DEVELOPMENT OF A LOW-COST SEMI-AUTOMATED INCUBATOR

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ABSTRACT

Most of the incubators available in Nigeria presently are imported, expensive and beyond the reach of majority of the farmers. Hence, a low cost semi- automated incubator powered by a back up inverter was developed and tested. An experiment was conducted in triplicate to determine the hatchability and incubation period of exotic chicken eggs using the incubator. The incubator consists of a heat source (100 W bulb), moisture container, a thermistor, 12 V battery, 1000 W inverter, 0.14 W electric fan and an incubating chamber having two egg trays of 80 eggs capacity each. The egg trays were turned at an interval of 6 hours. This arrangement maintained the chamber temperature and relative humidity within the range of 36 – 39 °C and 55 – 70% respectively. The hatchability of exotic chicken eggs was found to be 91% while the average incubation period was 21 days using the low cost semi-automated incubator. The incubator is suitable for hatching eggs of domestic fowls, turkeys and ducks on Nigeria farms where small-scale hatching operations are needed and there is no constant electricity supply.

KEYWORDS: Incubator, automation, thermistor, inverter, hatchability, eggs.

1. INTRODUCTION

Incubation is the process by which fertilized eggs are provided with optimum environmental condition of controlled temperature, humidity and ventilation, so that normal young chicks may be produced from them (Oluyemi and Roberts, 1988). An incubator is an enclosure providing such an optimum environmental condition.

Optimum incubation temperature is defined as the required temperature to achieve maximum hatchability (Wilson, 1991; Decuypere & Mitchels, 1992; Nakage *et al.,* 2003). Four factors are of major importance in incubating egg artificially, they are; temperature, humidity, ventilation and turning. Among these factors, temperature is the most important and if humidity is overlooked it can lead to many hatching problem. Nakage *et al.* (2003) reported that early embryonic mortality increased at low temperatures (<35.5 ºC), whereas intermediate and late embryonic mortality increased at high temperatures (>36.5 ºC). Also, Nakage *et al.* (2003) and Visschedijk (1991) had observed that under conditions of daily incubation of eggs in the same incubator, higher hatching rate can be obtained using temperatures between 35.5 ºC and 36.5 ºC.

Natural incubation involves the sitting of hen on the eggs especially when a limited number of chickens are to be raised, using the extensive system of poultry management. On the other hand, artificial incubation is achieved by the use of incubator, which is normally placed in hatchery. Heat source can be from electricity, oil, coal, steam, or gas. Odunsi (1998) categorized incubators into two types, namely; table incubators and cabinet incubators.

Isiaka and Achu (1988) had successfully hatched eggs from locally constructed hard boards and hard wood cabinet incubators of 250 eggs capacity with electric bulb as heat sources and kerosene stove or lantern as alternative heat source. Ojetunde (1995) also worked on the local construction of an incubator with plank and plywood having a capacity of 24 eggs. A hurricane lantern was used as heat source there was an outlet called chimney for the exit of smoke and other gases. The incubator had a total volume of 5400 cm^3 but it was reported to have not been tested due to time constrain. Bakare (1995) made a kerosene fuelled incubator, this incubator was constructed from locally sourced materials. The major component of this incubator includes heat source, humidifier and egg chamber. The incubator had a capacity of 80 eggs. Preliminary testing puts its working efficiency at 60%, an acceptable value considering it as a first stage design. The hatchability of chicken eggs using hurricane lantern incubator has been found by Abiola *et al.* (2008) and Adewumi (2006) to be 72.9% and 80% respectively. Also, Irtwange (2003) designed and constructed a passive solar powered poultry eggs incubator to provide free energy from the sun.

A modern/sophisticated incubator is beyond the reach of many peasant farmers and they lack the technical know-how to operate the machine coupled with the irregular electricity supply. The level of animal protein consumption in these countries had been reported to be below the recommended value (Osikoya, 2008). Hence, there is need to invent some ways that will increase the level of animal protein source in the country and one of the ways to do that is through the fabrication of a semi-automated incubator i.e. electric incubator.

The objective of this research was to develop a low cost semi-automated incubator powered by a back up inverter for use in Nigerian rural areas where there is no constant electricity supply.

