Full Paper

DEVELOPMENT OF A STILL-AIR INCUBATOR WITH A NON-THERMOSTATIC CONTROL

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ABSTRACT

The study reported is part of a continuing effort at improving locally fabricated incubators. The incubator developed uses electric bulbs as the heat source and has an uninterruptible power supply which is cheap to maintain, compared to a generating set. A resistance-varying device was used to control the temperature manually while the humidity was varied by varying the sizes of water pans placed on the floor of the incubator. The eggs were turned three times daily for the first eighteen days with a semi-automated device. The temperature and humidity were successfully controlled. The percent hatchability of the incubator was 62%, while the energy consumption was 3.96 kWh per chick.

1. INTRODUCTION

One of the branches in the poultry industry is the chick production. Because of the sensitivity of production, and the huge capital involved, it has become a specialized arm of the industry. Eggs may be incubated by the bird that laid them, by another bird, or artificially in a container called an incubator or setter.

There are basically two types of incubators, the forced-air and still-air incubators. Forced-air incubators have fans that provide internal air circulation. The capacity of these units may be very large. The still-air incubators, suitable for incubating 12 to 24 eggs, are usually small without fans for air circulation (Smith, 2000). 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. The size and type of incubator selected depends on the needs and future plans of the producer. For continuous incubation (when eggs are set in the incubator in batches), separation of incubator and hatcher units is recommended. The incubator and hatcher units must be located indoors to protect them from major weather changes. It is also essential that the room has a good ventilation system to provide sufficient fresh air.

Four factors are of major importance to successful incubation, chick embryo development and the hatching of robust, healthy chicks. These are temperature, humidity, ventilation and turning. Of these factors, temperature is the most critical. Temperature dictates the rate of embryonic growth and the successive proportional development of the different organs and body structures of the embryo in time (Meijerhof, 1999). Temperature in still-air incubator can vary from 38.3 ^{o}C to 39.4 ^{o}C with no harmful effects (Gleaves, 1997). However, Smith (2000) recommended a temperature of 37.8 ^{o}C throughout the entire incubation period when using forced-air incubator.

Humidity when overlooked can cause many hatching problems. Humidity must be carefully controlled to prevent unnecessary loss of egg moisture. The ideal moisture level is about 50% – 55% relative humidity for the first 18 days of incubation, and for the last three days, it should be about 65% (Gleaves, 1997). According to Oluyemi and Roberts (1979), humidity that is too low at the end of incubation impedes the emergence of chicks from their shells while too high humidity may lead to chicks emerging with wet down feathers.

Proper ventilation is very important during the incubation process. The best hatching results are obtained with normal atmospheric air, which usually contains 20% -21% oxygen. While the embryo is developing, oxygen enters the egg through the shell and carbon dioxide escapes in the same manner (Smith, 2000). Since the requirement for oxygen increases as incubation progresses, there must be provision for increased airflow around the eggs. Unobstructed ventilation holes, both above and below the eggs, are essential for proper air exchange.

Turning prevents the embryo from sticking to the shell membranes. Wageningen and Meinderts (1995) recommended a turning of 3 times a day for the first 19 days, thereafter turning is no longer necessary. The eggs must be turned through 180^{o} to allow for even distribution of heat on the eggs.

Temperature control with the use of a thermostat has always been the major setback of locally developed incubators with electrical heating system while the non-availability of constant electric power hampers the use of imported incubators. This study therefore was to develop a still–air incubator with a non-thermostatic electrical heating system and evaluate the performance of the incubator.

2. Materials And Experimental Procedure

The incubator was designed and constructed as a single unit with its framework made of 12.7 mm plywood (Fig. 1). It had two trays, each with a capacity of 20 eggs. Heat was supplied through four 15 W bulbs connected in parallel at the floor of the chamber and connected to the mains through an inverter. The circuit connection with the plan view of the incubator is shown in Fig. 2. The inverter is a device that converts direct current to alternating current. It provides continuous power supply to the bulbs in the event of power failure from the mains. With a 200 AH 12 V wet cell battery, the inverter can supply 40 h of uninterruptible power, according to the estimation:

$$\frac{200 \times 12\,Wh}{4 \times 15\,W} = 40\,h \qquad (1)$$

The hours of power supply can be increased with higher battery capacity. The inverter is self-charging. Whenever power is restored to the mains, it automatically switches over and charges the battery at the same time. At the floor of the incubator were pans containing water for humidity control. Ventilation holes were drilled at the sides of the incubator for cross movement of air. Fig. 3 shows the sectional view of the incubator.

