DESIGN AND DEVELOPMENT OF AN AUTOMATIC TURNING MECHANISM EGG INCUBATOR

BY

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MATRIC No. 2005/21604EA

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

JANUARY, 2011

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

JANUARY,2011

DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

Gunre (signature) 28-01-2011

Gunre,Opeoluwa Nathaniel Date

CERTIFICATION

This is to certify that this project entitled "Design and Development of an Automatic Turning Mechanism Egg Incubator" by Gunre, Opeoluwa Nathaniel meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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External Examiner Date

DEDICATION

dedicate this project work to Almighty God the Author and Finisher of my Faith for His infinite ıercy and to my parents for their tremendous support.

ACKNOWLEDGEMENTS

My profound gratitude goes to Almighty God the creator of the heavens and earth for his protection, guidance, wisdom and blessings HE has bestowed upon me unto this day and I pray that HE continues to bless me with his kindness and mercy in the years to come.

My gratitude also goes to my supervisor, Engr. Dr. Gbabo Agidi whom with his valuable pieces of professional advice and kind interactions during this project piloted me through and made it a total success.

I would also like to acknowledge and appreciate the efforts and knowledge impacted to me by my level adviser, Mr. J. J. Musa as well as Mr. Kehinde Bello including all the lecturers and staffs in the Agricultural and Bioresources department in their relentless efforts in impact knowledge and morals into me. May God Almighty bless you all.

Special thanks to my parents Rev. and Mrs. Sola Gunre may God give me the power to give my best to you as a child. I also want to you use this opportunity sisters, Tope and Seyi you both have been a source of inspiration to me.

To my friends who stayed close like brothers Simon, Benson, Kunle, Hannatu, Charles, Shuaibu , Kunle, Wale, Mugaf, Lanre, Aniekan, Titilayo, Shadrach and other unmentioned friends I love you all and would never forget the good and hard times we stayed together and watched our backs even till date. And to my colleagues in class under the same supervisor, Tobi, Owi, Joseph, Busayo, Ganiu and Gabriel, God bless you all. It was great working with you guys. Meet you all at the top.

ABSTRACT

In this study an automatic egg turning incubator was designed and fabricated to provide a conducive environment for eggs hatchability. The fabricated machine was tested to assess its performance. The results from the test showed that from 25 eggs, 5 eggs hatched after operating the machine. This gives 33% hatchability. This results showed that with further improvements the developed machine can adequately be adopted at the household level instead of the rearing of chickens for the purpose of incubating eggs.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Eggs are very essential to mankind and are also delicate in nature. Eggs laid by females of many different species, including birds, reptiles, amphibians and fishes have been eaten by mankind. Eggs are known to serve enormous purposes and are greatly utilized because their shells also have great importance. As a result of their delicate nature, it is compulsory for eggs to be kept in a conducive environment for their optimum development.

1.1.1 Incubator

Incubation can simply be defined as the maintenance of cells and microorganisms in an environment in which the temperature, humidity and oxygen levels can be controlled.

An Egg Incubator is an apparatus that manages fertilized eggs to ensure the satisfactory development of embryos into normal chicks either by natural or artificial methods. The egg is an extremely specialized structure which contains sufficient food and water to develop a fertilized cell into chick if subjected to adequate environmental conditions(Bolaji,2008).

The four factors of major importance for an artificial incubator include; temperature, relative humidity, air supply, egg turning. These parameters must be properly monitored during incubation. The control of temperature is probably the most critical single factor required for the successful hatching of chicks because developing embryos are extremely sensitive to the temperature of the environment. However humidity tends to be overlooked and cause many hatching problems(Gillespie,1995).

Extensive research has shown that the optimum incubator temperature is 100°F (37°Celsius) when the relative humidity is 60%, concentration of oxygen should be above 20%, and carbon-dioxide should be below 0.5%(Saxena and Keterlaars,1997).

There are three types of egg incubator;

1. Forced-Air Incubators

This kind of incubator have internal fans to circulate the air: The Forced air should be set at 99°F - 99.5°F and 60%-65% relative humidity (83°F -88°F wet bulb). The advantage of this type of incubator is that it is easier to maintain humidity at a constant level because of air circulation. Most units have automatic equipment for turning the eggs (Rice and Botsford,1999).

2. Still-Air Incubators

These types of incubator do not have fans so the air allowed to stratify. Still-Air incubator are smaller and air flows in through vents. Optimum temperature is 100.5^{0}F, humidity should be 60%-65 %(80°F - 90°F Wet Bulb) during incubation and 60%-70%(92°F - 97°F Wet Bulb)at hatching time. Incubating temperatures in these machines must be above the temperatures in forced-air (Rice and Botsford,1999).

More recently, in response to public concern over dietary fat, poultry has again become a popular substitute for beef and pork. As a result of modern technological development, many poultry houses now provide excellent environmental control, and the management and marketing of the birds are finely regulated (Charles,2005).

2.1.1 Chicken

The domestic chicken (*Gallus domesticus*) 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. In Harappa and Mohenjo-Daro, Pakistan, and -according to linguistic researchers- in Austronesia populations travelling across Southeast Asia and Oceania traces of chicken were found about 3000 – 2000BC, bones in unusual amounts and out of natural jungle range, thus denoting a breeding place. 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. Archaeological data is lacking for Thailand and Southeast Asia(http://en.wikipedia.org/wiki/).

