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Development and Performance Evaluation of a Low-Cost, Sustainable Poultry Incubator for Enhancing Rural Livelihoods in Taraba State, Nigeria

¹*Zenum N., ²Kabah J. D. and ¹Dike U. A.

¹*Department of Animal Production and Health, Faculty of Agriculture and Life Sciences, Federal University, Wukari, P. M. B. 1020, Wukari, Taraba State, Nigeria

²Department of Crop Protection, Faculty of Agriculture, Taraba State University Jalingo, Nigeria

*Corresponding Author: nuhuzenum@gmail.com /+234 7068131855

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ABSTRACT

A local poultry incubator was designed and constructed, using plywood. Two trials were done to ascertain the functionality of the lantern poultry incubator. In the first and second incubations, 120 eggs each were set. Fertility was 100% in the first and 98.33% in the first and second trials respectively. Hatchability was 21.61% and 51.66% in the first and second incubation respectively. The mean eggs weight set for the first and second trial were 38.73g and 37.01g respectively. This greatly affected hatchability as they were below recommended weight of 45-56g. It is however, recommended that acquisition of local lantern poultry incubator by local farmers will enhance poultry production in the long run. Knowledge of egg size and weight 45-56g will also guarantee better hatchability when all other management practices are optimized.

Keywords: Poultry Eggs, Incubator fabrication, Hatchability, Kerosene Lantern,

INTRODUCTION

Poultry production constitutes an important form of livelihood for rural and urban dwellers engaged in the production of meat, eggs, day-old chicks and poultry manures. Abiola *et al.* (2008) reported that production is globally promoted as the cheapest sources of animal protein for its high prolificacy and faster growth of the fowl. Poor fertility and hatchability rates are among other factors that constrains performance of the industry. Egg incubator provides opportunity for farmers to

produce chicks from eggs, two main types of incubation exist, natural and artificial, differentiated by sources of warmth provision to the developing eggs (Benjamin and Oye, 2012). Kerosene incubation for eggs hatchery is an important process involved in reproduction; this is a large-scale method of poultry farming for adequate supply of chicks since one cannot rely on broody hens. The eggs are held in trays which hatch several numbers of eggs at a time. The machine is an indigenous invention; thus,

all the basic parts are made from locally available raw materials (plywood

d). It is very cheap, durable, simple and efficient, therefore an indispensable asset to Nigerian agriculturist for reproduction in poultry (Samuel & Duvuna, 2011).

Several factors are known to affect hatchability of eggs in an incubator, these include temperature and humidity control, conditions of the eggs and turning frequency. Tona *et al.* (2005) indicated that turning eggs in the first week of incubation enables proper formation of extra embryonic membranes, while in the last week avoids embryonic malfunctioning. Egg turning facilitates the transfer of yolk nutrient to the embryo via the sub-embryonic fluid (Elibol and Brake, 2014). With modern incubators, automatic turning devices allow the eggs to be turned on hourly basis. However, for table top incubators, manual turning of eggs is very critical to the developing embryos. Abiola *et al.*, (2008) observed that manual turning of eggs once a day is suitable to ensure minimal egg weight loss. Different types of poultry egg incubators have been recommended for small scale hatchery operators (Irtwange, 2003) reported that in the developing countries, fabricated table type Kerosene incubators will greatly expand and enrich small scale hatchery operations.

Hatchability among free range chickens was reported to be satisfactory at 75% -80% percent (Byarugaba *et al.*, 2002, Sonaiya and Swan, 2004). Higher hatchability proportion among village chickens was reported in other countries (Moges *et al.*, 2010). A mean hatchability range of 80.4% in dry season to 89.3% in the wet had equally been observed in eastern Uganda (Kirunda *et al.*, 2010). Several other factors affect hatchability of eggs, they include, Season of laying, diseases, nutrition, chicken age, egg quality, genetic factors, hygiene and incubation conditions mainly temperature, humidity, ventilation, position and turning of the eggs (Damilov, 2000, Wilson, 2004 Tona *et*

al., 2005 and Kirunda *et al.*, 2010). Hatchability up to 72.9% was achieved when eggs were turned at least thrice a day (Abiola *et al.*, 2008). In addition, eggs initially need a controlled heat input to maintain the optimum temperature of about 38°C and moisture level of 60 to 80% r. h., for appropriate embryonic development (Sonaiya and Swan, 2004).

