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Manufacture and evaluation of a semi-automatic incubator for hatching quail eggs

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ABSTRACT

This research evaluates a semi-automatic incubator designed for hatching quail eggs using locally available materials, with the aim of increasing the quail population, since quails do not naturally incubate their eggs. The objective is to produce meat that competes with broilers as a rich source of protein. The study includes three experimental variables: three incubation temperatures (37, 37.5, and 37.7°C), three turning times (2, 6, and 12 times per day), and three post-hatching periods for chicks to remain in the incubator (2, 6, and 12 hours). The measurements include the percentage of total hatchability within the first 3 hours, as well as rates of deformation and mortality. The results of this research indicated that the manufactured semi-automatic incubator was able to maintain a high hatching percentage, low deformation percentage, and a low mortality percentage when using an incubation temperature of 37.5°C, turning the eggs 12 times per day, and allowing the chicks to stay in the incubator for 12 hours after hatching. Therefore, it is recommended to utilize the manufactured semi-automatic incubator for hatching quail eggs under the above-mentioned parameters.

1. Introduction

Artificial hatching is practiced in many countries to increase the population of domestic quails (*Coturnix japonica*) since they do not naturally incubate their eggs. Despite protein deficiency in poor societies, poultry, and in particular quail, has received less attention than other livestock (Aggrey et al. 2003). As the demand for animal protein rises, quail breeding is seen as an alternative method for meat production, competing with broilers as a protein source. Quail meat and eggs are rich in vitamin E, protein, minerals, fat, and hormones, making them a healthy dietary option that can help people in developing countries who lack some or all of the necessary nutrients for optimal health (Bayomy et al. 2017). Furthermore, quail meat surpasses chicken in terms of protein content. Quails exhibit greater disease resistance, reach sexual maturity at 6 weeks of age, and start laying eggs at 50 days of age (Randall and Bolla 2008). Additionally, quails have the advantage of reaching sexual maturity at a younger age. On average, quails produce approximately 280-300 eggs per year, weighing 19 g each (Kaur et al. 2008). Moreover, quail farming has higher production and a lower cost-to-benefit ratio compared to chicken farming.

The process of incubating embryonic eggs until the parents hatch them is known as the "incubation egg process" (Aru 2017). Artificial hatcheries are crucial for hatching eggs and are widely used in intensive poultry production to meet the increasing demand for poultry products. Temperature stability is a key factor in the incubation process, as it is maintained by the parent while sitting on the eggs. This helps maintain a constant temperature required for the fetus's growth during the specified incubation period. Eggs are generally placed in the incubation phase to facilitate successful hatching, and sufficient moisture availability is essential during the incubation process.

The eggs incubator is a device, similar to a box, that can regulate temperature, humidity, and other factors to promote various stages of fetal growth in the egg, until the hatching process (Umar 2016). There are two main types of incubators available on the market: forced air and still air. The first type circulates air using an exhaust fan, while the second type uses convection air exchange, where cold air enters and heated air exits through ventilation holes. Without an exhaust fan, a still air incubator cannot circulate the air. An exhaust fan is essential to maintain the incubator's heat, moisture level, and oxygen content (Nakage et al. 2003). Researchers have been working on developing incubators for different types of eggs, including chicken (Schmitt 2015), quail (Deka et al. 2016), partridge (Nakage et al. 2003), and others. These researchers have developed incubators with automated control systems, including temperature (Ohpagu and Nwosu 2016), humidity (Schmitt 2015), egg rotation (Ramli et al. 2015), and others, based on microcontroller technology (Ali and Amran 2016; Abdul-Rahaim et al. 2015).

Before placing an egg inside the incubator, it is crucial to assess its quality, as the likelihood of successful hatching significantly decreases if the egg is of low quality. For Japanese quails, the incubation period lasts between 17 and 19 days (Aru 2017), with a temperature range of 36.5°C to 37.5°C19±0.5°C (Schmitt 2015), and a relative humidity range of 50% to 65% (Umar et al. 2016). To prevent the embryo from sticking to the eggshell during incubation, the egg must be turned by 45° every four hours (Mashhadi et al. 2012).

Only a few studies on quail incubation have been published since domestic quail do not naturally incubate their eggs. Therefore, by artificially hatching them, we can produce chicks.

The objective of this research was to construct and evaluate a low-cost incubator using simple electronic components and local materials. The incubator allows control of temperature and humidity, and a manually operated mechanism was used to turn the quail eggs throughout the 17 days required for the day-old chicks to hatch.

