INFLUENCE OF TEMPERATURE REGULATING DEVICE AND RELATIVE HUMIDITY MONITORING ON PERFORMANCE OF A NATURAL CONVECTIVE HEATED INCUBATOR

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Abstract
The effect of temperature regulating device and relative humidity monitoring was carried out on a natural convective heated incubator. The experimental rig was used to evaluate the performance of the temperature regulating device and relative humidity in a natural convective heated incubator. A natural convective heated incubator experimental rig was designed, constructed and evaluated. The effect of temperature regulating device and relative humidity monitoring was carried out on a natural convective heated incubator. The temperature monitoring unit was made of ether and copper sheet and placed in the incubating chamber. The source of heat was kerosene stove. The performance of the incubator was done at no load and when loaded with fertile eggs for the two stages of experiments that were carried out. The incubator was observed to operate between 35^0C – 39^0C dry bulb temperature and 54% - 75% relative humidity respectively. The size of the aperture opening of the temperature regulating device was used to evaluate the performance of the device. The results of the t-test analysis of the effects of temperature regulating device on a natural heated incubator was 1.25 and 0.21 respectively at 5% probability level. The effects of the average dry bulb temperature on a natural heated incubator were 0.12 and 0.17 respectively at 5% probability level. The average temperature ranged from 35^0C to 39^0C while average relative humidity ranged from 60% to 83% respectively.

Keywords: convection, incubator, ether capsule, temperature regulation, relative humidity

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1. INTRODUCTION

Egg incubation is a technology that provides opportunity for farmers to produce chicks from egg without the consent of the mother hen, is also one of the ways of transforming eggs to chicks (Benjamin and Oye, 2012). Incubation is a process of managing fertilized eggs to ensure a satisfactory development of the embryo into a normal chick (Oluyemi and Robert, 1988). Incubation process is aimed at effective management of a fertilized egg to level of producing a normal chick. This process of incubation can be through natural or artificial methods. The most important difference between natural and artificial incubation is the fact that the natural parent provides warmth by contact rather than surrounding the egg with warm air. Early poultry farming practices involved free range extensive system that occupy a portion of land space and birds are allowed to move around without being confined. The birds used for poultry farming were the local breeds of fowls which produce less number of eggs and the eggs hatched through natural incubation are few. Natural method of incubation was observed to have low output because of the limited number of eggs the hen can incubate at a time (Oluyemi and Robert, 1988; Benjamin and Oye, 2012). Thus, the need for more improved egg production made researchers to come out with hybrid fowls to meet the need for more egg production. Poultry farming is done on a large scale nowadays, since the natural incubation cannot provide an adequate supply of chicks needed. According to FAO (2004) the artificial incubation attempts to duplicate entire tasks carried out by the brooder hen in natural incubation.

Modern incubators are highly sophisticated, expensive and standardized in which temperature and relative humidity are strictly controlled within the range values of 35-37^{o}C and 58-70% respective, and with adequate provision made for proper ventilation and egg turning (Onipede, 2004; Oluyemi and Robert, 1998). Temperature, humidity, ventilation and turning of eggs are very important factors during incubation, which must be monitored for successful hatching of eggs but care is needed to monitor these and other factors for incubation to be successful (Singh, 1990). Most poultry species have an optimum incubation temperature of 37-38^{o}C any small deviations from the optimum can have a major impact on hatching success and embryo development. Thus, there is a need to keep the temperature in the incubator constant and it is also important to insulate it well to prevent heat losses in the chamber (Wilson, 1991; French, 1996; Lourens et. al, 2005; Abu, 2008). Humidity and temperature are critical during incubation as the incubation process of egg is synonymous to drying process because egg need to lose moisture through the pores of the shell and it is best to prevent eggs from drying out because when the relative humidity is not correct the embryo will dry out or will not be able to get rid of poisonous gases in the eggs (Nico and Johan, 1995). Relative humidity of air within an incubator should be about 50-60% with an increase of 65-70% for the last three days of incubation. Philips (2006) reported that excessive humidity in the incubator prevent normal evaporation while low humidity results in excessive evaporation causing the chicks to stick to the shells.

