Development of an Automatic Electric Egg Incubator

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Abstract— An electric powered incubator using a forced draft principle was developed using the available local materials and it was tested with hatchable hen egg. The aim was to produce a low cost incubator and increase the production of day old chicks for small and medium scale poultry farmers. The incubator has the hatching capacity of 540 eggs. Factors that were considered during the performance evaluation of the incubator were humidity, 55% and temperature, 37^{o}C during the first 18 days and was maintained at 37.5^{o}C till hatching. Turning of eggs was achieved with the use of tilting trays mechanism using an electric gear motor (0.5 h p).The trays were lifted through an angle of 40^{o} either side of horizontal at every hour and lasted for four minutes. 420 clean, healthy, well developed and matured hatchable eggs were used to test the incubator. The result of the test revealed the following average values- fertile eggs 387, infertile eggs 29 hatched eggs 325 and hatchability of 84.06%.

Index Terms— development, automatic, incubator, egg incubator

1 Introduction

Incubation is the management of a fertilized egg to ensure satisfactory development of the embryo inside the fertilized egg into a normal chick [1], process of keeping the fertilized eggs warm in order to allow proper development of the embryo into a chick. It may either be natural or artificial. In natural incubation the bird provides the required conditions for the relatively few eggs she lays by sitting on the eggs intermittently until they hatch in an open space. An artificial incubator is a chamber in which temperature, humidity and ventilation are controlled for the purpose of hatching a relatively large number of eggs than a single hen can handle at a time [2]. The heat required for incubation is usually provided by coal, oil, gas or electricity. For small incubator about 58% relative humidity is kept at 120^{o}F (38 to 39^{o}C) up to the 18th day of incubation after which, the humidity goes to 70% and the temperature is lowered to 96^{o} F (36^{o}C) until the chick is hatched [3]. Incubators are usually placed away from walls at corners of rooms so as to allow adequate ventilation and provide sufficient work space for the incubator operator.

Hatching eggs deteriorate with storage and should not normally be kept for longer than seven days before being set for incubation. The storage temperature should be about 12.5^{o}C at which embryonic development is arrested. The relative humidity should not be less than 80% to prevent dehydration of the eggs. If the storage temperature is too low (-2^{o}C) the blastoderm may freeze [1].Eggs selected should be of normal shape, a minimum of 56.7 g in weight, with good shell texture, and free from faults. Efforts should be made to prevent hatching eggs from becoming fouled in the nest, but where this does occur, they should be scraped clean rather than washed, which is detrimental due to the fact that water may contain infectious microorganism and that washing usually opens up the pores on the eggs shell which encourages rapid evaporation. Colour of the egg does not affect hatchability, although extremely length colouring may indicate calcium deficiency in the shell [1].The need for a small cabinet incubator is to generally increase hatchability of eggs which leads to the improvement and increase in the production of chicks and eggs for human consumption and the economic market.

Small cabinet may be considered due to the following reasons. The increase in demand for chickens due to population growth, which cannot be met all alone by large cabinet incubator operators, the huge cost of installation and operation of the large cabinet incubations, also the high cost of imported parts as a result of unfavourable exchange rates, discourages the installation of such large cabinet incubators by small scale farmers. However, despite the fact that percentage hatchability from locally broody hen is more efficient than from any type of incubator from a given number of fertilized set of eggs using an incubator to hatch has three basic advantages over the broody hen; chicks are hatched whenever there is demand for it rather than having to wait for hens to become broody, large number of eggs can be hatched with incubator at a time, if the poultry breeder desires to sell baby chicks an incubator is absolutely necessary. This work aimed at developing an electric egg incubator which will meet all these conditions.