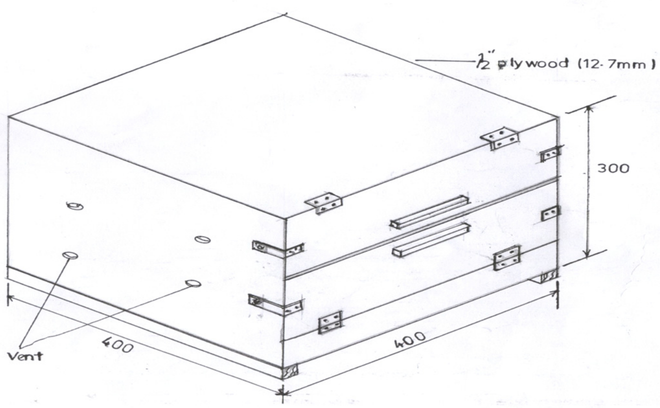

Figure 1: Side view of the still-air incubator.

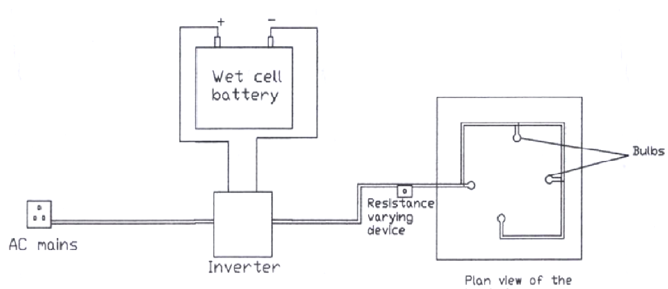

Figure 2: Circuit connection with the plan view of the incubator.

2.1 Temperature and Humidity Control

With the incubator empty, it was observed that with and without the bulbs on, the temperature of the air inside the incubator was directly related to the room temperature. This may have been as a result of heat exchange through the ventilation holes on the incubator and between the inside and the outside of the walls. Hence, the relationship was used as a basis for temperature calibration and control. An electric fan regulator was used to control the current flowing to the bulbs to generate heat in the incubator. The regulator has five resistance levels. The underlying principle was that the higher the resistance, the lower the current that flows to the bulbs, hence the lower the heat generated (and vice versa). The relationship is shown thus:

$$R \propto 1/I \qquad (2)$$

$$P = I^2 R \qquad (3)$$

where: I = current
R = resistance
P = heat generated.

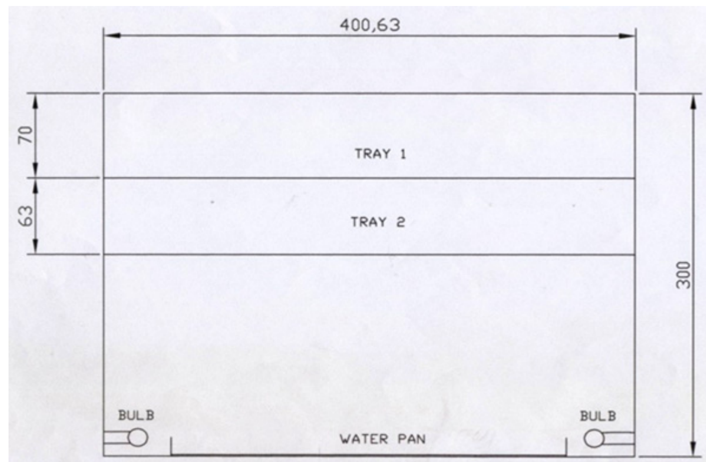

Figure 3: Sectional view of the incubator with the front side removed

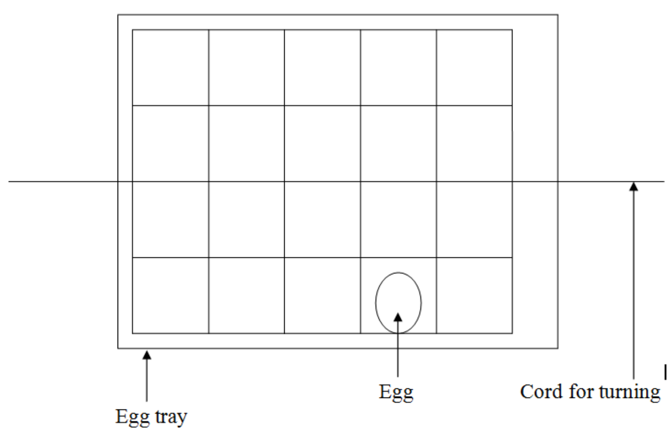

Figure 4: Plan view of the egg tray and crate for the turning (adapted from Ajayi et al., 1997).