Four factors are of major importance in incubating eggs artificially; temperature, relative humidity, ventilation and turning of eggs. Temperature is the most critical however; humidity tends to be over looked and causes many hatching problems (Philips, 2006). Optimum incubator temperature is 37.8^{o}C while relative humidity is 60%, also concentration of oxygen should be above 20% carbon dioxide should be below 0.5% and air movement past the eggs should be 0.00566m3/s (Philips, 2006). Relative humidity is the amount of moisture on the air in the incubator. Constant accuracy of humidity is less critical than that of temperature (Brinsa, 2006). The main objective of this study is to investigate and monitor temperature and relative humidity conditions in a natural convective heated incubator.

2. MATERIALS AND METHODS

2.1. Description of Experimental Materials

2.1.1. Description of experimental rig

The studies of the effects of temperature and relative humidity were investigated in a natural convective heated incubator. Ikewu (2005) designed and constructed a natural convection incubator but the performance was only on the ventilation levels. A natural convective incubator was designed and constructed as an experimental rig for the study. The experimental rig was used to evaluate the performance of the temperature regulating device and relative humidity in a natural convective heated incubator. The natural convective heated incubator consists of a boiler unit, hot/cold water tank, incubating chamber, seven banks of galvanized steel pipes, and temperature regulating device and water bowls for monitoring relative humidity. The choice of natural convective heated medium was aimed at providing cheaper and appropriate source of energy suitable for farmers at the instance of high cost of electricity to power their incubator. By design, the heat released from the surfaces of the seven hollow pipes was used to increase the ambient temperature (27^{0}C) to the required incubating temperature of 37^{0}C -38^{0}C under close monitoring with the aid of the temperature regulating unit. The temperature regulating device consists of an ether-capsule that was incorporated into the experimental rig to constitute the natural convective incubating system with temperature and relative humidity regulation. The developed incubator which served as an experimental rig was an adaptation of the natural convection and radiation heat transfer grain dyer. It consists of a boiler unit, incubating chamber, hot/cold water tank, ventilation holes, egg trays, and pipes. The whole components were supported by stands (Figure 1). The egg turning was achieved through vertical sliding of stirrer handle as shown in Fig. 1. The stirrer activates the rotation of the eggs tray such as to expose the eggs to uniform distribution of incubating temperature and prevailing relative humidity within the incubation chamber.

2.1.2. Ether capsule Temperature Regulating Device and Humidity Control

The ether capsule serves as the temperature control in the incubating chamber. It senses the temperature inside the chamber to ensure that it does not exceed its desired temperature of 38^{o}C by pushing the vertical rod shown in figure 1 towards the lid at the top of the incubator as the capsule expands.

The rod tilts and lifts a trap in the lid of the incubator to allow the escape of hot air from the inside. When the temperature drops, the capsule contracts and the trap close again.

The ether capsule is made up of copper sheet and liquid ether. It is hanged inside the incubator with a special support where a rod is attached to the upper capsule discs. This rod can slide up and down, a small tube linking the capsule holder to the incubator lid.

The volumetric capacity of the incubator was 0.272 m^3. The total volume covered by the lagging materials, egg trays, humidity bowls and eggs.

Heat energy required during incubation was estimated at 1227 kJ. Frankel et. al (1997), Holman (2005) and Rajput (2004) presented expressions for estimation of the heat transfer from the hot water flowing in the pipe to the surface of the pipe and the heat energy was calculated as 49.09 J/s. The ether capsule operates on heat differential before and after expansion during thermodynamics activities within the incubating chamber. The heat dissipated before and after expansion were estimated as 8.98×10^{-3} W and 8.98×10^{-3} W respectively. The differential in heat gained was 1.4×10^{-4} W.

(a) (b)

Figure 1. Illustration of (a) Experimental Rig showing the natural convective incubating system and (b) ether-capsule as temperature regulating device

2.2. Experimental Methods

2.2.1. Methods of Instrumentation of Experimental Rig

A natural convective heated incubator was constructed and used as an experimental rig for this experiment. Performance of the temperature control device and relative humidity were investigated to observe the control of temperature variation and relative humidity within the incubating chamber. The rig was disinfected and tested without load for 24 hours to correct any defect in the chamber before loading the eggs.