1.1 Factors Affecting the Performance of Incubator

These factors include temperature, humidity, air supply and egg turning. These four parameters must be properly monitored during incubation. Developing embryo receives oxygen from the atmosphere and releases carbon dioxide, the capability for ventilation must be incorporated in the

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incubator. Humidity help the eggs loose water during the incubation period, and the rate of loss depends on the relative humidity maintained within the hatching chamber. Metabolic balance must be maintained throughout the incubation period thus, humidity outside a relatively narrow range will affect the number of successfully hatched eggs. Optimum growth for most eggs require a relative humidity of 60% until the eggs begin to pip, after which the relative humidity should be raised to 70%. Condition moisture must be added to the hatching chamber too reach these relative humidity levels. This can be done by placing an open pan of water in the same area with the eggs. Relative humidity can be gauged by wrapping a wet cotton cloth around the bulb of thermometer and suspending it in the hatching compartment. Due to evaporation, the "wet" bulb thermometer will have a temperature below that of a dry bulb thermometer in the same compartment. Eggs should be placed in the incubation compartment large end up for best result. However a fairly good hatch can be obtained if the eggs are placed on their sides. An extremely poor hatch will occur if the eggs are placed in the incubator small end up. The eggs must be turned several times a day for best hatchability. This will ensure that the embryo will not stick to the shell. The turning should be repeated throughout the entire 24 hours day. However, the night turning may be eliminated as long as there is a late evening and at least four times during each 24 hours period. The eggs should be turned through a 90 degree plane as gentle as possible. Turning should continue until one or three day's period to hatching and until the egg has "piped" position or turning will then have no effect on hatching [4].

2 Materials

Plywood, electric fan, thermocouple, electric contactor, bearing and dimmer switch were used in developing the incubator. All these materials were sourced locally at various markets within Ibadan and Lagos, Nigeria. The components were measured, marked, cut and joined together according to the prescribed specifications.

2.1 Considerations of the Incubator

The incubator should be made with readily available materials, relatively cheap and be within the buying capacity of local farmers, able to hatch different shapes and sizes of egg, have higher capacity compared to natural methods, be simple to operate and maintain by local farmers who do not have any formal education.

2.2 Description of the Incubator

The incubator, fig. 1 was made of wood and has height of 2050 mm, breadth 1110 mm and width 630 mm. It is a forced draft type incubator in which a fan was used to circulate the air, which gives a uniform temperature throughout the machine. This helps to overcome the temperature gradients throughout the incubator. Positioning of the thermometer and temperature sensor was less critical. Eggs of different size was used and set in trays at different levels.

Electrical power would be supply to the incubator through the mains. Meanwhile, an alternative source of power was available in case of failure from mains; two standby generators (950 kVA and 1000 kVA) ensure constant power supply. A relay was installed inside the incubator, which create awareness whenever there is interruption in the power supply. A panel box (fig. 2) in which the dimmer switch, temperature contactor, the alarm contactor, the electric motor contactor were located was positioned on the outside of the incubator for the convenience of the operator.

Fig. 1. Incubator

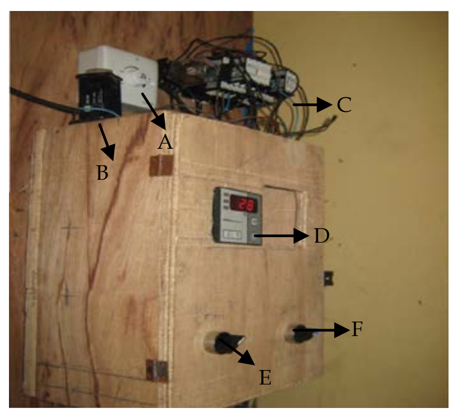
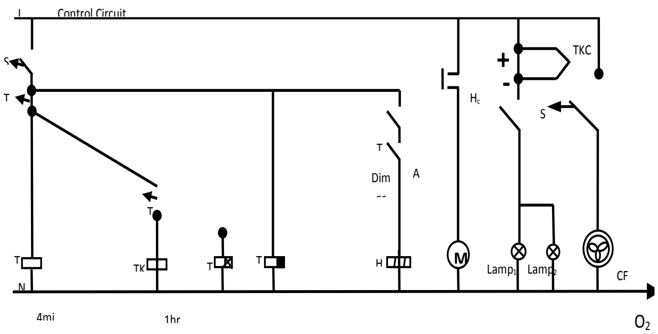


Fig. 2. The panel box (A-dimmer switch, B-alarm contactor, C-electrical contactor, D-temperature indicator, E-fan switch and F-main switch)

