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Development and Performance Evaluation of Home-Made Electric and Kerosene Lump Egg Incubator

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ABSTRACT

This study was carried out to develop and evaluate the performance of home-made electric and kerosene lump egg incubator capable of incubating 150 eggs at predetermined temperature and humidity. The fabricated incubator consists of an egg cabinet made from MDF and plywood, egg tray made from mesh wire, TS-C700 temperature controller, hygrometer, a kerosene lump, water pan, and cooling fan system. The performances were evaluated in terms of hatchability rate, chick normality, fertility, and embryonic mortality rate. The experimental design used was simple descriptive statistics against the biological performance of the incubator. Naturally mated stock koekoek chicken eggs were used for evaluation of the developed incubator. The investigation revealed that the machine was evaluated at temperature of 37.5^{0}C and 60% relative humidity for the first 18 days of incubation and then temperature was lowered to 36.5^{0}C and increasing relative humidity to 65%. The ambient temperature of egg incubator has more effect on the interior temperature making the interior temperature varied. The average hatchability rate, fertility, embryonic mortality rate, and chick normality were 77.60%, 57.02%, 9.61% and 91.96% at average temperature of 37.24^{0}C and 60.75% of relative humidity were observed during incubation test. Depending on the performance results of the the incubator, it is concluded that the constructed incubator machine can be effectively and efficiently used by small and medium-scale poultry farmers.

INTRODUCTION

Poultry is the largest livestock group in the world estimated to be about 23.39 billion consisting mainly of chickens, ducks and turkeys (FAO, 2010; CSA., 2013) while chicken alone reached over 1 billion and has remained to be important in the improvement of food security and livelihood (Dessie *et al*., 2013 and Addis *et al*., 2014) and contributing about 28- 30% of all animal protein consumed in the world (FAO, 2010; ELMP, 2014; and Emebet *et al*., 2013).

According to the CSA (2012), the population dynamics of the chicken population in Ethiopia comprises of 40.11% chicks, 33% laying hens, 9.76% cocks, 9.19% pullets, 4.84% cockerels, and 3.1% non- laying hens. The same survey report indicated that the indigenous birds comprise over 95% of the county's chicken population while the remaining (1.03%) and (3.97%) are hybrids and exotic commercial chicken breeds. Further, the report indicated that the majority of the country's chickens (36.41%) are reared in Oromia, followed by Amhara (31.44%), SNNPR (23.18%) and Tigray (11.14%) regional states. The rest of the regions hold only 3.19% of the total poultry.

Thus household poultry of the Ethiopian indigenous chicken has a unique position in the rural household economy and plays a significant role in the religious and cultural life of the society (Tadelle and Ogle, 1996a). However, the contribution of the indigenous chicken resource to human nutrition and export earnings is disproportionately small. All the available literature tends to indicate that the per capita poultry and poultry product consumption in Ethiopia is one of the lowest in the world: 57 eggs and 2.85 kg of chicken meat per annum (Alemu, 1995).

The low productivity of local scavenging chickens is not only because of their low egg production potential, but also due to high chick mortality and longer reproductive cycle. About 40-60% of the chicks hatched die during the first 8 weeks of age (Hoyle, 1992, Tadelle and Ogle, 1996a) mainly due to disease and predators attack. About half of the eggs produced have to be hatched to replace chicken that have died (Tadelle and Ogle, 1996a), and the brooding time of the laying hens is longer, with many brooding cycles required to compensate for its unsuccessful brooding. It is estimated that, under scavenging conditions, the reproductive cycle of indigenous hens consists of 20-days of laying phase, 21-days of incubation phase and 56-days of brooding phase (Alemu and Tadelle, 1997). This implies the fact that, the number of clutches per hen per year is probably 2-3. Assuming 3 clutches per hen per year, the hen would have to stay for about 168 days out of production every year, entirely engaged in brooding activities.

