

5.2 Recommendations

1.0 The performance of an automatic turning mechanism incubator could be improved by using uninterruptible electric power supply such as generator.

2.0 An automatic turning mechanism solar incubator could be recommended to solve problem of unstable electric power supply.

3.0 An incubator using kerosene stove as source of heat energy for incubating eggs instead of electricity.

4.0 The performance of the incubator can be improved by the addition of an automatic relative humidity monitoring and regulating unit.

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APPENDICES

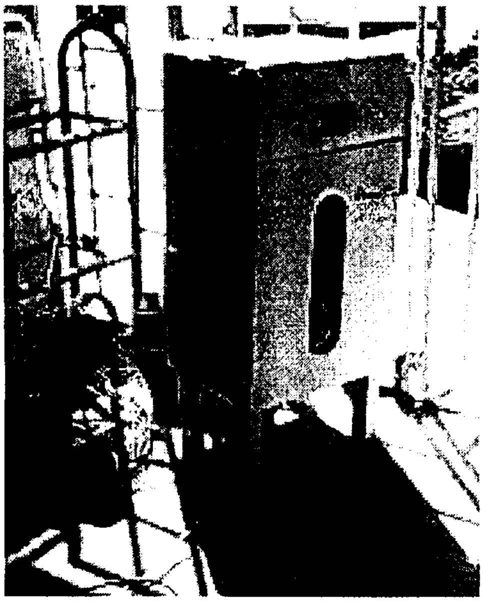
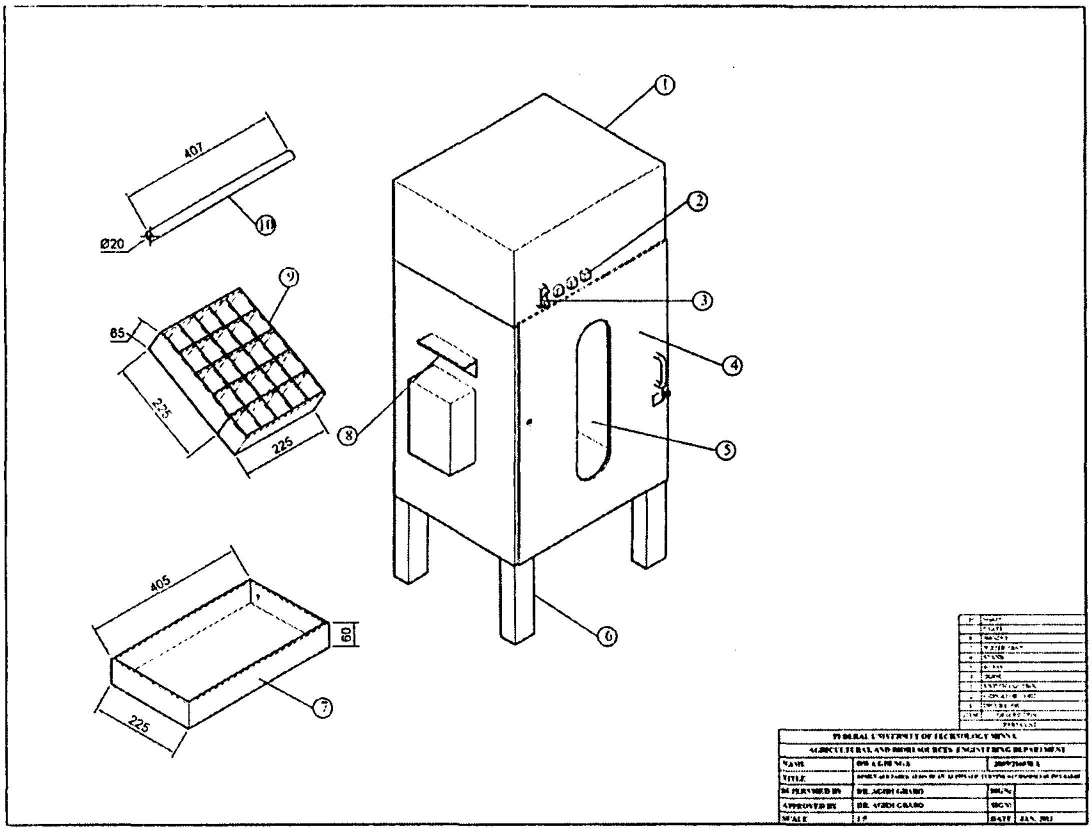


Plate 1: Front view of the constructed incubator.

Plate 2: An incubator showing its cabinet.

Plates 3: Networks of wires and other electrical components of the incubator.



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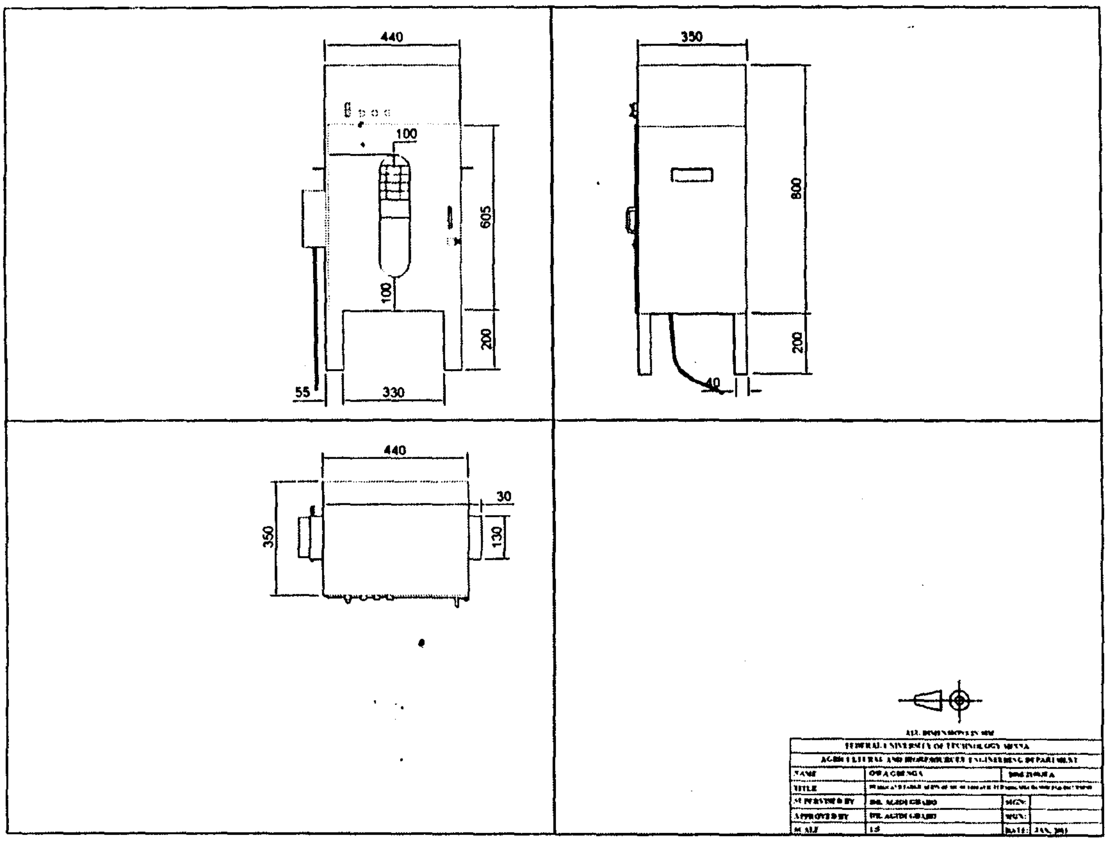
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