The incubator was placed in a room with adequate ventilation. It was loaded with sixty eggs in the tray with their broad ends up with an ambient temperature of 35^0C and relative humidity of 70%. The temperature control device is to ensure that the temperature within incubating chamber is within 38^0C. This device regulates the opening and closing of the vent in the chamber. The size of the aperture opening was related to the changes in the temperature within the incubating chamber.

The null hypothesis on the statistical analysis of the effects of temperature and relative humidity variations with respect to size of the aperture opening of ether capsule that regulates temperature device was accepted. This indicates that the automatic opening and closing of the temperature regulating device provided the desired optimum incubator chamber temperature of 37^0C - 38^0C. The aperture, regulated by ether capsule, created by the vent allows air to move in or out of the chamber. The size of the aperture was measured as the ether capsule expands or contract. Sets of thermometers were inserted into the chamber to capture the temperature readings periodically.

The wet and dry bulb thermometers were recorded with their corresponding relative humidity daily at least four times. Humidity was regulated by putting a water container below the underlying pipes in the incubating chamber.

The volume of water in the assigned container was regulated within a fixed period. Egg turning was done manually with the aid of a handle from the outside of the incubator which turns the egg tray sideways at an angle of 45^0C. The turning was done four times daily but was stopped after 19^{th} day of incubation as cited by Onipede (2004).

Candling was done on the ninth and eighteenth days of incubation respectively by passing a light beam from a home-made eye viewer through each egg to determine their fertility.

Preliminary tests were conducted to determine how efficient the machine would be i.e. the incubator was tested without installing temperature control device. This was done to know how long it will take the temperature to get to 38^0C. The incubator was also tested at no feed and at load when the temperature control device was installed. The incubator was loaded with sixty fertile eggs. Factors considered for effective hatching of the fertile eggs are temperature, relative humidity and turning.

2.2.2. Temperature control measurement

The expansion of the ether capsule that regulates the temperature variation within the incubating chamber through the opening of the trap was measured. The exposed area (A) of the trap and height (H) of the lever were measured with respect to internal temperature (T). These measurements were taken at an interval of six hours for twenty-one days.

Another important logic that was employed in controlling the temperature inside the incubating chamber is by opening the vent on top and below the incubating chamber when the temperature in the chamber is above the incubating temperature.

The vent whether half or fully opened allows more air into the chamber, thereby reducing the temperature to the desired incubating temperature.

Four readings of the size of the aperture were taken at equal interval per day at no load and at full load.

The corresponding temperature readings were taken. The null hypothesis that was generated for the purpose of this study is

Hypothesis I (H_{o1}): there is no significant relationship between the temperature control device and the system performance.

2.2.3. Relative humidity measurement

Since the heating chamber is completely shielded away from the influence of the immediate environment. The two bowls containing water were place below the underlying pipes in the incubators in order to boost the humidity level. The bowls were filled to maximum levels marked as x1 and minimum level as x2. The reduction was monitored and then measured throughout the incubation period. The time taken for the water to reduce to its lowest marked level was noted and the water was replenished after the measurement was taken.Four readings were taken at equal interval per day at no load and when loaded with fertile eggs to monitor relative humidity within the incubating chamber. The corresponding readings were taken and recorded. The null hypothesis that was generated is Hypothesis II (H_{o2}): there is no significant relationship between the relative humidity and the system performance.

2.2.4. Turning of Egg Trays

Turning is needed in order to avoid the sticking of the chicks to the egg shell and to improve gaseous exchange. To achieve this, a flat bar was hinged to the edge of the egg trays. This was connected with another flat bar that leads to the top of the incubator chamber. Three holes were drilled on the flat bar leading to the top of the incubator. It was drilled to tilt the trays through an angle of 450 either side of the horizontal (an overall angle of 90^o) at predetermined intervals. This was tilted every six hours (four times in a day) and record was taken each day was later stopped on the nineteenth day of incubation.

2.3. Performance parameters

The temperature variation within the incubating chamber was observed and monitored through the size of the aperture. The size of the vent opening was taken periodically and corresponding incubating temperature was recorded accordingly.