There are majorly two types of incubation viz; natural and artificial incubation. The most important difference between natural and artificial incubation is the fact that in natural incubation mother hen provides warmth by contact rather than surrounding the egg with warm air as it is in artificial incubation. An egg incubator is equipment which provides opportunity for farmers to produce

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chicks from eggs without the consent of the mother hen and it is an enclosure which has controlled temperature, humidity, and ventilation for hatching of poultry eggs such as chicken eggs, turkey eggs, quail eggs, guinea fowl eggs, etc. (University of Illinois, 2014)

Eggs have been incubated by artificial means for thousands of years. Both the Chinese and the Egyptians are credited with originating artificial incubation procedures. The Chinese developed a method in which they burned charcoal to supply the heat while the Egyptians constructed large brick incubators that they heated with fires right in the rooms where the eggs were incubated. Over the years incubators have been refined and developed so that they are almost completely automatic. (University of Illinois, 2014)

Modern commercial incubators are heated by electricity. They have automatic egg-turning devices, and are equipped with automatic controls to maintain the proper levels of heat, humidity, and air exchange. Both still-air and forced-draft incubators are used in hatcheries. However, all the new commercial incubators are forced-draft; that is; they have fans to circulate the air. They are capable of maintaining more even temperature, humidity, and oxygen levels than still-air incubators. (University of Illinois, 2014)

In Ethiopia, there are several private large scale commercial poultry farms in and in the vicinity of Addis Ababa, the majority of which are located in Bishoftu. ELFORA, Alema and Genesis are the top 3 largest commercial poultry farms with modern production and processing facilities (incubators, hatcheries e.t.c) (Molla.M, 2010).

There are also, other private limited companies and dealers (Shaya and Hagbes plc) imports a small scale egg incubator of capacity (50 to 1000) which is operated only by electricity. Moreover, these incubators are manually operated for egg turner; it may cost from 30,000 up to 128,000 ETB for (50- 200 egg incubators) and have no spare parts available which has no guarantee to afford this technology under farmer condition.

The epileptic nature of the power supply in the country contributes to the difficulty encountered in the smooth running of an incubator machine for hatching of poultry eggs. Alternative source of electricity from a stand-by generator has always been employed to complement the energy needs of an incubator machine for the period of twenty one (21) days for poultry birds' incubation. However, the huge additional cost of power supply from a stand-by generator adds up to the overall cost of day-old chicks upon production.

The maintenance of the stand-by generator on its own incur an added costs, besides the fact that an expert skilled in the services and maintenance of generating sets will have to be available for the whole period of hatching of the eggs. The unsteady and unreliable power supply in the country has a huge impact in the economic activities of poultry farms.

As a means to improve poultry productivity, there had been number of farmers who have adopted improved exotic chicken with hay-box brooder by AAERC particularly in the Arsi and west Arsi areas of the Oromiya region. The Center was also interested in assisting community driven and proper input supply system (Hay-box brooder, day old chichen, feeds, market access, health care e.t.c) for improved poultry production suitable to smallholder farmers' management condition. However, the adoption of these promising hay-box brooder was interrupted due lack of supply of day-old chicks from available poultry farms which may calls for a scientific study in the area, of artificial egg incubation technologies.

The demand for agricultural day old chicks by commercial and private poultry farmers has always been on the increase going by the unprecedented population growth. The ever increasing demand for poultry meat all over our immediate environment in response to public concern over dietary fat has resulted to a hike in the cost of poultry meat.

Even though, there were few small and large scale agricultural machineries importer like egg incubator, still there is no proven egg incubator that can be used under farmers' conditions which is not only because of their expensive cost, but also because of their dependency on electricity.

Since day old chicks requires a steady power supply for the period of incubation for a particular batch of poultry eggs, the use of kerosene lump to generate an alternative energy supply will ease the energy crisis in the economic activities of a poultry farmer.

Hence, the application of electricity and kerosene lump as the source of heat to hatchery units can prove to be the most economical means so far and it will encourage and facilitate poultry egg production in the country.

Therefore, this research project is meant to design, develop, test and evaluate electric and kerosene lump egg incubator following scientific procedures. To develop and evaluate performance of electric and kerosene lump egg incubator

MATERIAL AND METHODS

Materials

The materials used for the development and performance evaluation of egg incubator was Hygrometer, Thermostat, 60 w bulbs, 200 w bulbs, Ventilator, poultry mesh wire, ply wood, MDF, Double glass, Hay-box brooder, Kerosene lump, nails, 6mm diameter of the round bar for egg turner, Electric wire, Water pan, temperature controller, Egg Candler and experimental eggs.

METHODOLOGY

Design Consideration

The incubator was made with readily available materials, relatively cheap and be affordable to local farmers, able to hatch eggs of different shapes and sizes, have higher capacity compared to natural methods, be simple to operate and maintain by local farmers.