Energy use in agriculture relates closely to the economic development of a country, particularly poultry production of day-old chicks (Da-silva and Mhlanga, 2011, Smith, 2014). Commercial production of day-old chicks hinges on an incubator, which are equipment that provide regulated heat for embryonic development of chicks from eggs within a period of 21 days. Different types of incubators exist; named according to the source of heat used in the incubation process. Kerosene lantern incubator is powered by kerosene oil for 21 days' period of incubation. This popular incubator is cheap to construct but limited by the costs of kerosene oil, and do not technically require skilled personnel. Air exchange is attained by mere evaporation due to heat, while fresh air enters near the base of the incubator (Benjamin and Oye, 2012).

Natural incubation depends on large healthy broody hens. A maximum of 14-16 eggs may be brooded in one nest, but hatchability often declines with more than 10 eggs (King'Ori, 2011). The incubation period for chicken eggs is 20-21 days, and increases up to 30 days for other poultry bird's eggs. The eggs are tested for fertility after one week by candling to ascertain its fertility (Banerjee, 2013; Umar *et al.*, 2016). Hatchability ranges of 75-80 percent is satisfactory for natural incubation, turning the eggs several times, each day is important to prevent the embryo from sticking to the shell membranes, with hand turning systems 4-6 times a day will ensure proper orientation of the developing embryo (Umar *et al.*, 2016). Poor results are mostly produced with improper control of temperature and humidity, it means that if too high or too low for a length of time,

will interfere with the normal growth and development of the embryo, same also for poor ventilation, egg turning frequency and sanitation, the incubator and handlers (Smith, 2014).

Throughout the incubation period, where these conditions are optimal, best hatchability is obtained. An excellent method to determine correct humidity is the candling inspection, the normal size of the air cell after 7,14 and 18 days of incubation, the Chicken eggs weight decreases by up to 12% if good hatches are expected (University of Illinois, 2014). Level of humidity is optimal in properly ventilated still-air incubators, providing additional pan of wet air or a wet sponge, humidity is maintained by increasing the exposed water surface area (Shingane *et al.*, 2011). The developing embryo needs oxygen supplied through the eggshell, while carbon-dioxide escape outward. Ventilation holes adequately improves the incubator efficiency, over-heating and oxygen budget may greatly suffocate the embryo (University of Illinois, 2014). Eggs must be turned at least 4-6 times daily during the incubation period, but not during the last 3 days before hatching, as the embryos are moving into the hatching position. Optimum temperatures humidity and ventilation are critical at these later stages of hatching (Umar *et al.*, 2016).

The eggs are initially placed in the incubator with the large end up or horizontally with the large end slightly elevated. This enables the embryo to remain oriented in a proper position for hatching, the small end should never be turned upwards, during turning of eggs always ensure non greasy or dusty substances as this reduces hatchability. Furthermore, the developing embryos have delicate blood vessels which easily ruptures so handle the eggs with utmost care not to kill the embryo (Mahdi *et al.*, 2010). Benjamin and Oye (2012) reported to achieve optimum hatchability, optimum temperature must be considered in the design of an incubator machine, since slight