For hundreds of years, chickens were kept in small flocks for home consumption of eggs and meat, with any surplus sold or exchanged for other produce. Not until the 20th century did poultry farming become commercialized. The production of eggs came first; for years the production of broilers was merely an offshoot, the male chickens being raised until about 10 to 16 weeks old and then sold for meat (Microsoft Encarta, 2009)

A modern poultry farm may have several hundred thousand or even more than a million laying hens. In the United Kingdom and Ireland, adult male chickens are primarily known as cocks whereas in Canada, Australia and America they are commonly known as roosters. Males under a year old are called cockerels, castrated cocks are called capons.

Females over a year old are called hen and the younger females are pullets while babies are referred to as chicks (Smith, 1997).Cocks were pitted together in fights originally as a kind of fertility ritual as an attempt by primitive people to ensure many children, bountiful crops and adequate livestock.

More than 50 billion chickens are reared annually as a source of food (Wilson, 2002). Chickens can be classified under the following two : Broilers and Layers;

2.1.1.1 Broilers

These are chickens that are reared just for their meat, they take less than six weeks to reach slaughter size. They've been selectively bred and reared for their meat rather than eggs, they are noted for having very fast growth rates(Parker,1998)

2.1.1.2 Layers

These refers to chickens that are farmed for their eggs, they are fed with feeds called layer mash or pellets, these increases their productivity. They are slaughtered after about 12 months when the productivity starts to decline, a pullet would start laying at 5months old. Some hens can produce about 300 eggs a year and they do not need a cock to lay their eggs(Parker,1998)

2.2 Egg formation in Hen

The development of an egg takes place in the ovary and oviduct. Chickens have only one ovary on the left side. Certain wild birds however have two ovaries and oviduct. The egg actually starts as a yolk which is correctly called an Oocyte at this point and is produced by the Hen during ovulation which happens every day depending on the breed of hen, her age and season.

Hens produced eggs whether or not roosters are present, the rooster only fertilizes the eggs so if no rooster is present the eggs grow but will not be fertile. If the hen was bred she would have the sperm in her oviduct and fertilization will occur.

The Germinal disc is a spot on the side of the yolk which will later grow into the chick if the egg is fertilized. As the yolk passes down through the spiraling oviduct it twists and thin strands called chalazae form. The chalaza holds the yolk in place, anchoring it to either end of the. The egg shell itself forms last then gets its bloom" a thin coating which helps it pass through the cloacae smoothly just before the egg is laid. The whole process takes 24hours and begins again shortly after an egg is laid (Nelson, 1998).

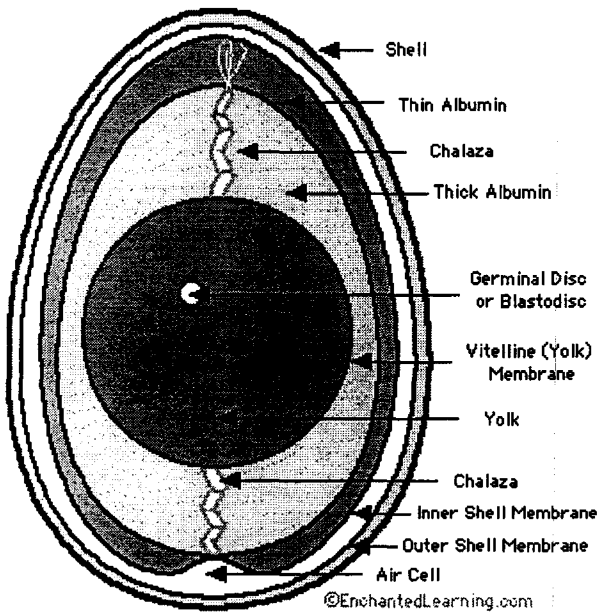

Plate 2.1,Showing egg components

2.3 Egg expulsion from Hen

Chickens lay in the morning but each day a little later. Sometimes the last egg of a series is produced in the early afternoon. When it gets too late they take the next day off. The hen approaches the nest in a very hesitant way, and finally enters. There she sits quiet for a long time, often for half an hour or more. She closes an eye or calmly puts a straw on her back, but finally she gets more exited. Now and then, the hen raises her tail and spreads the feathers of her bottom. These movements increase gradually. Under her tail, between the feathers, is a small opening in the form of a horizontal slit, about an inch wide. It is surrounded by a ribbed rim, with skin and feathers further outside. It is called the vent, suddenly the hen stands up with her feet wide apart, tail raised, bottom feathers spread out, and back feathers upright. As her vent opens a little, you begin to see a red membrane as the hen lowers her bottom, her vent widens rapidly and the rim is stretched further. The membrane forms a pinkish dome around the egg which is not yet visible at this stage. The vent is now wide open and the ribbed rim has become narrow and far stretched. Through the opening bulges a pink hemisphere of tissue revealing distinct blood vessels. Its top is pointed downward where a new opening arises. The egg appears as a much lighter-colored disk. Even brown eggs are much lighter than the surrounding membrane. The hen strains at intervals. Each time, the egg comes a little further out. As it does, the membrane opens to form a red collar around the wider, middle portion of the egg. The membrane will protrude a little ways from the ribbed rim. The moist egg pops out. Sometimes it will come out blunt end first, sometimes pointed end first. For a few seconds after the egg is laid, a small red cone still remains outside, but it is retracted almost immediately and the vent is closed again. The bird stands high above the egg and rests, beak open and panting after the heavy work. The entire process (from rising to dropping the egg) is quite fast and is finished within half a minute. Therefore, it is hard to observe.