Description of the Incubator

An egg Incubator was constructed to test and evaluate its performance. The incubator cabinet or box's dimensions was decided up on three principal diameters of eggs bay taking 50 eggs as sample. Figure 1 shows that, the incubator box has two compartments, one is where kerosene lump was placed at the bottom and the upper portion is where the egg tray was placed. It was made from 20 mm thick MDF. The inside of the cabinet was covered with insulation water proof plywood to minimize heat losses by absorption and transmission through the walls to the atmosphere. The door of the incubator was made from wood and glass. MDF and Plywood were chosen because of their insulating properties, ease in fabrication, durability and availability in the local market. Likewise, glass was chosen for the visibility of the eggs inside.

Figure 1: Prototype of electric and kerosene lump egg incubator

Egg Trays

The trays for egg setting are very important for the positioning of the eggs. The egg incubation chamber has one egg tray that has the capacity of 150 eggs spread on the trays. Figure 2 shows that, it was constructed from wood as frame, aluminum mesh wire as egg tray and galvanized sheet metal to cover bottom of tray (mesh wire) in order to prevent kerosene dusts from the eggs. The net tray dimensions were 86cm x 88cm x 5cm. The developed incubator's egg tray was rectangular shape and its dimensions were decided based on physical properties of the egg.

Figure 2: Construction of Egg tray and it installation

Egg Turning

In this egg incubator, the eggs were turned four times per day for normal embryonic development to take place. Eggs turning were achieved in the incubator manually by pulling and pushing rectangular roller frame until the eggs are rolled 1800 which is indicated in figure 3. Rectangular egg roller was made from 6mm diameter of mild steel round bar with dimension of 850mm x 520mm x 6mm which partitioned into rows and columns of 55mm x 45mm rectangular portion in order to hold each egg separately. Markings of eggs with sign of "X" and "✓" were conducted before the eggs were loaded into the incubation chamber.

The marked eggs were arranged in rectangular egg turner frame on mesh wire egg trays horizontally along the length. The egg turner was pushed or pulled horizontally at every six hours intervals until the eggs rolled 180o. The eggs were turned in order for the embryo to sweep into fresh nutrients, allowing the embryo to develop and preventing embryo stacking to one side shell.

Egg-turning failures may reduce the formation of embryonic fluids, as well as hinder the formation and growth of embryonic annexes, thereby hindering embryonic and fetal development (Robinson *et al.*, 2013; Boleli etal., 2016).

Figure 3: Frame of manual egg turner

Temperature

Heat energy is a major requirement for successful hatching of eggs into chicks and eventual growth of the young chicks in the brooding house to maturity (Ahiaba *et al.*, 2015).

Temperature is a very important factor in egg incubation. It is extremely crucial during incubation period. Differences of more than one degree from the optimum temperature will harmfully affect the number of eggs to be hatched successfully. Four incandescent bulbs, 60 Watts each were used as heat source within the incubator for the entire incubation period. These bulbs were placed out for effective heat distribution. The heat supplied through the bulbs was controlled by the use of TS-C700 temperature controller device.

However, during the interruption of power supply, kerosene lump was used as heat source in order to keep the inside temperature constant for developing embryo. Uniform air circulation is important inside the incubator to get best hatch. One electric fan was deliberately placed within the incubator for an evenly distribution of heated air produced by the bulbs. A temperature controller or thermocouple was installed within the machine to monitor the air temperature inside the incubation chamber. Nevertheless, the set temperature between 36°C and 39°C gives best results during the first 18 days as radical temperature difference can affect hatching rates especially in forced-air incubator (J.S. Jeffrey *et al.*, 2008). Therefore, it was maintained at 37.5oC till hatching give the best result within the eggs.

Sanitation

The incubator chamber needs to be carefully cleaned before setting the eggs and after hatching process. The incubator and the environment need a proper fumigation before setting of eggs in order to avoid infection which can affect the hatchability of the egg. Moreover, the machine and the environment need to be carefully treated and cleaned because of the left over shell, un-hatched egg in the incubator for next incubation processes.

Humidity

The relative humidity in the incubator between setting and three days before hatching was ranged between 58%-60% (Othman *et al.*, 2013; Umar *et al.*, 2016).