The performance of the incubator was evaluated by using the following indicators by Philips (2005) and Onipede (2004)

a) Percentage fertility: percentage of fertile eggs of all egg produced

Percentage fertility = number of fertile eggs / number of eggs produced

b) Percentage hatchability: is the percentage of fertile eggs which actually hatched

% hatchability = number of eggs hatched / number of fertile eggs

c) Percentage mortality: is percentage of dead chicks of all fertile eggs produced

% mortality = number of dead chicks/ total number fertile eggs

3. RESULTS AND DISCUSSION

Data obtained when comparing the experiment at no load and when loaded with fertile eggs for average temperatures (^{0}C), average relative humidity (%), average aperture opening above zero reading (mm) and for the amount of water depleted (cm^3) during first and second experiments are presented in Tables 1-5 respectively. The data were subjected to statistical analysis using t-test; test of significant was conducted at 5% probability level to compare the set of data obtained. Results of performance of the incubator when loaded with fertile eggs are presented in Tables 6-7 respectively.

The cumulative average for the temperature and relative humidity were 37.4^{0}C and 62.30%. The highest values for the average temperature and average relative humidity were 40^{0}C and 73% respectively while the lowest values obtained were 36.2^{0}C and 51.1% respectively (Table 1).

The maximum value for the average temperature and relative humidity when it was loaded were 39^{0}C and 83.8% while the cumulative average for the temperature relative humidity were 37.40c and 70% (Table 2). Table 3 shows the cumulative average and relative humidity as 37.3^{0}C and 60%; maximum and minimum values for average temperature were 38.7^{0}C and 34.7^{0}C while maximum and minimum values for average relative humidity were 75.7% and 57.8%.

Table 1. Summary of the experimental results obtained from the test at No load.

Days	Dry Bulb Temperature (°C)*	Relative Humidity(%) **	Aperture Opening above zero Reading (mm)***
1	38.0	56.2	8.0
2	40.0	51.1	15.0
3	37.0	67.0	22.0
4	37.7	63.3	28.0
5	36.5	73.0	16.0
6	36.7	62.3	29.0
7	36.2	63.2	29.0
Mean	37.4	62.3	21.0
Std Deviation	1.2	7.0	8.0
Mode	-	-	29.0
Median	37.0	63.2	22.0

* Average Temperature taken per day at 6 hours intervals.
** Average Relative Humidity taken per day at 6 hours intervals.
*** Average Aperture Opening taken per day at 6 hours intervals.

Table 2. Summary of the experimental results obtained when loaded (Rep I)

Days	Dry Bulb Temperature (°C)*	Relative Humidity (%) **	Aperture Opening above zero Reading (mm)***
1	38.1	60.0	7.0
2	36.8	54.4	14.0
3	38.4	72.1	18.0
4	37.7	68.9	18.0
5	38.4	79.9	33.0
6	37.5	83.3	24.0
7	38.8	82.7	19.0
8	36.8	78.7	17.0
9	36.1	77.8	22.0
10	37.8	64.0	18.0
11	37.6	69.7	18.0
12	35.0	77.0	13.0
13	38.4	69.7	14.0
14	39.0	79.8	13.0
15	37.6	75.1	14.0
16	37.5	67.6	13.0
17	35.0	62.2	14.0
18	37.5	64.8	19.0
19	37.1	62.5	16.0
20	37.6	60.5	20.0
21	37.5	61.6	25.0
22	37.1	68.9	19.0
23	37.3	67.6	20.0
Mean	37.4	70.0	17.7
Std Deviation	1.0	8.1	5.2
Mode	37.6	68.9	14.0
Median	38.8	-	18.0

* Average Temperature taken per day at 6 hours intervals.
** Average Relative Humidity taken per day at 6 hours intervals.
*** Average Aperture Opening taken per day at 6 hours intervals.

Table 3. Summary of the experimental results obtained when loaded (Rep II).