After a while, the hen looks back, inspects the egg with her beak and leaves the nest under loud cackles. The hen then eats and drinks and goes her usual ways (Wiebe, 2005). Eggs laid can be further classified into Fertilized eggs and unfertilized eggs.

2.3.1 Fertilized Eggs

These eggs can also be referred to as hatching eggs, when a hen mates with a cock before laying, the semen is stored in the oviduct for later use. When the hen is ready to lay the eggs, a sperm fertilizes the egg before the shell surrounds it. The sperm is viable for about a month in the oviduct. If fertilized eggs are well incubated they hatch into chicks

2.3.2 Unfertilized Eggs

These refer to eggs produced by hen that did not mate with a cock before laying. These ones are sold in shops which we call table eggs, unfertilized eggs do not hatch into chicks.

2.4 Composition of egg

The percentage of several parts of the egg of chicken, duck, turkey and quail are shown in table 2.1. It is evident from the following table below that percentage composition of egg contacts varies among different species of bids. Yolk size and amount of albumen in the shell.

Table 2.1: Composition of egg

Species	Albumen %	Proportional parts Yolk %	Shell %
Chicken	55.8	31.9	12.3
Duck	52.5	35.4	12.0
Turkey	55.9	32.3	11.8
Quail	55.8	29.4	14.7

Source: Poultry eggs; Winton/R.L Lakhotia, 2003

2.5 Nutritive value of eggs

The egg of the birds is composed of substances that from the basis of all animal life. Eggs are composed of proteins, fats, carbohydrates, minerals and vitamins.

All these chemical constituents are distributed among the egg component structures in a very specific manner.

2.5.1 Proteins

The proteins are present in every part of the egg. The chief source of protein is albumen and yolk and only small amount is present in the shell membranes. The various parts of the chicken egg contain the following amount of protein as shown in table 2.2.

Table 2.2: Amount of protein of the various parts of egg

Egg parts	Amount of protein weight (g)	Percent content
Yolk	3.1	44.30
Albumen	3.5	50.00
Shell	0.15	2.10
Shell membranes	0.25	3.60

Source: poultry eggs; Winton/R.L Lakhotia, 2003

2.5.2 Fats

In the egg a variety of fats are present which are of high energy value. Fats of egg are of four main types are shown in table 2.3.

Table 2.3: Variety of fats that are present in eggs

Types of Egg fats	Weight (g)	Percentage (%)
True fat (Glycerides)	3.8	62.3
Phospholipids	2.0	32.8
Sterols (cholesterol)	0.3	4.9
Cerebro sides	Traces	Traces

Source (Lakhotia, 2003).

2.5.3 Carbohydrates

The egg contains only 1% of carbohydrates of the total egg content. The energy value of egg varies because of the species of egg size (Lakhotia, 2003).

2.5.4 Minerals

Mineral are essential to life and only small quantities are needed. Eggs offer an excellent source of many major and trace minerals.

Major mineral: calcium, phosphorus, magnesium, potassium, chlorine, sodium, sulphur and iron.

Trace mineral: Zinc, Copper, bromine, manganese and iodine (Lakhotia, 2003).

2.5.5 Vitamins

Eggs are especially valuable for many vitamins which are groups as: fat soluble vitamins: These are vitamins A, D, E and K

Water soluble vitamins: The nine water soluble vitamins namely Thiamin, riboflavin, niacin, pantothenia, inositol, Pyiodixide, biotin, folic acid and chlorine (Lakhotia,2003).

2.6 Uses of Eggs

Eggs are mostly consumed as food but there are other excellent uses of eggs which are:

i. Egg can reduce the puffiness under the eye.

ii. Egg white mask can make the pores appear almost invisible right away.

iii. Egg mask can make the skin tighter and firmer.egg yolk mask is ideal for those with sensitive and dry skin. Egg yolk is rich in vitamin A that is a strong anti-wrinkle vitamin.

iv. Egg mask is ideal for irritated skin, because it contains amino acids that help nourish skin cells to reduce inflammation

2.7 Incubation

The history of egg incubation may be traced back right from the existence of man. Naturally, under normal conditions all birds incubate their eggs and hatch the fertilized ones when due. But due to certain fact that cause a decline in the population of birds, such as; Killer diseases, unwillingness of some birds to incubate their eggs, increased rates of predation, reduction of suitable habitat and competition for nesting sites, the early man realized the need to find new ways of increasing the rate at which both eggs and chicks were produced (Romjin,1998).

Man was able to develop a number of skills but the most popular ones include;

a) Replacing an egg laid by a particular bird with that of another bird. This idea may have been gotten from a small majority of birds that do not hatch their eggs with the heat of their own bodies, they drop their eggs into the nest of birds of other species and then give little or no further attention to their progeny. The brood parasites include a number of cuckoos widespread over the world and more sparingly represented in the new world, the cow birds of America, the parasitic weaver bird and honey guides of America and the black headed duck of Southern America (Birkhead and Hemmings,2003).

b) Digging an inverted T-like hole underground about 2 feet deep at their usual fire wood cooking stand, after which they placed the eggs inside a cotton sack and inserted through one end of the two opposite horizontal openings and then pour in ash until top hole is filled (Birkhead and Hemmings,2003).