At each resistance level, the incubator temperature and corresponding room temperature were taken at intervals for a 3-day period and presented in Fig. 5.

Based on the recommendation by Smith (2000) on still-air incubators, water pans with total surface area equivalent to one-half and two-thirds the floor surface area were placed inside the incubator to raise the relative humidity to the range of 50-60% and 61-70%, respectively.

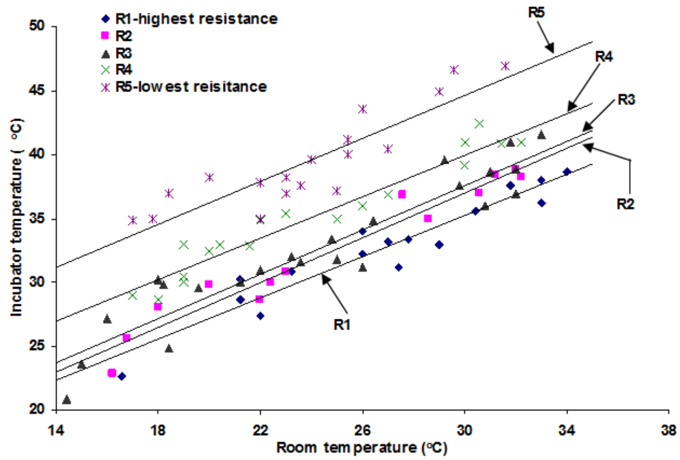

Figure 5: Calibration curves of incubator temperatures against room temperature.

2.2 Turning Mechanism

Turning of the eggs was carried out without opening the incubator door as reported by Ajayi et al. (1997). The mechanism was semi-automated in that all the eggs were turned at the same time with the use of a single solid frame partitioned into 20 egg spaces (Fig. 4). A '+' sign was placed on one side of each egg and '–' on the other side, using a pencil. This served as an aide to determine whether all eggs were turned 180°.

2.3 Test Run

Sixteen chicken eggs, of approximately 55 g each, that were laid within 7 days and stored at between 12 °C to 20 °C and between 70% to 80% relative humidity were set in the incubator. The eggs were allowed to reach room temperature; thereafter the heat was gradually increased to avoid heat shock to the eggs. The temperature inside the incubator was observed to be fairly stable in the early hours of the morning; it rose towards noon and was at its peak later in the day. The resistance level of the regulator was adjusted (with reference to Fig. 5) to control the current flowing to the bulbs to produce the required heat. Three incubator temperature readings were taken each day, at 8 am, 2 pm and 10 pm and average daily temperature calculated, from the start to the end of incubation (Fig. 6). Relative humidity was measured using a hygrometer and the reading was taken each day at 2 pm, for consistency, from the start to the end of incubation. The eggs were turned three times daily for the first eighteen days; thereafter turning was stopped. Candling was done on the seventh day to detect infertile eggs and monitor the development of the embryo.

3. Results And Discussion

The results of the regression analysis showed a significant ($P \le 0.05$) linear relationship between the incubator and room temperatures at all resistance levels. The pooled estimate of the resistance levels also showed a significant ($P \le 0.05$) relationship:

$$y = 0.76x + 15.72,\ R^2 = 0.56 \qquad (4)$$

where y = Incubator temperature and x = Room temperature

Fig. 5 showed the linear curves obtained from the data points of the resistance levels. It was observed that incubator temperature increased as room temperature increased. At the highest resistance (R1), the incubator temperature was lowest for the same room temperature at all the resistance levels.