deviations from the optimum conditions will inhibit Oogenesis. Three factors affect temperature of developing embryo: incubator temperature; heat transmission between the incubator and the embryo; and metabolic heat generated by the embryo. Abraham *et al.* (2014), reported that with increasing chicken demand, poultry egg incubation is very crucial as against conventional methods which are slow and expensive. Agidi *et al.* (2014) reported that poultry production is a lucrative business in Nigeria, but inadequate hatchery machines limit its expansion and day-old chicks vary expensive, presently, only few commercially owned poultry hatcheries exist in Nigeria, located far away in the Western and Eastern parts of the country. Several factors hamper adversely the establishment of medium to large scale poultry production out-fits in the rural areas of the country. However, with this artificially powered egg incubator technology, poultry farmers in Nigeria are likely to incubate, hatch eggs and breed day old chicks in a sustainable manner (Benjamin and Oye, 2012). Abiola, *et al.* (2008); Samuel and Duvuna (2011) designed artificial incubators, with several specification and locally sourced materials, with 20-200 eggs capacity. Thus, the objectives of the study to design, construct and test efficiency of kerosene powered lantern poultry egg incubator, with capacity for 120 eggs and evaluate percentage hatchability of local chicken eggs.

MATERIALS AND METHODS

The Study Area

This research was carried out at Federal University Wukari, Teaching and Research Farm, located between Latitude 7° 85' N and 7° 85' N and Longitude 9° 42' E and 9° 78' E (Google Maps retrieved March, 2024). Design and construction of the wooden lantern incubator: The available materials were sourced and used in the design and construction of the lantern poultry incubator; their consideration was mainly availability. This incubator is a

wooden box constructed in the following dimensions: length 40.1cm; width 30.9cm and height, 70.7cm. The lit lantern is placed outside and the top inserted into an 88mm wide PVC pipe, which connects to an elbowed pipe 90mm wide opening into the wooden incubator box (Wayne, 2014, Elavius and Alan, 2000). The reservoir of the lantern holds the kerosene oil, the wick of which burns to provide the required heat needed to power the incubator. Temperature is constantly regulated within physiological limits of 36° to 39°C after Samuel and Duvuna (2011). Four layers of eggs holding tray were placed inside the incubator, a vacuum were the egg trays stand, were constructed. A total of four hatching trays housing 30 eggs each, hence a 120-capacity incubator. A thermometer, maximum and minimum readings is placed inside the incubator and read at four hourly intervals for the experimental period of 19-22 days to maximize hatchability. The top most part of the incubator is perforated to enable proper ventilation and escape of carbon monoxide generated from the lantern.

Heat transfer from the lantern enters through the pipe by simple conduction and convection. Heat distribution is achieved inside the incubator, since we are using the still air model. Below the bottom compartment, a plastic plate containing soaked cotton wool (humidifier) which is renewed after 12 hours maintain consistency in the humidity inside the incubator and regulates the temperature within 38°C range. The incubator was kept in a well-ventilated room throughout the experimental period. The set-up using these materials were sterilized for 24h- ours in-line with the recommendations of Abiola *et al.* (2008), while eggs were placed horizontally.

In the four hatching trays, each containing 30 eggs. Eggs turning commenced thereafter, at every four hours interval. These eggs were labelled 1- 30 with black permanent marker for tray A. While trays B, C and D each with 30 eggs holding capacity are labelled using red,

blue and green markers respectively as the replicates. Melvin (2008), Glatz (2013), Udeh and Omeje (2014) recommended incubated eggs to be candled on the 7th and 18th days respectively, all the 120 eggs were fertile on the first candling (7th day). During the candling, the "air space" is noted to increase inside the eggs. By the 18th day of incubation, the eggs were set for hatching with the upper broad end facing up while the narrow end downward. Eggs turning is finally stopped while hatchability recorded accordingly. Data collection and analysis. The trial terminates on 27th days after, some eggs had hatched, and 21 durations for chicken incubations had elapsed. Chick's weight was measured and administered intraocular vaccines. Furthermore, after additional three days had elapsed, eggs that failed to hatch were broken open to record the level of embryo developments. All data generated except for weight were converted to percentages and subjected to statistical analysis at P=0.05%.