It is therefore evident that the problem of killer diseases and unwillingness of some birds to sit on their eggs was solved in (a) above. However, another problem is created as the replaced eggs have to be discarded when the embryo has not began early development which rendered the egg uneatable. In cognizance to the above problem the early man improvised amongst others, solution (b) above. Here the advantage was both ventilation and egg turning requirements were achieved through two opposite horizontal openings and pulling of sack respectively. The set back of this method was, the heat supplied was based on an estimation as such that the temperature which the eggs were been subjected to might be greater or less than the required. For this reason the efficiency of this method was small (Bale, 2004)

A series of improvements on the methods of incubation led to the establishment of a standard apparatus called an incubator which stimulates the broody bird with all the incubation requirement.

Eggs may be naturally or artificially incubated. The incubation period for fertilized chicken eggs is 21days according to Their and Fraser(1986).The method used does not affect the quality of the chicken hatched. There are also two main methods used;

a) The natural method of incubating.

b) The artificial methods of incubating.

2.7.1 Natural Incubation

Natural Incubation means that the eggs are kept warm at a constant temperature of 39.5degreesC for a period of 21 days, after which it hatches and this is done by a hen. The hen provides heat by laying on the eggs which is called "brooding". While cold is provided when a hot brood spot develops on the breast of the hen. The method provided by the hen has been so much studied and so humidity and temperature are provided. The hen turns the eggs to give them equal amount of heat and ventilation (Joy and Wibberly, 1969).

Another study of such method is from an "Introduction to animal husbandry in the tropic" by Williamson and Payne (1959).It states that most of the indigenous breeds chicks produced in our villages are by these methods. The village hen sits on the usual chick of some 8 to 10 eggs of which need little food or no attention. This contributes to poor results of hatching of eggs. The requirements for such hen needs water, food and protection against pest which is not much taken into consideration with in the villages.

During such time the hen should be provided with food, water and should not be disturbed. It should also be allowed to move off her nest to her breeding quarters at will. The nest should also be free from pest and should be damped daily.

2.7.2 Advantages of the Natural Method

The hen does the work, one does not have to worry about turning the eggs or keeping the temperature stable.

i. There is no maintenance cost.

ii. It has a higher percentage hatching eggs.

2.7.3 Disadvantages of the Natural Method

i. It cannot hatch large number of eggs for commercial purposes.

ii. Broody hen sitters are not always available.

iii. One cannot guarantee that the hen would be a good mother.

iv. There is the danger of pests.

2.7.4 Artificial Incubation

3000 years B.C, the men practiced already the artificial incubation. In the scale of civilization, it is in China that the first traces of artificial incubation were found, about 3000 years B.C. (http://www.catoire-fantasque.be/Farmyard/chicken-incubation)

This method has been found useful and of good quality, large scale commercial hatcheries are equipped with various types of automated artificial incubators, which are now operating in almost all tropical countries. In southeast Asia, the old artificial hatching methods are still been practiced.

The old artificial hatching system used by the Chinese in Malaysia is well desired (Thunaisinghan and Wah, 1971).The results obtain is compared and is found to be quite good with the records from modern incubators, hatching rate to 75% to 85% being normal (Williamson and Payne, 1959).

An incubator is usually provided with all the necessary condition such as box, thermometer to tell the temperature, tray containing water for humidity.

Artificial incubators are operated 48hrs, and temperature adjusted to 39.5^0C before the eggs are placed in. The eggs are placed in a tray (that is egg tray) before finally into the incubator(Rahn and pagenell,1997).

There are three types of artificial egg incubator;

1. Forced-Air Incubators

This kind of incubator which is the type we are working on have internal fans to circulate the air: The Forced air should be set at 99°F - 99.5°F and 60%-65% relative humidity (83°F -88°F wet bulb). The advantage of this type of incubator is that it is easier to maintain humidity at a constant level because of air circulation. Most units have automatic equipment for turning the eggs (Brinsea,2003).

2. Still-Air Incubators

This type of incubator do not have fans so the air allowed to stratify. Still-Air incubators are smaller and air flows in through vents. Optimum temperature is 100.5^0F, humidity should be 60% - 65% (80°F - 90°F Wet Bulb) during incubation and 60% - 70% (92°F - 97°F Wet Bulb) at hatching time. Incubating temperatures in these machines must be above the temperatures in forced-air (Brinsea,2003).

3 . Contact Incubators

In contact incubation, the temperature tends to fall at later stages of incubation as a result of the embryo's own blood circulation which becomes significantly more important than embryonic metabolism in determining temperature distribution and heat flow within the egg. Contact incubation mimics the natural incubation process that occurs in the nest (Brinsea,2003).

On the other hand the artificial method is more advantageous over the natural method of incubation.

2.7.5 Advantages of artificial method

i. It has no danger of pests.

ii. The incubator can be used any time.

iii. It can be used continuously.

iv. It can be used to incubate large numbers of eggs

2.7.6 Disadvantages of artificial method

i. It has high maintenance cost.

ii. There is lower percentage hatch.

iii. It has high material cost

Comparing these two methods it's obvious that the artificial method is relatively advantageous. We can now decide to fabricate a simple type of incubator using solar as the heat source which would be less complex and small enough to transport.