Days	Dry Bulb Temperature (°C)*	Relative Humidity (%) **	Aperture Opening above zero Reading (mm)***
1	38.3	57.8	7.0
2	38.0	68.6	15.0
3	38.2	66.1	22.0
4	38.2	68.6	23.0
5	38.5	70.0	20.0
6	38.2	70.1	23.0
7	36.7	71.7	26.0
8	38.2	70.2	32.0
9	37.5	69.5	34.0
10	37.2	71.6	26.0
11	34.7	73.2	21.0
12	36.0	66.7	15.0
13	36.7	67.8	14.0
14	36.7	67.0	12.0
15	37.5	69.6	20.0
16	38.7	71.4	19.0
17	38.0	69.8	15.0
18	37.0	72.3	20.0
19	37.0	73.4	18.0
20	36.5	75.7	17.0
21	37.5	68.3	25.0
22	36.7	64.1	22.0
23	37.2	64.4	23.0
Mean	37.4	69.1	20.4
Std Deviation	0.9	3.7	6.2
Mode	37.5	69.6	15.0
Median	38.2	68.6	20.0

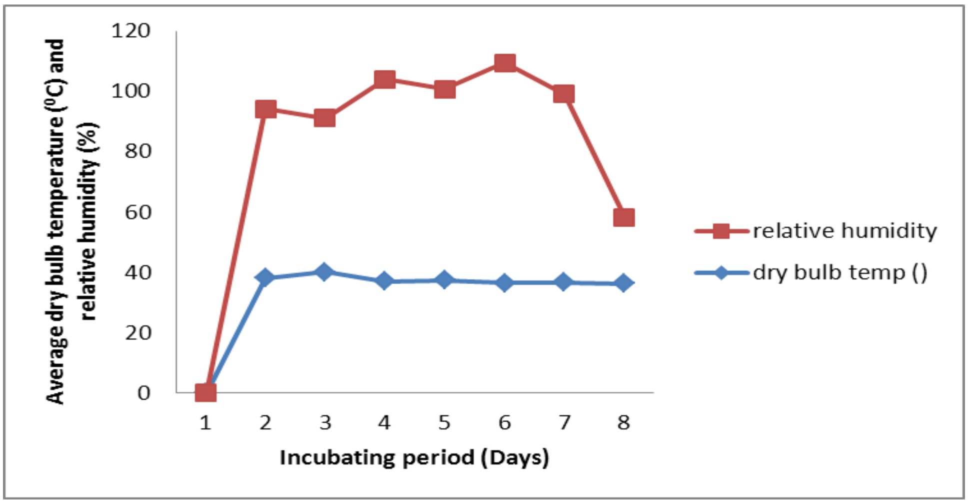

Figure 2: Average dry bulb temperature and relative humidity against incubation period at no load

3.1 Effects of temperature regulating device on a natural convective heated incubator

Figure 2 shows the effects of temperature regulating device and relative humidity monitoring on a natural convective incubator at no load. The experiment was performed for a week at no load. Nico *et al.* (2004) inferred that it is advisable to operate a new incubator for one week without eggs to detect and rectify any abnormality in the incubator. Figure 3 shows experimental result of the effect of temperature regulating device and relative humidity monitoring on a natural convective heated incubator when loaded with fertile eggs.

The average temperature ranged from 35^0C to 39^0C while average relative humidity ranged from 60% to 83% respectively. This may be as a result of the regulating and monitoring devices being introduced into the incubating chamber.
Tables 1 and 2 show that temperatures are not significant 5% probability level. This implies that the difference will not influence the hatchability of the fertile eggs hence, null hypothesis I was accepted.

3.2 Effects of relative humidity monitoring device on a natural convective heated incubator

Relative humidity monitoring device is significant at 5% probability level. This shows that the difference will influence the hatchability of the fertile eggs hence the null hypothesis is rejected.

3.2.1 Effects of amount of water depleted during incubation

Result of the test showed that water depleted in the bowls was significant at 5% probability level. This indicates that the difference will influence the hatchability of the eggs in the incubator. As a result of this hypothesis which states that there is no significant relationship between the amounts of water depleted in the bowls during the experiment was rejected.

3.2.2 Effects of the aperture opening on the incubating chamber

Tables 6 and 7 show the effect of the aperture opening on the incubating chamber with assume of an equal variance on the fertile eggs. The result of the test showed that the aperture opening on the incubating chamber was not significant at 5% probability level. This indicates that the difference will not influence the hatchability of the fertile eggs in the incubator; hence, the null hypothesis is accepted.