Water evaporates from Eggs during the incubation period, and the rate of water loss based on the relative humidity maintained within the incubation chamber. The humidity inside the incubator was read by hygrometer clock. A rectangular mild steel water holder with full of water having a volume of 400 mm x 200mm x 250mm was placed near to sets of eggs and on top of water can; cooling fan was installed to raise the humidity in the incubator as shown in figure 4. The relative humidity in the

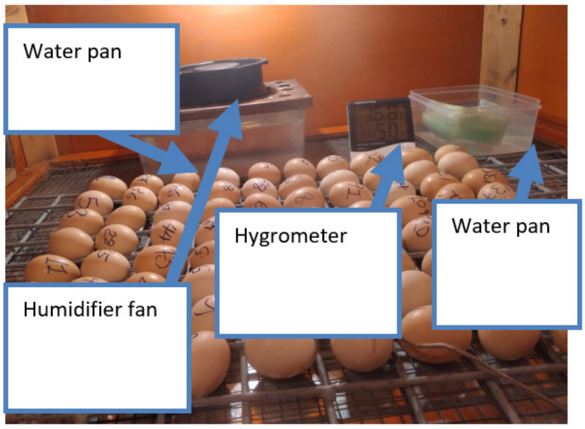

Figure 4: Installation of humidifier, water pan and hygrometer

incubator was set in between 58%-60% three days prior to hatching to have a good result, and it was increased between 65% - 70% for last three days of hatching.

Air Ventilation

Ventilation plays an important role during artificial incubation period for cooling of an overheated egg incubator, as well as making sure that maximizing the exchange of oxygen and carbon dioxide at a proper time (Umar *et al.*, 2016). Therefore, the three air ventilation holes with 20mm diameter were provided at each top phase of front, left and right side of incubator, to ensure proper distributions of temperature and humidity.

Performance Evaluation of the Egg Incubator

Performance evaluation of the developed egg incubator was carried out using electricity as main and kerosene lump as supplement heat source for incubator. The hatchability rate, embryo mortality rate and chick vigor rate of the eggs were determined as it is shown in figure 5, using the following equations.

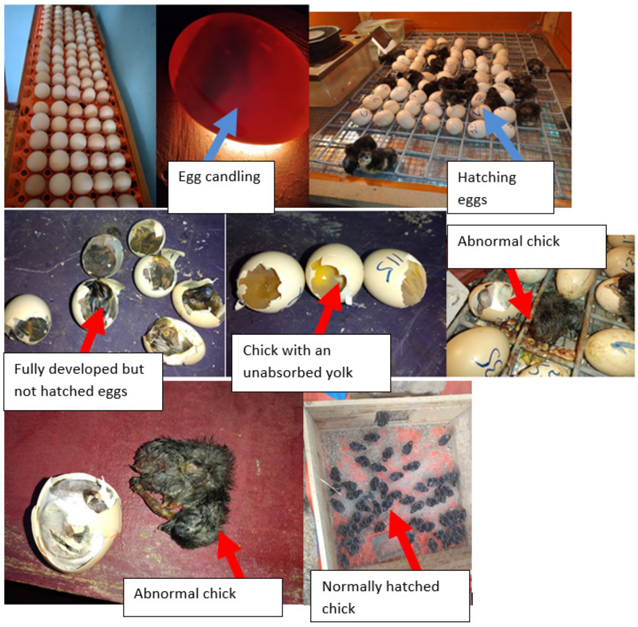

Figure 5: Performance evaluation of the developed incubator

Percent Hatchability

Hatchability rate is the percentage of fertile eggs which actually hatch out as live young and it was calculated as follow (Dzungwe JT *et al.*, 2018)

$$hachability\ rate(\%) = \frac{number\ of\ hatched\ eggs}{number\ of\ fertile\ eggs} x100$$

Percent Fertility

Eggs of the KoeKoek chicken were stored vertically in clean plastic crates with the small end placed downwards at room temperature for 2 days before incubation. Temperature was automatically controlled as well as relative humidity and ventilation was carefully adjusted in the incubation chamber. Eggs of the KoeKoek chicken were placed in incubator at a temperature of 37.5°C and relative humidity of 58%. The eggs were candled at the 7th day of incubation to check for fertile eggs. Consequently, eggs that showed signs of developing embryos by means of a visible network of blood vessels spreading from the center of the eggs outwards were considered to be fertile and recorded.

Fertility rate is the percentage of fertile eggs of all eggs produced and it was determined as follows (Dzungwe JT *et al.*, 2018)

$$Fertility\ rate(\%) = \frac{number\ of\ fertile\ eggs}{Total\ number\ of\ eggs\ incubated} x100$$

Early Embryonic Mortality Rate

Eggs candling were carried out on the 14th day to determine early embryonic mortality rate. Eggs with developing embryos that had blood ring visible on the inside of the egg shell were considered quitters; they were removed, counted and recorded accordingly. Percentage early embryonic mortality was calculated using the number of quitters (Dzungwe JT *et al.*, 2018).

$$Embryo\ mortality\ rate(\%) = \frac{number\ of\ dead\ embryo}{number\ of\ fertile\ eggs} x100$$