2.8 Requirement for successful hatching

2.8.1 Temperature

Accurate incubation temperature is by far the most important requirement for successful hatching of chicks. Even marginal temperature differences can affect hatch rates, although these differences seem to have less effect on eggs in contact incubators. The growth processes in the development of the embryo are very temperature sensitive and small deviation can cause development to progress out of sequence resulting in losses or deformities. It is the egg centre or embryo temperature, that is most critical. To ensure this is correct it is of highest importance that the incubator is set up correctly, particularly for still air machines. Still air incubators have temperature variations from top to bottom, therefore, the sensor of the temperature controller and the thermometer bulb needs to be positioned as close as possible to the top of the eggs. Here the temperature needs to be slightly higher than the mean temperature used in forced draft incubators and accounts for the important difference found in the instructions (Brinsea, 2003).

2.8.2 Humidity

Constant accuracy of humidity is less critical than that of temperature. Ideally, the egg needs to lose 13 – 15% of its weight between the time of laying and pipping. Fairly wide tolerances in humidity are bearable although not ideal, as long as the chick ends up having lost the correct amount of weight by the time of hatching. Correction can be made in later stages for errors earlier. All incubators should have the facility to adjust humidity levels. There are two controllable factors that influence humidity levels. These are the amount of water surface area and the amount of fresh air that the incubator draws in. The greater the water surface area and the less fresh air being drawn in, the higher the humidity levels inside the incubator will be. One method to increase water surface area is to use evaporating pads or blotting paper. Finally, the environment in which the incubator is set up in can have an effect on accurate humidity control. If the ambient humidity in the air outside the incubator is very dry, then incubation humidity levels will be lower than if the air is very humid (wet). Also, cold air cannot retain much water vapour, so when cold winter air is warmed the RH level will be very low. This happens in heated houses in winter, and also inside incubators. The result of this in general is that humidity levels tend to be lower in the winter than in summer and so humidity levels should be adjusted with this in mind. Some breeders go to great lengths to control the incubation room environment and overcome seasonal variations in ambient humidity. In extreme cases, sections of the egg's shell are removed to allow extra water loss, or covered with tape to reduce water loss. This should be regarded as strictly for the experts though and a high risk method. The humidity levels required when a chick is hatching need to be higher than previously in the incubation period. For the last day or so, high humidity levels are required to prevent the membranes of the egg drying too fast as the chick hatches and becoming tough and difficult to tear. The humidity level when hatching should therefore be at least 60% RH (Brinsea, 2003).

2.8.3 Turning

As the embryo develops on the yolk, it causes that part of the yolk to become lighter and float upwards. If, after the egg is moved, the embryo is downwards it will cause the yolk to rotate in the inner thin white until it is uppermost again. The yolk is held in position by a structure called the chalaza and by membranes. It still tends to float upwards, deforming the inner membranes and eventually the yolk will touch the shell membranes. If this happens with the embryo uppermost the embryo will stick to the shell and die. For this reason, turning is essential for survival of a healthy chick. As the egg is turned the embryo is swept into fresh nutrients, allowing the embryo to develop. This is critical for the first week when the embryo has no circulation system. After the first week, eggs still need to be turned but not as often. The turning regime is often different between species and tends to need more frequent turning than precocial birds. Whereas fowl are turned through 80 degrees every hour or so, parrots are often turned through180 degrees many times an hour in the early stage, (Brinsea,2003).

In incubators today there are four types of turning mechanisms;

a. Tilting Trays

Most commercial incubators are provided with plastic egg trays that hold the egg vertically, with the small end down. The tray is then tilted through an angle of about 40° either side of horizontal (an overall angle of 80°) at predetermined intervals, perhaps every hour for example. This method works well with poultry for which it was developed, and is very efficient to operate on a commercial scale. However, this is very different from the natural process adopted by birds. So, this technique is fine for poultry but not so good for wild birds, (Brinsea,2003).

b. Moving Floor

In some smaller incubators where there is no need for multiple layers of eggs, the eggs lie on a horizontal floor or conveyor, which moves from side to side. Eggs are restrained from the lateral movement by fixed dividers so that the eggs roll. This kind of system works well with eggs which are reasonably symmetrical end for end, for example duck eggs, but pointed eggs tend to bunch together with this system, (Brinsea,2003).

c. Rollers

Rollers work by being rotated by a moving floor. Eggs sit on rollers that in turn sit on the moving floor. Ribs on the rollers help reduce the tendency for an egg to 'walk' along the roller length (Brinsea, 2003).

d. Troughs or Channels

Semicircular shaped tilting channels are used for the turning very small eggs, such as quail for example. The downside of this is that turn angles are limited (Brinsea, 2003).

2.9 Selection of hatching egg

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 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 mishappen eggs are eliminated for use as hatching eggs. The too small or too large hatch badly. The eggs with abnormal shell (bumps, vacuums, pad, thin, porous or too thick shell, limestone grains, fissures, very pointed end) are to be set aside.(La catoire-fantasque,1999)

2.10 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 hatching to viable and strong chicks as shown in table 2.4.

Table 2.4: Optimum size of hatching eggs

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

Source: Poultry eggs; Winton/R.L Lakhotia,2003.