2. MATERIALS AND METHODS

2.1 Design Consideration

The primary consideration is to provide the favourable temperature and relative humidity range of 35 - 39 ^{o}C and 50 – 70 %, respectively required for poultry egg embryos development (Nakage *et al.*, 2003). The following assumptions as suggested by Bakare (1995) were made in the design of the incubator:

i. Steady state condition exist in the incubator
ii. One dimensional heat flow prevails
iii. The materials have a constant thermal conductivity.
iv. The incubator is a closed system.
v. The incubation chamber temperature is 38 ^{o}C and ambient temperature is 27 ^{o}C.
vi. Heating and humidifying sources in the incubator chamber is provided.
vii. Regulation of air quality through vent holes

The incubating chamber was humidified by placing water container inside it. The value of relative humidity depends on the air movement over the water surface, distance between heat source and water, and the water surface area. The design procedure was made in such a way that it fits into the generalize block diagram as shown in Figure 1 to realize the auto room temperature control.

2.2 Capacity of the Incubator

The incubator was designed to have two egg trays that were sized to contain at least 80 eggs each for incubating and hatching. Therefore the capacity of the incubator was 160 eggs. The cross-sectional area of an egg tray was 0.1m^2. The volume of incubator was 0.54 m^3.

2.3 Estimation of Heat Load of the Incubation Chamber

Using the second law of thermodynamics expressed as

$$\Sigma \text{ Heat gain} = \text{Useful heat} + \Sigma \text{ heat loss} \quad (1)$$

The heat balance equation of the incubator chamber at temperature (38 ^{o}C) is given as:

$$Q_{heat\ load} = Q_{sup} + Q_{egg} - Q_{loss} \quad (2)$$

$$Q_{heat\ load} = m_{air} \times C_p \times \Delta t. \quad (3)$$

$$Q_{egg} = H_{emb} - H_{water\ loss} \quad (4)$$

$$Q_{loss} = Q_{condc} + Q_{conv} \quad (5)$$

Where

$Q_{heat\ load}$ = Incubator heat loss
Q_{sup} = heat supply from electric bulb
Q_{egg} = heat supply by egg due to metabolic processes (Lourrens *et al.,* 2006)
Q_{condc} = heat loss by conduction to the environment
$Q_{conv.}$ = heat loss by convention from vents to the environment.
C_p = specific heat of air (kJ/ kg^{o}C)
Δt = change in temperature in the incubation chamber
m_{air} = mass of air in the incubator, kg
H_{emb} = heat produced by embryo
$H_{water\ loss}$ = heat loss due to water loss from the shell

2.4 Determination of Size of Ventilation Area

According to Roth (2007), the size of ventilation area (A) for the air vents is given as:

$$A = V/\phi U \quad (6)$$

Where U and ϕ are the theoretical discharge velocity and a reduction factor for discharge cross section of the area respectively.

2.5 Construction of the Incubator

The incubator was fabricated from locally sourced materials. The materials were selected based on their availability, mechanical properties and relative cost. Materials used include battery inverter, thermometers, thermistor, plastic plates, aluminum sheets, chicken wire gauze, hexagonal wire gauze for building egg trays, gum, glue, hinges, iron handles, paints, set of gears, spurs and gears, a 100 W bulb, lamp holder and 0.14 W electric fan (Figures 1, 2 and 3). The materials used in the construction of the inverter were locally sourced. In selecting most of these materials adequate consideration and allocations were made to cater for the problems such as over ranges, corrosive action, rigidity and heat transfer and also cost of purchasing these materials.