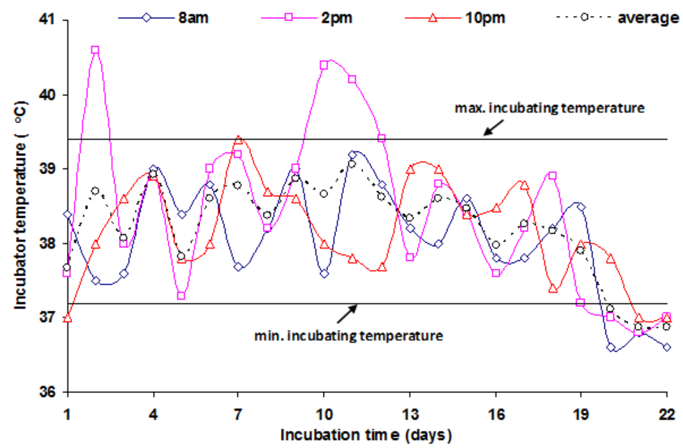

Figure 6: Profile of incubator temperatures during incubation

The incubation lasted 22 days and it was observed that the average daily temperatures were within the range of 37.2 °C and 39.4 °C for the first eighteen days (Fig. 6). However, maximum deviations of 1.2 °C, 1.0 °C and 0.8 °C above the upper limit occurred on the second, tenth and eleventh day, respectively, during the 2 pm readings. Relative humidity range of between 50% and 60% for the first eighteen days was achieved with the placement of pans with total surface area of one-half the floor space of the incubator while the range of 61% - 70% for the last four days was achieved with pans of total surface area of two-thirds the floor space (Fig. 7). Humidity was found to have a positive correlation with water surface area and incubator temperature. The eggs were turned through 180° as monitored by the '+' and '–' signs placed on each egg. The results of the candling showed that 13 eggs were fertilized as revealed by an embryo looking like a large red spider. On the twenty first day, 6 eggs were hatched and 2 others hatched on the twenty second day. On the twenty third day, the remaining 5 eggs were carefully broken and it was discovered that 2 eggs contained dead developing embryos while the remaining 3 contained fully developed weak chicks.

Observations of the temperature showed that deviations from the normal temperature did not affect the incubation adversely as the fertilized eggs still developed into fully-grown chicks. The 3 unfertilized eggs may have been due to old age of male stock or wrong mating ratio of parent stock (Wageningen and Meinderts, 1995; Anonymous, 1997). The 2 dead developing embryos may have been due to presence of bacterial and fungal infection in the incubator (Das et al., 1994) or faulty nutrition of parent stock (Oluyemi and Roberts, 1979). The 3 developed but unhatched chicks were attributed to be unhealthy (Gleaves, 1997) or may have genetic weakness (Anonymous, 1997). It is also correct to speculate that if incubation had been continued for an additional 24 hours or more, the remaining 3 chicks would have hatched. This is in accordance with Wilson (1991) and Yildirim and Yetisir (2004) who stated that lower incubation temperatures during the third week of incubation would allow for a normal hatch, reduced water loss, but increase in incubation period.

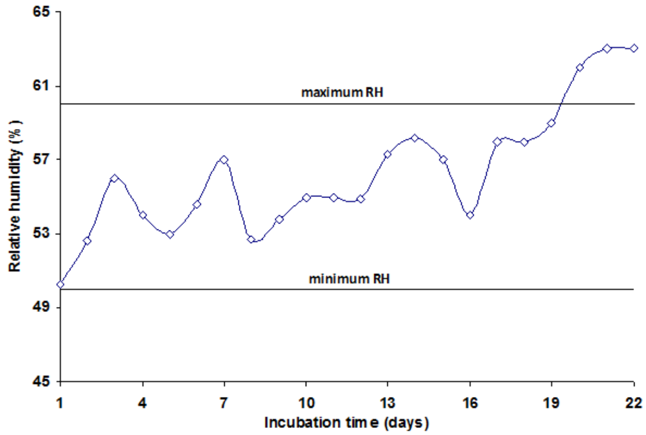

Figure 7: Profile of relative humidity during incubation.

Consequently, the percent hatchability, which is also the efficiency of the incubator, was estimated thus:

$$\% \, hatchability = \frac{total \; number \; of \; eggs \; hatch}{total \; number \; of \; fertile \; eggs} \times 100\% \qquad (5)$$

$$= 61.5\%$$

Energy consumption of the incubator was estimated based on the use of four 15 W bulbs for 22 days at 24 h/day, and found to be 3.96 kWh/chick.

4. Conclusion

A still-air incubator with an electrical heating system and with a capacity of 40 eggs per incubation period was developed. The materials are readily available to an average farmer. The heat source produced no carbon monoxide; hence the air inside was safe to the developing embryos. Temperature and humidity were successfully controlled, and were within recommended range. Turning of the eggs during incubation was effectively achieved. The percent hatchability was 62% and energy consumption, 3.96 kWh per chick.

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