In conducting this project the eggs chicken and quails were weighted by using beam balance in order to achieve maximum hatchability.

Very small eggs oversized eggs are sold for human food. 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 hatch than smaller ones. Hence eggs with abnormal size do not hatch well.

2.11 Storage of Hatching Eggs

Hatching eggs are stored with the large end-up storage times of over one week cause a decline in hatchability. Generally, an egg room temperature of 60oF (16oC) is ideal for hatching eggs stored for one week. Eggs stored for 10-14 days at 50-55oF (10-13oC) hatch better than those stored at high temperatures. In any case hatching eggs should not be stored at temperature under 50°F (10°C), the relative humidity should be kept at 80-85 percent during storage,(La catoire-fantasque,1999).

2.12 Transportation of Hatching Eggs

Excessive jerking or shaking of hatching egg should be avoided during collection and transportation, which sometimes results in a condition known as "tremulous air cells "a condition that tends to lower hatchability (Vadehra,1989).

2.13 Cleanliness of Egg

Clean eggs hatch better than soiled eggs. The effect of shell, contamination of floor egg is significantly reflected in hatchability. Soiled eggs are washed with water warmer than normal egg, containing compatible odourless, germicidal colorless and non toxic detergent sanitizer (Geers *et al*,1998).

2.14 Incubation Period of Hatching Eggs

The incubation period of a number of species of poultry vary considerably as tabulated in table 2.5

Table 2.5 Incubation periods of hatching eggs

s/no	Species	Incubation periods (day)
1	Conturnix Quail	16-17
2	Pigeon	17-19
3	Bobwhite quail	22-24
4	Chicken	20-21
5	Guinea fowl	26-28
6	Pleasant	23-28
7	Turkey	26-28
8	Duck	26-26
9	Geese	28-34
10	Ostrich	40-42

Source: Oluyemi and Roberts, (1994).

CHAPTPER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The following apparatus were used in the fabrication of the egg incubator;

1.Plywood

2.Fan

3.Thermostat

4.Heating element

5.Wet and Dry Bulb thermometer

6.Relays

7.Piece of glass

8.Wires

9.Shaft

10.Top Bond Glue

11.Transformer

12.Electric Motor

13.Paint

14.Bolts and Nuts

15.Bearings

3.2 METHODS

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.

3.2.1 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

The volume of the egg tray can be estimated from;

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

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

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

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

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

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

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

$$B = \sqrt{0.0208}$$

$$= 0.144\text{m}$$

$$Therefore, L = 2 \times B$$

$$L = 2 \times 0.144$$

$$= 0.288m$$

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

3.2.2 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 $0.0787m^3$

3.2.3 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 = $0.0787m^3$

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

$$M_a = \rho_a \times V$$

$= 1.23 \times 0.0787$

$= 0.097kg$

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

3.2.4 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

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

$M_p = \rho_p \times V$

$= 540 \times 0.0787$

$= 42.50kg$

3.2.5 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).

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

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^{0}C

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

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

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

$$= (51425 + 97.49) \times 14$$

$$= 51522.49 \times 14$$

$$=721314.86J$$

3.2.6 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 × 60 × 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.

3.2.7 Designs for Ventilation Holes

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

$$Q_v = C \times V_e \times (T_2 - T_1) \tag{3.8}$$

Where;

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

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

V_e is the ventilation rate, m^3/s

T_1 is the room temperature, = 25^{0}C

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

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

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

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

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

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

= 0.00046m^3/s

The ventilation rate is 0.0046m^3/s.

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

Where;

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

A is the area of hole, m^2

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

$$V_e = A \times S$$

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

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

$$= 0.00023 m^2$$

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

3.2.8 Area of the Egg Tray

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

$$A = L \times B \tag{3.10}$$

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

$$A = L \times B$$

$$= 0.288 \times 0.144$$

$$= 0.0415 m^2$$

3.2.9 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.

$$L = \frac{\theta \times 2 \times \pi \times r}{360} \tag{3.11}$$

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

3.2.10 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;

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

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

3.2.11 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).

$$A = L \times B \qquad (3.13)$$

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

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

$$= \frac{0.4368}{0.015}$$

$$= 29.12\text{W}$$

But, it is two opposite surfaces.

$$q_T = 29.12 \times 2$$

$$= 58.24\text{W}$$

3.2.12 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

$$A = L \times B$$

$$= 0.44 \times 0.35$$

$$= 0.154\text{m}^2$$

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

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

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

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

$$A = L \times B \tag{3.15}$$

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

$$A = L \times B$$

$$= 0.8 \times 0.44$$

$$=0.352m^2$$

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

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

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

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 $A_g = 0.04m^2$.

$A = A_T - A_g$

$= 0.352 - 0.04$

$= 0.312m^2$

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

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

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

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

$$= 32.45\text{W}$$

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

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 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).

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

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

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

$$= 60\%$$

4.1.2 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).

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

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

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

$$= 33\%$$

4.2 DICUSSION 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 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

4.2.2 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

4.2.3 Labour Cost

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

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

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

4.2.4 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

4.2.5 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.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This work focused on the design and fabrication of an automatic turning mechanism egg incubator that is easy to maintain and less energy consuming. The automatic turning of the incubator is so important as it doesn't require the ever presence of an operator. The automatic turning mechanism egg incubator would go a long way in encouraging people to practice poultry farming which will in turn agricultural productivity and this will have a positive effect on the country as a whole. Most parts of the incubator were fabricated from ply wood, except for the all the electrical components also for the shaft which was made of steel and the egg crate and water tray which was made from plastic. The turning mechanism was designed to turn egg crate at predetermined intervals, for this design the egg crate was screwed to a shaft which is powered by a motor this arrangement consequently provides the turning needed by the eggs in the egg crate.