2.3 Control Circuit Diagram of the Incubator

Fig. 3 shows the control circuit diagram of the incubator. The following materials were responsible for heat source and heating control- thermocouple Tk, temperature controller Tc, contactor to switch ON and OFF the lamp through temperature controller and bulbs. Turning of eggs was being achieved through two timer relay T_1 and T_2, turning contactor

Tk and turning motor M. Turning process- timer relay T_3 was set at an hour, this was to keep the turning of motor rest for 1hr, then Timer T_1 and contactor Tk will be energize thereby make the turning motor turn for 4 minutes at timer T_1 set to 4 minutes. Heat is being produce four filament bulbs of 60 W each within the cabinet and the temperature was maintained between 37^o-39^oC by the means of sensing device called thermocouple.



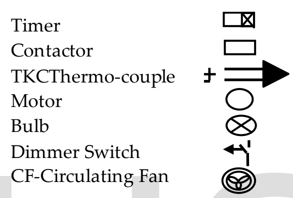


Fig. 3. Control circuit diagram of incubator [TK-turning contactor; T_1- turning timer; T_3- interval timer; T_C- temperature contractor; H_C- heat contactor (blower)]

Set temperature of 37^oC and controlled or actual temperature is done through a temperature controller, temperature controller will in turn energize or de-energize lamp contactor through its change-over relay within the temperature controller to ON and OFF the lamp used at its set point of 37^oC, ON 2^oC below (i.e. 35^oC), the OFF 2^oC above set point (i.e. 39^oC). Circulating fan will be ON through switch S_2, for temperature uniformity within incubator cabinet.

2.4 Functions of Electrical Devices Used

1. Contactor, fig. 4 is a magnetic switch with its parts- coil, fixed core, moving core, fixed contact, moving contact.

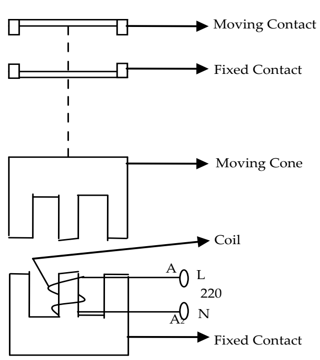


Fig. 4. Contactor

2. Timer relay is an electronically designed device for a timing system in an electrical circuit through inbuilt relay of change over contact normally open and normally close contact.

3. Temperature controller is also an electronically control device which works with change in temperature, it also has inbuilt change over relay with its contacts. It can only work with thermocouple connected to its terminals read (+ and -).

4. Thermocouple is a sensor that sense heat through its probe inserted into any cabinet where heat is being applied.

2.5 Considerations Regarding the Environments within the Incubator

In the development of this machine, the following environmental factors were taken into consideration– sanitation, humidity, temperature and ventilation.

2.5.1 Humidity

Eggs lose water during the incubation period, and the rate of loss depends on the relative humidity maintained within the hatching chamber. The humidity inside the incubator was read with the help of hygrometer. The relative humidity in the incubator was set at 55% [5] to have a good result, and was maintained at 58-60% three days prior to hatching [6].

2.5.2 Temperature

Temperature is extremely important during incubation. Variations of more than one degree from the optimum will adversely affect the number of eggs that will successfully hatch. Four filament bulbs, 60 Watts each were used as heat source within the incubator. These bulbs were spaced out for effective heat distribution. The heat supplied through the bulbs was controlled by the use of a dimmer switch. Air circulation is important inside the machine. Three fans were strategically positioned within the incubator for an evenly distribution of heated air produced by the bulbs.

A thermocouple was installed within the incubator to monitor the temperature of the inside air. However, the set temperature was between 37^oC and 39^oC during the first 18 days as drastic temperature difference can affect hatch rates especially in forced-air incubator and was maintained at 37.5^oC till hatching give the best result with eggs [7].

2.5.2 Turning of eggs

Turning of eggs was achieved in the incubator with the use of tilting trays mechanism which obtained power through an electric gear motor (0.5 h p). The eggs were arranged in plastic egg trays vertically with the small end down. The tray was then lifted through an angle of 40^o either side of horizontal at every hour and lasted for four minutes. A timer is connected to the electric gear motor, for this process to be made possible. The egg was turned in order for the embryo to sweep into fresh nutrients, allowing the embryo to develop. This is critical for the first week when the embryo has no circulation system.