Hatching Mortality

At the end of the incubation process, the un-hatched eggs were gently cracked to identify the eggs with dead chicks, number of eggs that piped but died were used to determine hatching mortality using the formula of hatchability (Dzungwe JT *et al.*, 2018)

$$hatching\ mortality\ rate(\%) = \frac{\text{Dead chicks}}{\text{number of egg set for hatching}} x100$$

Cost Estimation

Estimation of annual and hourly operational costs of the home-made egg incubator was depending on capital cost of the egg incubator, interest on capital, cost of repairs and spare parts, labor cost, and depreciation. The operational cost components of the egg incubator prototype were estimated in Birr (EB) according to Wen-yuan Huang *et al* (1979). An economic life of 10 years and 6048 hours per year for egg incubator were assumed and as well as the Electric and kerosene lump consumption are expected to be used 5328 and 720 hours per year respectively (Mariani MJP, 2021).

Cost Estimation for Egg Incubator

Fixed Cost for Home-Made Egg Incubator

D_p= (PP-SV)/(LxH), (EB/h)

D_p= (15914.77-1591.5)/(10x6048) = 0.24 (EB/h)

I= ((PP + SV)/(2)) x (I%/H), (EB/h)

I= ((15914.77 + 1591.5)/(2)) x ((10)/(6048 x 100))= 0.14 (EB/h)

IT = 1% of PP

IT = (1 x 15914.77)/(100 x 6048)= 0.03 (EB/h)

Housing = 1% of PP

Housing = (1 x 15914.77)/(100 x 6048)= 0.03 (EB/h)

Total fixed cost t = Dp + I + IT + Housing

Total fixed cost for incubator= 0.24 + 0.14 + 0.03 + 0.03= 0.44 (EB/h)

Variable Cost for Home-Made Egg Incubator

RM = 10% of PP

RM = (1 x 15914.77)/(100 x 6048)= 0.03 (EB/h)

Fuel consumption cost in one hour 0.18 liter was consumed and prevailing kerosene price was 23.06 EB/lit

Therefore, fuel cost for incubator was found to be 4.15 EB/h

Labor cost= 200 EB/day, assume the operator works 8h/day, then

Labor cost = 25.00 EB/h

Electricity Consumption Formula

E.C = Wattage x operating time per day x incubation days per year x electric cost per kw hr

Electric cost per Kw-hr was 0.767 ETB/ Kw-hr and assuming available electric supply of 263hr per year

Then,

E.C = 0.24Kw x 24hr per day x 300 days per year x 0.767 ETB per kw hr = 1325.40 ETB/year

Therefore, Electric consumption was found to be 5.04ETB/hr

total variable cost of incubator= RM + FC + LaC + E.C

= 0.30 + 4.15 + 25.00 + 5.04

= 34.50 EB/h

Total operating cost of incubator= fixed cost + variable cost

Total operating cost of incubator= 0.44 + 34.50= 34.94 EB/h

Total revenue of home-made egg incubator was also determined based on hatching efficiency, unit prices of hatched chick and number of incubation operation in a year.

Revenue= hatching eficincy x unit price of chick x number of incubation per year

Assuming unit price of day old chick as 55 ETB and 12 available incubation batches per year:

Revenue= 0.77 x 55 ETB x 150 eggs x 12= 76,230 ETB/year

Where, Purchase price (Pp): 15914.77 EB, Salvage value (SV): 10%, Interest rate: 10 %, Repair and maintenance (RM): 10% , Insurance & taxes (IT): 1% of PP, Housing: 1 % of PP, Fuel consumption: 0.5 lit/hour , FC = 23.06 EB per lit, Labor cost (LaC): 200 EB per day and Dp = Depreciation

Experimental Design and Data Analysis

The experimental design was simple descriptive statistics for electric bulb and kerosene lump as heat source for the mean values of Biological data assessments and replicated three times.

RESULTS AND DISCUSSION

Temperature and Relative Humidity of Incubation Chamber

The mean incubation temperature and relative humidity obtained with the electric and kerosene lump egg incubator were 37.24^{0}C and 60.75 % respectively at ambient conditions of 25.13^{0}C temperature and 88% relative humidity (Table 1). The coefficient of variation of the incubation temperature was 1.43 ^{0}C while that of that of the relative humidity was 7.74 %. This indicated that the variation of the incubator relative humidity obtained over the test period was high since humidity in the incubation was manually controlled.