The percentage hatchability of the incubator was 33%, it was observed that the incubator functioned as expected.

5.2 Recommendations

The following are recommended for further research;

- Incubators for other egg species such as turkey eggs should be worked on so as to provide comprehensive informations for the design of incubators.
- The government should provide constant electric supply to enable unobstructed operation of incubators.
- There is need for government to establish hatcheries across the country for easy access to fertile eggs.
- A motor with lower rating should be used to avoid high turning speed.

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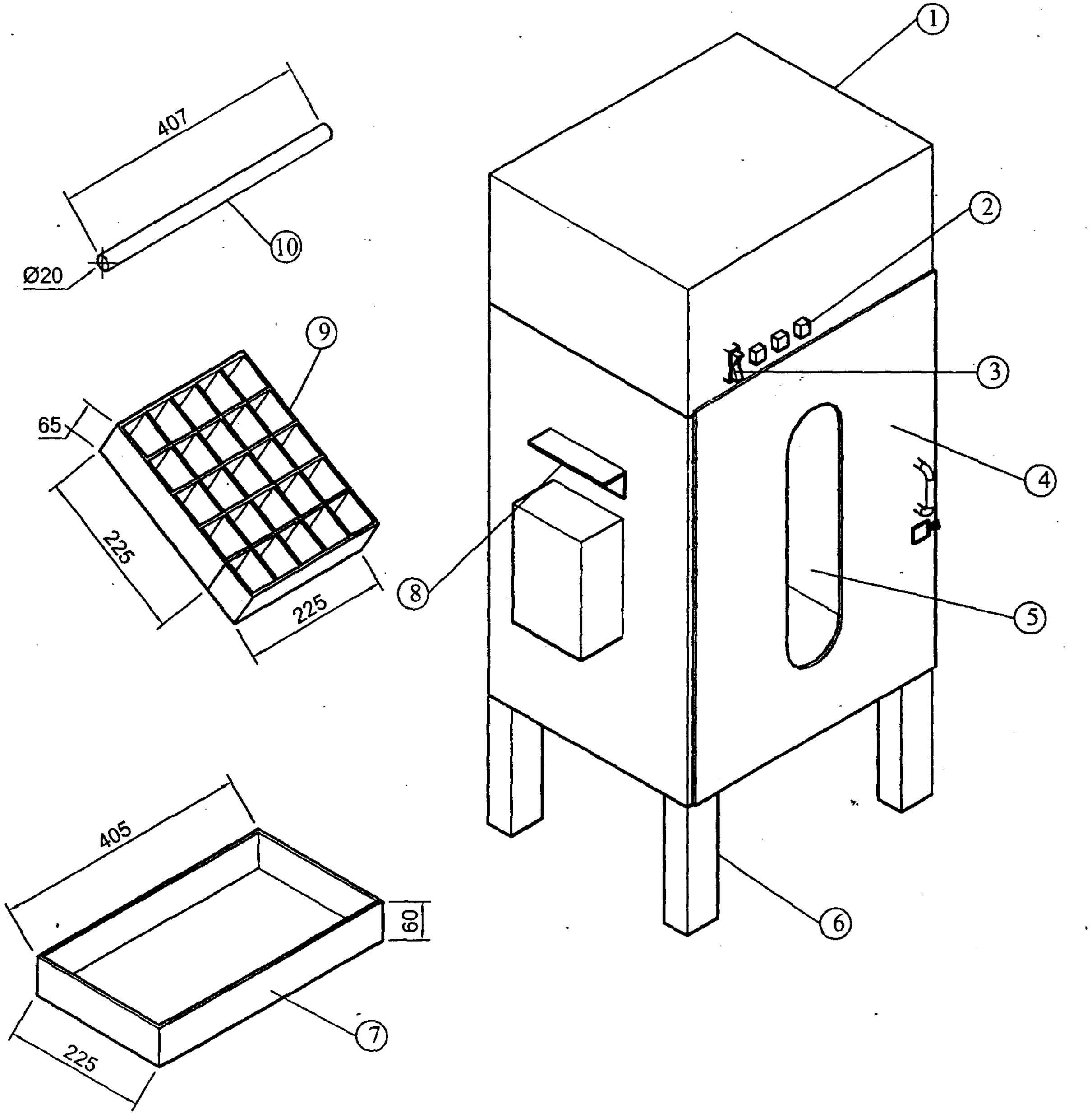
ABSTRACT

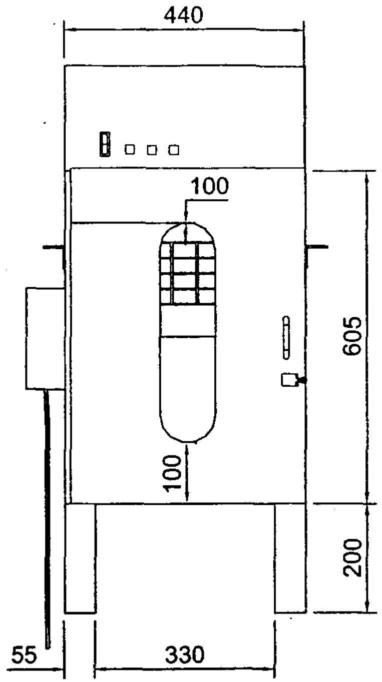
In this study an automatic egg turning incubator was designed and fabricated to provide a conducive environment for eggs hatchability. The fabricated machine was tested to assess its performance. The results from the test showed that from 25 eggs, 5 eggs hatched after operating the machine. This gives 33% hatchability. This results showed that with further improvements the developed machine can adequately be adopted at the household level instead of the rearing of chickens for the purpose of incubating eggs.