RESULTS AND DISCUSSION

Results obtained from the performance test on the local lantern poultry constructed incubator depends on controlled temperature 35°-37°C and relative humidity range 45-65%. After the incubation period (21 days), the efficiency of the incubator was determined based on the percentage hatchability i. e. the percentage of eggs hatched during the experimental period. A total of 36 and 62 eggs hatched representing 21.67 and 51.66 per cent respectively. 7-8 litres of kerosene were used throughout the incubation duration per experiment at N250.00 per litre only. The cost implication translates to chick number hatched and day-old chick sales at N100.00 per chick. Economic difference gave advantage of over N600.00 amount per experiment, in agreement with Okeoma, (2016). The average eggs weight obtained in first trial was higher, 38.93±0.42g, but shows no significant difference with the second trial, 37.01 ± 0.50g, t-value with assumed equal

variance was 2.63% $P(\alpha=0.05) = 0.039$ at 95% CI of 3.32. The implications of these findings are evidenced in relatedness of the egg sources for incubation and homogeneity, presumed at 45-50g common to village and unimproved chickens (Takidir *et al.*, 2014, Barbari *et al.*, 2006). The most influential egg factor affecting hatchability are weight, shell thickness, porosity, shape index i. e. breadth x length ratio and consistency of the content. Average values of these parameters result to successful and maximum hatchability as reported by Asuquo and Okon (1993).

Egg Size range, 45-56g hatch better than the larger, 51-56g eggs and medium 45-50g eggs giving 88.2% and 84.8% respectively as against smaller eggs 37.5-44g reported by Asuquo and Okon (1993) and Abiola *et al.*, (2008). Large egg weight 60g and above had lowest hatchability. (King'Ori *et al.*, 2010), several workers reported positive correlation between egg weights and hatchability. The results of the hatchability agree with reports of Asuquo and Okon (1993) and Abiola, *et al.* (2008), that eggs weighing 45-56 g hatches better than eggs that weight 51-56g in the first trial 100% fertility was recorded. This result surpassed the report of Rasyaf (2008) and Muryanto, *et al.* (2013). The chicken eggs collected gave 80-100% fertility, as were reported for local chickens at 83.4-85 percent by Rasyaf (2008) and Muryanto *et al.* (2013). High fertility obtained could be attributed to proper sex ratio of mating by one or few cocks serving 6-10 hens in free range system (Muryono 2004; Sutyono *et al.*, 2006). King' Ori, (2011) reported that fertility and hatchability are traits influenced by genetic and environmental factors like post lay handling of fertile eggs and correct incubation process. Abiola, *et al.* (2008) attributed turning frequency during incubation also affects hatchability of eggs.

On days 7, 14, and 18 candling reveals optimum levels of fertility, however development was slowed due probably to reasons advanced by Kirundo and Muwerenza (2011). Through candling, the condition of the air cell, yolk and albumen were evaluated, also the presence of the initial blood vessel became evident radiating like a huge red spider web. Anonymous (2013) reported in dead embryos a blood ring forms away from the embryo. Effectiveness of the kerosene incubator on eggs hatchability, as deduced from the experiment shows an average effectiveness of the incubator as 21.67 ± 10.93 and 51.66 ± 7.99 hatchability for experiments I and II respectively. The t-test with equal variance assumed (-2.216) and P-value (Significance level) =0.069 at 3.133 upper 95% CI. The implication of this is P-value ($\alpha=0.05$) is lower, showing no significant difference in the means of the two experiments. Percentage hatchability was low compared to results of other workers with over 70% hatchability in local chickens in Nigeria (Sola-Ojo, 2011). It was also lower than 70-100% reported by Fayeye, *et al.* (2005). The underlying factor responsible for the low hatchability was size of the eggs. At a mean weight of 38.73 ± 0.42 g in the first trial and 37.01 ± 0.50 g in the second trials the result agrees with the report of Asuquo and Okon (1993) and Abiola, *et al.* (2005) who reported that eggs weighing 45-56g had better hatchability. The average in this study was also low, 21.67 ± 10.93 and 51.66 ± 7.99 as against 80.9% (Moges *et al.*, 2010) in Ethiopia, 78% (Khalafalla, 2000) in Sudan, 74% (Maphosa *et al.*, 2004) in Zimbabwe and 84.9- 88.2% (Kirunda *et al.*, 2010) in Uganda. Reason for this low average hatchability is attributed amongst other things to egg size and weight.