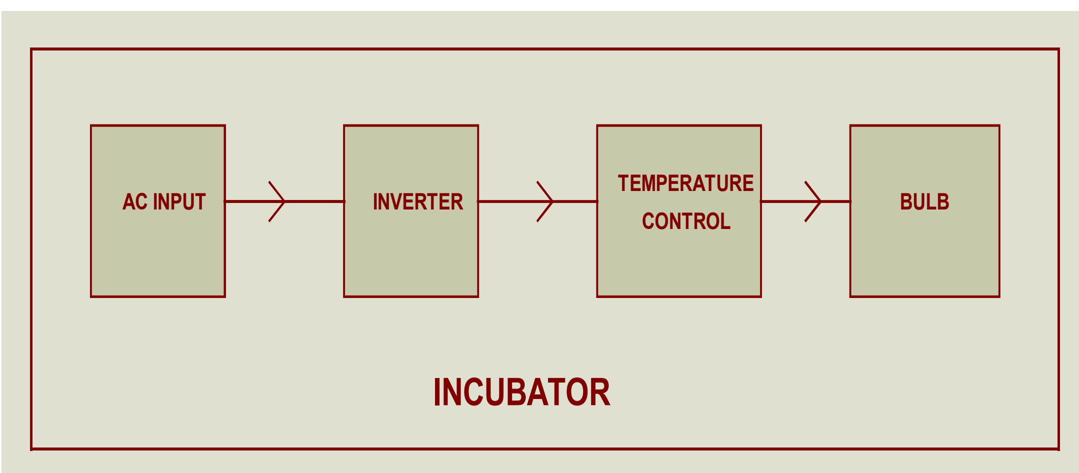

Fig 1. Block diagram of the incubator

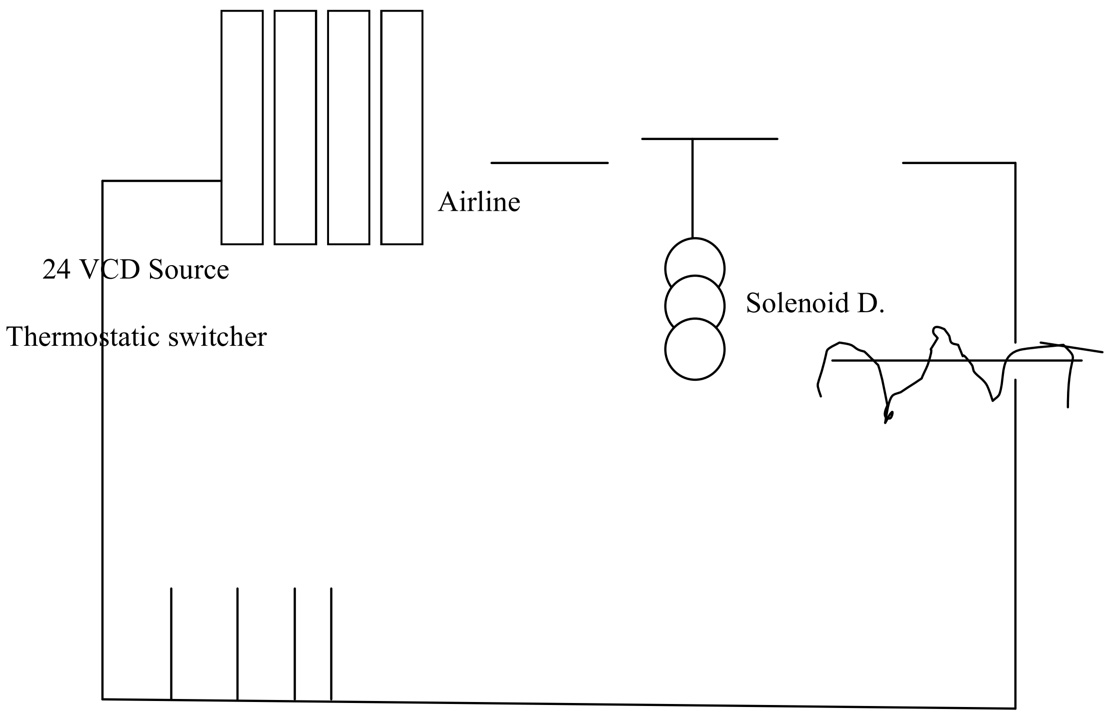

Fig 2. Circuit diagram of electrical connection of the incubator

Figure 3. Fabricated low cost semi- automated incubator showing eggs for incubation

2.6 Inverter Running Time

The total power of the load on the battery, which includes the bulb (100 W), electric fan (0.14 W) and thermistor (of negligible power rating) is 100.14 W. The capacity of the battery is 60 AH at 12 V.

Current drained by the load, I is given by

$$I = \frac{P}{V} \quad (7)$$

Where; P = Power of the load on battery, V = Voltage of the battery, P = 100.14 W and V = 12 V,

The current drained by the load, I = $\frac{100.14W}{12V}$ = 8.35 A

Therefore, the load drains a continuous current of 8.35 A from the battery.

The Battery Running time, t is given by;

$$t = \frac{FA}{I} \quad (8)$$

Where; F = Power Factor, A = Battery Amperage Capacity, I = Current drawn by load

For the inverter used as a back-up for the incubator, F = 80%, A = 60 AH, I = 8.35 A
The Battery Running time, t

$$= \frac{0.8 \times 60AH}{8.35A} = 5.75 \text{ hrs}$$

2.7 Battery Charging Time

To charge back the battery, we used a step down transformer of 15 V at 10 A. The voltage from the transformer was rectified to direct current (D.C) by a diode bridge and then filtered by a 4700µF, 50 V capacity, the output of the rectified DC is then connected to the battery, when the battery was completely charged, a comparator circuit monitors the battery voltage and stops the charging.