Table 4. Summary of the amount of water depleted during the Incubation Process when loaded (Rep I)

Days	Water Depleted in Bowl 1(cm^3)*	Water Depleted in Bowl 2(cm^3)**
1	87.3	92.0
2	92.0	77.6
3	73.7	82.5
4	77.6	92.0
5	82.5	87.3
6	92.0	73.7
7	82.5	87.3
8	63.1	82.5
9	77.6	93.1
10	54.3	82.5
11	63.1	82.5
12	58.2	106.7
13	63.1	93.1
14	87.3	87.3
15	58.2	92.0
16	77.6	116.4
17	82.5	73.7
18	82.5	87.3
19	63.1	87.3
20	63.1	97.0
21	54.3	73.7
22	82.5	87.3
23	63.1	93.1
Mean	73.1	87.9
Std Deviation	12.4	9.9
Mode	63.1	87.3
Median	77.6	87.3

***** Average water depleted taken per day at 6 hours intervals in bowl 1.
** Average water depleted taken per day at 6 hours intervals in bowl 2.

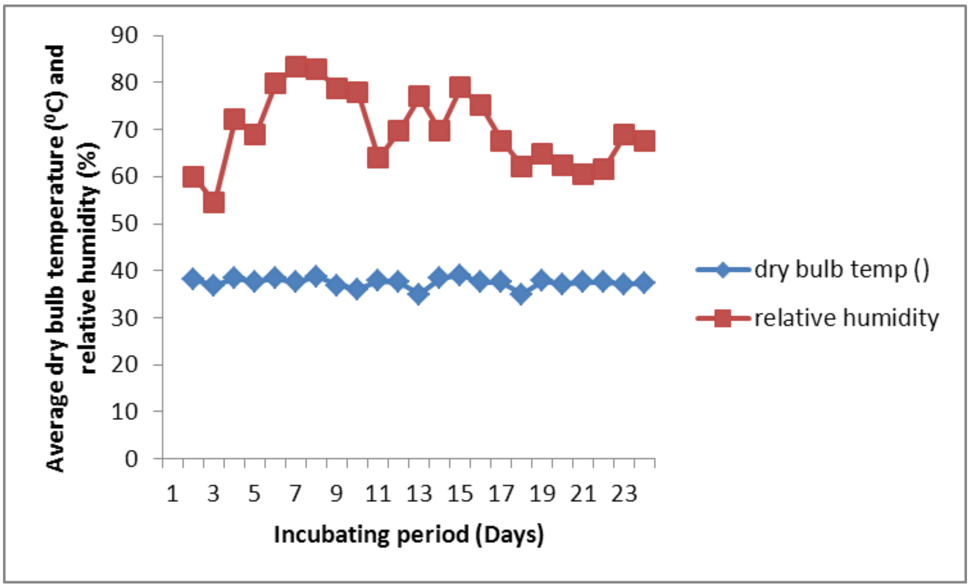

Figure 3: Average dry bulb temperature and relative humidity against incubation period when loaded (Rep I)

Table 6: t-Test Assuming Equal Variance on the Aperture Opening on Incubating Chamber during the Incubation Process when loaded (Rep I)

	No load	*Loaded 1*
Mean	2.1	1.774
Variance	0.68	0.273
Observations	7	23
df	28	
t Stat	1.259	
t Critical two-tail (calculated)	2.048	

Table 7: t-Test Assuming Equal Variance on the Aperture Opening on the Incubating Chamber during the Incubation Process when loaded (Rep II)

	No load	*Loaded 2*
Mean	2.1	2.039
Variance	0.68	0.376
Observations	7	23
df	28	
t Stat	0.212	
t Critical two-tail (calculated)	2.048	

4. CONCLUSIONS

The effects of temperature regulating device and relative humidity monitoring on a natural convective heated incubator was investigated. The incubating was fabricated and tested with fertile eggs. Based on experimental results, the following conclusions were drawn:

1. At no load, the cumulative average temperature and relative humidity of the incubator were 37.4^{0}C and 62.3%
2. The natural convective heated incubator when loaded with fertile eggs during the first experiment gave cumulative temperature of 37.4^{0}C and relative humidity of 70%.
3. Since the environmental condition for the hatching of different poultry eggs are within a similar range (Abu, 2008; Benjamin and Oye, 2012) this equipment could be used to hatch the eggs of poultry such as ducks, turkeys, goose, guinea fowl and ostrich, thus, increasing the country's food production. It is recommended for household use, subsistent poultry farmers to increase the production of poultry products.

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