From table 1, it can be seen that, the temperatures of incubation were higher than the room and ambient temperatures at different of incubation periods. The highest value of the mean incubation temperature (38.1^{0}C) was attained on the 7 th day at 21^{0}C room temperature and 26.1^{0}C ambient temperature. As shown in the table 1, the relative humidity obtained at these temperatures was 58% and 88% in the incubator and the ambient respectively which was slightly similar with the findings of Ndirika, V.I.O. and S.A. Ademoye (2007). It has been reported by some researchers that the temperature is the most important factor for incubation as it affects both quantity and quality of hatching (Molenaar *et al*., 2013; Mansaray and Yansaneh, 2015; Almeida *et al*., 2016). A constant incubation temperature of 37.8◦C is the thermal homeostasis of the chick embryos and gives the best embryo development and hatchability (Abiola et. al., 2008; Benjamin *et al*., 2012; Manasary & Yansaneh, 2015). These researchers recommended that incubator temperature should be maintained between 37.2◦C and 37.7◦C, but they suggested that a range of 36◦C to 38.9◦C is acceptable. Mortality is seen if the temperature drops below 35.6◦C or rises above 39.4◦C for some hours. If the temperature stays at either of the extremes for several days, the eggs may not hatch.

Table 1: Mean incubator and ambient conditions over the incubation period

Period (days)	Ambient Temperature(^{0}C)	Room Temperature (^{0}C)	Incubation Temperature (^{0}C)	Room R.H (%)	Incubation R.H. (%)	Ambient R.H. (%)
1	24.5	19.8	37.5	42	58	87
2	24.2	19.5	37.3	42	58	87
3	25.6	20.2	37.8	45	57	85
4	24.3	19.6	37.4	39	55	82
5	23.7	19.1	36.9	45	60	91
6	25.9	21.4	38.1	46	59	89
7	26.1	21.6	38.1	42	58	88
8	25.8	20.8	37.7	43	57	87
9	24.1	19.5	36.9	41	56	85
10	23.9	19.2	36.8	42	58	88
11	24.1	19.5	37.1	43	58	87
12	25.3	20.3	37.6	45	59	86
13	25.4	20.6	37.2	46	60	90
14	24.0	19.4	36.9	43	57	85
15	26	21.1	37.9	43	57	85
16	26.2	21.5	38.0	45	60	89
17	26.0	21.3	37.8	44	58	86
18	25.2	20.7	37.0	46	65	90
19	25.2	20.4	36.8	45	68	92
20	26.0	21.3	36.6	42	70	93
21	25.1	20.8	36.5	40	69	91
22	24.9	20.4	36.8	43	66	90
23	25.2	20.5	36.6	46	67	89
24	26.3	21.1	36.5	43	68	90
Mean	**25.13**	**20.4**	**37.24**	**43.38**	**60.75**	**88**
SD	**0.84**	**0.79**	**0.53**	**1.95**	**4.70**	**2.65**
CV(%)	**3.33**	**3.87**	**1.43**	**4.50**	**7.74**	**3.02**

Effects of Ambient Temperature on the Incubation Chamber

Table 2 indicates the effect of ambient temperature on the interior temperature of the electric and kerosene egg incubator during the incubation period. The result shows that the interior temperature of the incubator was greatly affected by ambient temperature which made the interior of the incubator not have a constant temperature throughout the test run. From Table 2, it can be seen that the ambient temperature of egg incubator has more effect on the interior temperature making the interior temperature to be varied. However, by using TS-C700 temperature controller device, the interior temperature of the incubator was kept within the recommended range of 36°C to 39°C by adjusting the temperature controller to 37.5°C for the first 18th day of incubation and 36.5°C for the last three days of incubation.

The thermocouple acted as breaks and made device to control the operation of the electric bulb. To maintain optimum temperature in the incubator, the electric bulb has to be switched off and on while the length in which its operation varies with time. Moreover, from table 2 it was observed that as the ambient and interior temperatures increased, the shining time of electric bulb decreased as time continued. This revealed that, as the ambient temperature increases, the heat required to maintain the interior temperature within recommended range tends to reduce while it's increased as the ambient temperature decreases. The temperature of the incubator was maintained at a particular range value to enhance the hatchability of the fertile eggs and maximum temperature variation was avoided.