The Battery Charging time, t is given by;

$$t = \frac{A}{I} \quad (9)$$

Where; A = Battery Amperage Capacity, I = Charging Current

Therefore, $t = \frac{60AH}{10A}$

=6 hrs

2.8 Mode of Turning of Egg Trays

The egg trays were turned every 6 hours to maintain a uniform distribution of heat around the eggs during incubation.

2.9 Cost Analysis

The total cost of this low cost semi-automated incubator was sixty seven thousand seven hundred and fifty naira (₦67,750). The breakdown of this cost is given in Table 1.

The economic feasibility of the machine was evaluated using the payback period (P_p) method expressed as:

$$P_p = \frac{TCO}{ACI} \quad (10)$$

Where; TCO = Total cash outlay, ACI = Annual cash inflow

Then from equation 10, $P_{p=}$ 0.81 year ≈ 10 months

Based on this calculation, in 10 months of business operation, the capital investment will be recovered.

Table 1. Description of construction materials

S/N	Material	Description	Rate	Cost (₦)
1	Angle fron	1 by 1	1200	1800
2	Angle fron	1½ by 1½	1600	2400
3	Pipe	¾	750	750
4	Rod	¼	350	1400
5	Pipe	2 by 2	1700	3400
6	Electrode	-	1200	1200
7	Fibre		3500	3500
8	Pant		1200	1200
9	Galvanized sheet	-	5500	11000
10	Metal sheet	0.9	3500	8750
11	Workmanship	-	8000	8000
12	Transport	-	-	3000
13	100 watts bulb	1	100	100
14	Lamp holder	1	50	50
15	12v cooling fan		300	300
16	Temperature sensing thermistor		400	400
17	Lead		500	500
18	Inverter		10000	10000
19	Battery		10000	10000
		Total Cost		67,750

2.10 Performance Testing of Semi-Automated Incubator

The test running of the incubator was carried out without loading for four days. The test involved monitoring the temperature as well as that of the ambient in order to determine the suitability of the system as an incubator. The temperatures were measured by using a mercury thermometer. The biological evaluation of the incubator was done by loading the equipment with exotic chicken eggs. The inverter was plugged to an electric power source and the 100 W bulb, thermistor and electric fan was set into a working condition. The temperature of the incubator was maintained at 36 – 39 °C and this triggered the thermistor to close or open the control circuit that supplies current to the bulb and electric fan.

2.11 Determination of Hatchability and Incubation Period of Exotic Chicken Eggs

An experiment was conducted in triplicates to determine the hatchability and incubation period of exotic chicken eggs using the incubator.

The hatchability of the eggs was determined by the ratio of numbers of hatched eggs to numbers of fertile eggs in the incubator**.**

$$\text{Hatchability, } E = \frac{He}{Fe} \times 100\% \qquad (11)$$

Where; He =No of hatched eggs, Fe = No of fertile eggs

3. RESULTS AND DISCUSSION

The temperature readings (38 – 39 ^{o}C) during test running of the incubator met the recommended range (Nakage *et al.*, 2003) and showed that the machine was suitable for the incubation of fertile eggs (Table 2). The relative humidity observed during the test running of the incubator varied from 49 – 60% as recommended by Oluyemi and Robert (1988) and close to the range 55% – 70% maintained by Odike and Okonkwo (2011) in their incubation.

Table 3 shows the incubating chamber temperatures which were maintained at different hours of the day from the first day to the 21st day of incubation. The incubator recorded a minimum chamber temperature of 36 ^{o}C of the incubation and the maximum temperature of 39 ^{o}C.
Table 4 shows the relative humidity which were maintained at different hours of the day from the first day to the 21st day of incubation. The incubator recorded a minimum relative humidity of 55% of the incubation and the maximum relative humidity of 70%.

Fifteen eggs were set in the first hatchability test while the second and third tests involved setting ten eggs each. The average hatchability of the eggs was found to be 91% while the average incubation period was 21 days (Table 5 and Figure 4). This was improvement of the values obtained by Abiola *et al.* (2008) and Adewumi (2006) whose values were 72.9% and 80% respectively for the hatchability of chicken eggs using hurricane lantern incubator.