Table 1. Mean Egg Weight, Day Old Chick Weight, Percentage Fertile Eggs and Hatchability of Local Chicken after 21 Days' Artificial Incubation

Experiment	Parameters			
	Egg weight (g)	Fertile Egg (%)	Hatchability (%)	Day old chick weight (g)
I	38.73±0.42	100±0.00	21.67±10.93	20.75±6.96
II	37.01±0.50	98.33±1.67	51.66±7.99	27.81±1.28
T-value (Equal Variance assumed)	2.631	1.00	-2.22	-0.99
P-value	0.039	0.356	0.069	0.357
95% CL.	3.32	5.75	3.13	10.26

Note: Values for weight are means, while fertility and hatchability are in percentages.

Day old chicks' weight recorded after 24 hours of hatching when chick's feathers had dried (Table 1). Reduction in the chicks' weight compared to the eggs weight was expected as reported by Bachari, *et al.* (2006) and Takidir, *et al.* (2014). In this research, the day-old chick weight recorded were 20.75±6.96g and 27.81±1.28g for experiment I and II respectively. Although these values were low, compared to other findings in literatures, yet majority of these experiments use exotic breeds and improved roosters. The egg weight loss is an index of higher metabolic activities during embryonic development and hatching (Anonymous, 2013). After the 21 days of incubation, the eggs hatched. Both the hatchability and the dead embryos were observed in all treatment trays, when unhatched eggs were opened up and the values recorded (Table 2) as: (i) no development occurred, (ii) early embryo mortality, and (iii) late embryo mortality, both are referred to as dead in the germ and lastly dead in the shell (Abiola, *et al.*, 2008; Udeh and Omeje, 2014). There was no significant difference ($P > 0.05$) between mean effects of fertility and number of dead embryos

(germ) between experiment I and II at different stages. Table 2, showed different stages of embryo mortality being less during the first 7 days (5.83 ± 2.50 and 7.50 ± 1.60) of the incubation period for the I and II experiment, while 8.33 ± 5.00 and 10.83 ± 2.10 were recorded for the last 4 days of incubation (late embryo mortality). The t-test assumed equal variances between the two experiments I and II as -0.561, P value = 0.595 ($\alpha=0.05$) at 5.59 CI (upper limit) for early embryo mortality and -0.461 at $P = 0.661$, with 10.769 CI for the late embryo mortality. Furthermore, no development was recorded in some eggs, while higher values of the eggs showed maximum development as chicks with feathers, but do not hatch (dead on the shell) as corroborated by Anonymous (2013). The significance of these findings may be attributed to variations (lower and higher) in incubation temperatures and most probably higher humidity conditions, other Suggestions were insufficient turning of eggs, hence mal-positioning of embryos (Elibol and Brake, 2004) or nutrient deficiency in the parent birds or most likely lethal genes (Udeh and Omeje, 2014).

Table: Mean Developmental Stages (Embryo Development) of Local Chicken Eggs after 21 Days' Artificial Incubation

Experiments	No. Development	Early embryo mortality	Late embryo mortality	Dead in Shell
I.	26.67±11.99	5.83±2.50	8.33±5.00	36.66±6.80
II.	4.99±0.96	7.50±1.60	10.83±2.10	23.38±10.08
T-value	1.809	-0.56	-0.461	1.093
P-value	0.120	0.595	0.661	0.317
95% CI	50.98	5.59	10.769	43.031

Key: CI = Confidence Interval

CONCLUSION AND RECOMMENDATIONS

The efficiency of the kerosene incubator was calculated based on 120 eggs capacity with 51.7% efficiency at 35°C–37°C and 45–65% r.h., within 21 days management period. Thus, resource poor farmers can enhance day old chick's productivity using locally made lantern poultry incubators, limited only by egg size, weight, fertility, hatchability of the eggs and proper incubation management. This technology is proven to be efficient and satisfactorily functional for reasonable economic returns on eggs and day-old chick business. Resource poor farmers and rural communities can adopt its findings, but further studies are hereby recommended.

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