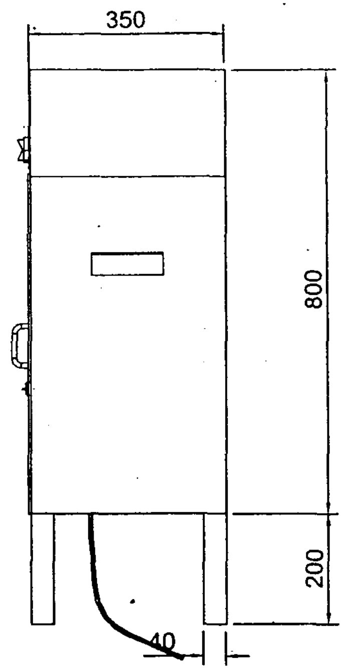


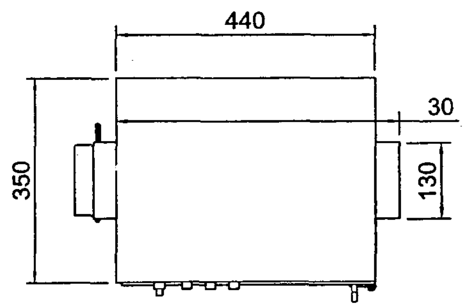
ITEM	DESCRIPTION
10	SHAFT
9	CRATE
8	HANDLE
7	WATER TRAY
6	STAND
5	GLASS
4	DOOR
3	SWITCH CONTROL
2	INDICATOR LIGHT
1	INCUBATOR

PARTS LIST

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA			
AGRICULTURAL AND BIORESOURCES ENGINEERING DEPARTMENT			
NAME	GUNRE OPEOLUWA NATHANIEL	2005/21604EA	
TITLE	DESIGN AND FABRICATION OF AN AUTOMATIC TURNING MECHANISM EGG INCUBATOR		
SUPERVISED BY	DR. AGIDI	SIGN:	
APPROVED BY	DR. AGIDI	SIGN:	
SCALE	1:5	DATE:	NOVEMBER 2010







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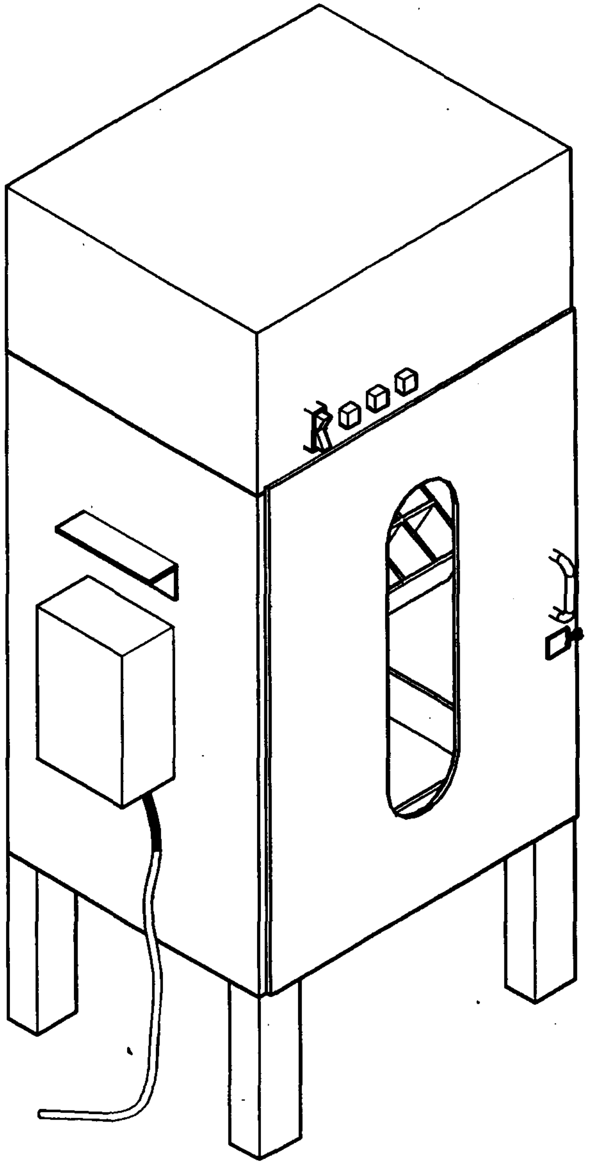
SUPERVISED BY	DR. AGIDI	SIGN:	
APPROVED BY	DR. AGIDI	SIGN:	
SCALE	1:5	DATE:	NOVEMBER 2010



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