Table 2: Effects of ambient temperature on the incubation chamber

Time	Incubator Temperature, (°C)	Ambient Temperature, (°C)	Electric Bulb (time on), seconds	Electric Bulb (time off), seconds
Morning				
6:00 AM	36.5	22.5	30	8
7:00	36.5	22.4	30	8
8:00	36.7	22.8	26	10
9:00	36.8	23.0	26	11
10:00	37.0	23.5	25	13
11:00	37.1	23.7	24	13
12:00	37.3	24.1	22	13
Noon				
13:00 PM	37.8	24.6	20	15
14:00	37.8	24.8	20	15
15:00	37.9	26.0	16	17
16:00	38.2	25.0	16	17
17:00	38.5	24.6	15	18
18:00	37.8	24.2	13	18
Night				
19:00	37.6	23.9	13	18
20:00	37.5	23.9	18	15
21:00	37.4	22.1	21	13
22:00	37.4	21.6	25	11
23:00	37.3	20.5	26	10
24:00 (mid-night)	37.3	19.5	28	9
1:00	37.3	19.5	28	9
2:00	37.2	19.3	29	9
3:00	37	19.3	30	8
4:00	37	19.1	30	8
5:00	36.8	19.1	30	8
6:00	36.8	19.1	30	8

Fertility and Hatchability Rate

Electric and kerosene lump egg incubation was used in hatching koekoek chicken eggs. Hatch able eggs were sourced from local poultry farm at Tiyo woreda, Arsi zone of Ethiopia and placed in the developed electric and kerosene lump incubator for the entire incubation processes. As it is presented in table 3, performance evaluation of the developed egg incubator was evaluated three times in this study.

Fertility and hatchability are major constraints of the chicken production and appears to be directly related to egg fertility rate. Fertility in naturally mated stock ranges from 49%-58% while using artificial insemination ranged from 70%- 80% Galor (1983).

Then, 70, 140 and 102 eggs of naturally mated stock were set on the egg tray inside the incubator at 1st, 2nd and 3rd incubation trials respectively even though; the egg tray can accommodate 150 eggs. The eggs were turned at six hours regular intervals for the first 18th day of the incubation period at predetermined temperature of 37.5 ^{0}C and 58% - 60% relative humidity. Turning of eggs on the 18th day of the incubation was discontinued to enhance easy hatching. The incubation period was lasted for 24 days and hatching started on the 20th day until 24th day. This is slightly longer than the maximum 21 days or natural method (Sonaiya *et al*., 1995) and this slight variation may be due to temperature fluctuation during the experiment.

The candling of the eggs was conducted on the 7th and 14th day of incubation to check fertility of incubated eggs and remove the infertile eggs from the incubation chamber. From table 3, it was found that, 32, 72 and 74 eggs out of 70, 140 and 102 loaded eggs were fertile at 1st, 2nd and 3rd trials respectively having an average of 57.02 % fertility rate. From these fertile eggs, 20, 55 and 63 eggs were hatched after the incubation period of 24 days at 1st, 2nd and 3rd trials respectively having an average of 77.60 % hatchability rate. The result was higher than the values (68%) reported by Khairunesa *et al*. (2016), (70%-75%) by Galor (1983) and 74.2% hatchability rates was reported by Bernarki *et al*. (2012) under artificial incubation.

The results in Table 3 also indicated that the number of eggs that have embryos with unabsorbed yolk in each replication were 3, 6and 2 at 1st, 2nd and 3rd trials respectively having an average percentage value of 6.24 % of the total number of eggs that have embryos with unabsorbed yolk in the incubator. Furthermore, the numbers of eggs that have fully developed chicks but not hatched in each 1st, 2nd and 3rd trials were 4, 4 and 4 respectively and the average percentage of eggs that have embryos fully developed chicks but not hatched was found to be 6.74%.

Embryonic Mortality Rate

As indicated in table 3, it was found that the number of eggs with dead embryos in each replication were 5, 7 and 5 out of 32, 72 and 74 fertile eggs at 1st, 2nd and 3rd trials respectively having 9.61 % of mortality rate. Early embryonic mortality reported in Table 3 was less than those 12.2 % reported by Dzungwe JT,*et al*., (2018).

The embryonic mortalities might be caused by a bacterial or fungal infection of the eggs in the chamber, or the existence of cracks (micro) on the egg shells through which the embryos may have been susceptible (Abiola *et al*., 2008 and Abraham *et al*., 2014). Mortality may also be caused by malposition due to genetic factors, positioning of the eggs in the incubation trays, age, size of eggs and many other factors. (Ngambi *et al*.,2013). The developed but un-hatched chicks may have been unhealthy (Almeida *et al*., 2015) or have a genetic weakness.