2.5.3 Sanitation

The cleaning of the enclosure needs to be taken care of before setting the eggs, when the egg is in the enclosure and after hatching process. The system and the environment need a proper fumigation before the eggs can be set in order to avoid infection which can affect the hatchability of the egg. Also, a dipper is needed during the process of incubating in the entrance of the housing of the system. Moreover, the system and the environment need to be treated because of the left over shell, unhatched egg in the incubator for next operation on the system.

2.5.4 Ventilation of air

Ventilation cannot be overemphasized in the incubator as well as oxygen and carbon dioxide exchange. Since the developing embryo receives oxygen from the atmosphere and release carbon dioxide, the more eggs in the incubator compartment, the more the oxygen required.

3 Testing of the Incubator

Before running the test, fig. 5 the incubator was protected from weather changes by locating it indoor. The temperature and humidity were set and maintained uniformly at between 37^{o}-39^{o}C and 55% respectively. The ambient temperature and humidity were 33^{o}C and 42%. 420 clean eggs of hen were selected from breeders. The eggs were healthy, well developed and matured. The temperature and humidity were under control and recorded at every hour. This process was to last for 21 days. The eggs were turned through an angle of 40^{o} either side of horizontal at every hour and this turning lasted for four minutes. The turning effect was (halted) on the 18 day.

Fig. 5. The incubator loaded with eggs (A- Fan, B- 60 Watt electric bulb, C- egg tray rack, D- tray turning spring, E- thermocouple)

The eggs were candled alongside the incubation process as the experimentation continues. This was to determine the air space size in order to have a guide to the weight loss rate of the egg content. Also, to observe the development of the embryo so that infertile or dead embryo can be safely removed from the machine. Finally, on the 21 day hatching process took place. During this process close observation was made. Assistance was given to chicks during the hatch, those chicks that failed to break the shell after 12 hours duration. From the big end of the egg [8] larger holes of egg were broken starting with the two holes slowly. This procedure was repeated for the same number of eggs five times, Table 1. The incubation was powered by two standby generators during the process of evaluation to prevent the distortion that may tend to occur due to the inconsistent of the mains. The relationship below given by [3] was used to determine the hatchability of the machine.

$$Hatchability = \frac{Number\ of\ hatched\ eggs}{Number\ of\ fertile\ eggs} x100 \qquad (1)$$

4 Results and Discussion

Table 1 shows the results of the performance evaluation of the incubator which revealed the following average results, 387 fertile eggs, 325 hatched eggs and 84.06% hatchability. Table 2 shows the summary result of cost of evaluating the incubator with power obtained through generator only. This result showed that about ₦27,804 will be required to run the incubator on generator for 21 days. Fig. 5. Shows some freshly hatched chicks by the incubator.

Fig. 6. Freshly hatched chicks

TABLE 1
RESULTS OF THE TESTING OF INCUBATOR

Trial	No of Eggs Set	Fertile Eggs	Infertile Eggs	Hatched Eggs	Hatchability (%)
1	420	389	31	302	77.6
2	420	378	42	299	79.1
3	420	390	30	338	86.6
4	420	382	38	340	89.0
5	420	398	22	350	88.0
Total	2100	1937	146	1629	420.3
Average	420	387.4	29.2	325.8	84.06

TABLE 2
ECONOMIC ANALYSIS OF OPERATING THE INCUBATOR USING GENERATOR ONLY FOR 21 DAYS

Item	Rate (Naira, ₦)	Amount (Naira, ₦)
Fuel (petrol)	12l @ ₦97 per litre for 21 days	24,444.00
Engine Oil	₦60 for 21 days	1,260.00
Transportation	₦100 for 21 days	2,100.00
Total		27,804.00

5 Conclusion

It was inferred from the result that the locally made electric egg incubator with a hatcher along with egg Candler, alarming system and the turning mechanisms was tested and found to be reliable as the performance test carried out yielded an average of 84.06% hatchability. The incubator was developed to serve a dual purpose, unlike the imported type which has a separate hatcher and setter. This machine can therefore be adopted by small scale poultry farmers.

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