Table 2: Temperature readings during test running of incubator

S/N	Date of test	Morning temp ^{o}c	Afternoon temp ^{o}c
1	24/11/09	38	39
2.	25/11/09	39	38
3.	26/11/09	38	38
4.	27/11/09	38	38

Table 3. Incubation and hatchability trials

S/N day	Date of trial	Morning temperature ^{o}c	Afternoon Temperature ^{o}c	Night Temperature ^{o}c
1.	01/12/09	38	38	37
2	02/12/09	38	39	38
3	03/12/09	37	38	38
4	04/12/09	38	38	38
5	05/12/09	38	38	37
6	06/12/09	39	38	37
7	07/12/09	38	38	37
8	08/12/09	38	38	37
9	09/12/09	39	38	37
10	10/12/09	38	38	38
11	11/12/09	38	38	39
12	12/12/09	38	38	37
13	13/12/09	38	39	38
14	14/12/09	39	39	38
15	15/12/09	39	39	38
16	16/12/09	38	37	38
17	17/12/09	39	36	38
18	18/12/09	38	38	38
19	19/12/09	39	38	39
20	20/12/09	38	37	37
21	21/12/09	39	38	38

Table 4. Relative Humidity of the Incubation

Date	7.00 am			9.00 am			12.00 pm			3.00 pm			6.00 pm			9.00 pm		
2011	DBT	WBT	RH%	DBT	WBT	RH%	DBT	WBT	RH%	DBT	WBT	RH%	DBT	WBT	RH%	DBT	WBT	RH%
30/11							38	32	65	38	33	70	37	33	65	36	320	63
01/12	37	30	63	37	31	60	39	32	65	39	33	70	39	33	65	38	30	55
02/12	38	31	60	38	31	60	39	30	55	38	32	65	40	33	60	38	33	70
03/12	38	29	50	38	32	65	38	33	70	38	33	70	38	33	70	38	31	60
04/12	36	30	65	39	33	65	38	32	65	38	33	70	39	33	60	38	33	70
05/12	36	31	70	38	31	60	37	32	70	39	33	70	39	33	65	37	30	60
06/12	37	30	60	37	32	70	39	34	70	38	35	70	39	32	60	36	31	70
07/12	37	31	60	38	30	55	37	33	70	39	33	70	39	33	65	36	31	70
08/12	37	30	65	38	30	55	38	32	65	39	33	65	38	33	70	37	33	70
09/12	36	30	65	38	31	60	38	33	70	38	32	65	38	32	65	38	33	70
10/12	36	31	70	37	32	70	39	33	70	38	33	70	37	32	70	37	31	60
11/12	37	30	60	38	32	65	39	33	70	37	33	70	38	32	65	38	30	55
12/12	37	29	55	37	31	63	38	33	65	38	33	70	38	32	65	37	31	60
13/12	37	31	65	37	32	70	38	33	70	38	32	65	38	32	65	38	30	55
14/12	37	30	60	38	32	65	39	34	70	38	32	65	39	33	65	37	32	70
15/12	36	32	70	37	31	60	37	32	70	38	32	65	39	33	65	38	32	65
16/12	36	30	65	37	31	60	38	32	65	39	34	70	39	33	65	38	32	65
17/12	36	31	70	37	32	70	37	32	60	38	34	70	39	34	70	37	32	70
18/12	36	32	70	37	31	60	38	32	65	39	34	70	38	32	65	38	32	65
19/12	36	30	65	37	32	70	38	31	60	38	33	70	38	32	65	37	32	70
20/12	36	32	70	37	33	70	38	34	70	39	32	70	38	33	70	37	31	65

Table 4. Average efficiency and incubating days

Experiment	No of fertile eggs	No of hatched eggs	Hatchability%	Average Incubating days
1	15	14	93.8	21 days
2	9	8	88.8	21 days
3	10	9	90	21 days
Average	11	10	91	21 days


Figure 4. Low cost semi-automated incubator showing hatched eggs

4. CONCLUSION

A low cost semi- automated incubator powered by a back up inverter was designed and constructed based on the introduction of a thermistor which was a component that detects heat and temperature changes in the incubator. The rating of the semi automated incubator was 100.14 W with a capacity of 160 eggs. This arrangement maintained the chamber temperature and relative humidity within the range of 36 – 39 °C and 55 – 70 % respectively. The hatchability of the eggs was found to be 91% while the average incubation period was 21 days. The incubator is suitable for hatching eggs of domestic fowls, turkeys and ducks on Nigeria farms where small-scale hatching operations are needed and there is no constant electricity supply.

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