Nonetheless, hatching begun on 20th day of incubation, and 4, 12 and 18 chicks were hatched at 1st, 2nd and 3rd trials respectively. The total number of chicks that hatched on the 22nd and 23rd day of incubation was 70 for all trials. Most of the chicks that hatched on the 24th day of the incubation died. From the result obtained, it was observed that about 91.96 % of hatched chicks were normal. However, the chicks that hatched after 23rd day of incubation were so weak compared to the ones that hatched on the 20th and 21st days of incubation. It was observed that the more the days away from the 21 days of incubation the more the weaker the chicks hatched.

Table 3: Biological performance data of egg incubator

Biological Performance Parameter	**Evaluation Trials**			**Mean**	**Percentage (%)**
	1	**2**	**3**		
Fertile eggs (Fertility)	32	72	74	59.3	57.02
Infertile eggs (infertility)	38	68	28	44.7	42.98
Hatched eggs (Hatchability)	20	55	63	46	77.60
Normal chicks hatched (Normality)	19	52	56	42.3	91.96
Chicks with broken leg or abnormal (Abnormality)	1	3	7	3.7	8.04
Chicks that hatched late	4	2	5	3.7	8.04
Embryonic death	5	7	5	5.7	9.61
fully developed chicks but not hatched	4	4	4	4	6.74
Chicks with unabsorbed yolk	3	6	2	3.7	6.24
Total number of eggs loaded	**70**	**140**	**102**	**104**	**100**

Partial Cost Estimation

Egg incubation by home-made egg incubator for hatching was determined in view of fixed and variable costs. The production cost of home-made egg incubator was determined by calculating the cost of different parts and their fabrication cost was 12,037.42 birr. The fixed cost for developed incubator in an hour (0.44 birr) and variable cost (41.87 birr) were determined. Annual operation of the developed incubator was considered as 6048 hours based on 252 probable days annually for incubation process with 24 daily working hours. From Table 3 it can be seen that, from the total available incubation days, annual revenue for home-made egg incubator was determined and found to be 76,230 ETB and the imported one accounts for 79,200 ETB revenue. The imported incubator requires additional generator in order to supply heat during power interruption which adds cost on initial investment.

Table 4: Cost estimation of developed egg incubator and imported incubator

	Developed incubator with 150 egg capacity	**Imported egg incubator with 150 egg capacity**
Costs		
Electricity	1,325.40 ETB/year	1,325.40 ETB/year
Labor	24,000ETB/year	24,000ETB/year
Fuel	2988 ETB/year	7,306.56 ETB/year
Lubrication	N/A	697.33
Sub-total	28,313.40	33,329.29
Revenue	76,230 ETB/year	79,200 ETB/year
Net income	47,916.60 ETB/year	45,870.71 ETB/year
Additional generator	N/A	18,000 ETB
Total cost of owning	**15,914.77 ETB**	**18,000+115,000= 133,000**

CONCLUSION

An electric and kerosene lump-powered incubator which has capacity to incubate 150 eggs at once was developed from readily available materials and tested with naturally mated stock koekoek eggs. From this experiment result it can be concluded that, the developed incubator gives high percentage of hatchability for each trial tested which shows that the machine is highly efficient and effective.

The developed incubator was found promising and operated 24 hours a day throughout the incubation period. The hatchability and mortality rate of the machine were 77.60% and 9.61%, respectively. The developed egg incubator was able to maintain the temperatures of the incubator between 36°C and 38.1°C with the use of TS-C700 temperature controller and an average of 60.75% incubator relative humidity. The results obtained revealed that the egg incubator performed its functional requirement of hatching eggs effectively due to the temperature and humidity values being within the recommended ranges.

When it comes to cost-effectiveness it can be concluded that the developed incubator requires significantly lower cost of owning and had greater net income when compared to imported egg incubator.

Therefore, the application of the electric and kerosene lump egg incubator can give a solution to major constraints of electric power interruption in poultry egg incubations by using kerosene lump as a supplementary heat source. Generally, it can be concluded that the machine can be used as import substitution with ease of owning.

RECOMMENDATIONS

The performance test shows that the machine can be used well in poultry egg incubations. Nevertheless, the following must be addressed to make the incubator more effective, efficient, popular, adaptable and usable among the farmers.

- An automatic egg turner motor and automatic humidifier should be used so as to regulate the turning of eggs every one hour for a period of 18 days of incubation.
- Increasing the capacity of the incubator to more than 500 egg-holding capacity makes the machine to meet the demands of day-old chicken.
- A constant supply of heat is needed to enable unobstructed operation of the incubation processes.

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