2. Materials and Methods

The current study was conducted at a private farm located at EL-Sharqia Government, Egypt. The research consisted of two stages. The first stage involved gathering fertile eggs, while the second stage involved manufacturing and evaluating a semi-automatic incubator for quail eggs.

2.1. Incubator description and structure

A rectangular box, shown in Figure 1, has been constructed for manufacturing the incubator. The incubator is designed for small-scale producers and has a hatching capacity of 350 eggs per cycle. It was constructed at a private workshop. As depicted in Figure 1 and 2, the incubator includes a hatching chamber, egg trays, a hatch box, an electric heater, a fan, a water pan, a hygrometer, and a digital thermostat.

2.1.1. Hatching chamber

The hatching chamber has a wooden body with an aluminum-bar jacket made of thermally insulated material. The metallic wall has a thickness of 5 cm. The dimensions of the chamber are 70 cm length, 50 cm width and 50 cm height.

2.1.2. Egg trays and hatching box

Inside the hatching chamber, two egg trays (56 cm long and 35 cm wide) and a hatching box were constructed. Each tray can accommodate 175 eggs for 15 days, after which they are transferred to the hatching box for an additional 3 days in the same incubator.

2.1.3. Electric heater

An electric heater with a 2000 watt output provides heat inside the hatching chamber. The electric heater is controlled using a digital thermostat.

2.1.4. Digital Thermostat

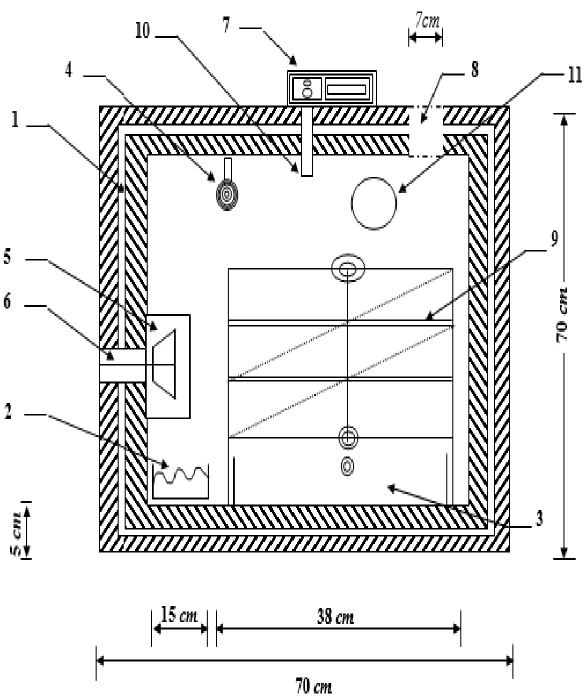
The temperature inside the hatching chamber is adjusted by a thermostat with an accuracy of 0.1°C. It operates within the appropriate temperature range of 5-50°C.

2.1.5. Water Pan

A water pan with dimensions of 10×15×50 cm is placed under the fan inside the hatching chamber to control the relative humidity within the desired range of 0-100%.

2.1.6. Hygrometer

A hygrometer is placed inside the hatching chamber to continuously monitor humidity levels. The eggs are automatically turned at a 45° angle with the help of a timer. Two openings in the hatching chamber are used for natural ventilation.



1- Double insulation wall.
2- Water pan.
3- Hatcher box.
4- Light.
5- Fan + Electric heater.
6- Vent.
7- Digital thermostat.
8- Vent.
9- Eggs tray.
10- Temperature sensor.
11- Hygrometer.

Figure 1. The schematic diagram of the semi-automatic incubator.

Figure 2. The semi-automatic incubator

2.2. Experimental procedure

Uniformly sized quail eggs, from a single production day, were collected for the incubation process and placed inside the hatching trays.. Cracked or extremely unclean eggs were excluded from the investigation. All eggs were thoroughly cleansed with a lukewarm water solution of the mild disinfectant Savlon before setting. The incubator box (hatching tray) was extensively fumigated with formaldehyde and potassium permanganate before laying the quail eggs. Pankaj et al. (2016) also recommended turning the quail eggs until the 15th day of incubation. Candling of the eggs was performed every alternate day using a torchlight, and one fertilized egg was sacrificed to monitor the embryo's developmental pattern. A pan of water was placed in the incubator box to maintain the ideal humidity for hatching. The humidity was adjusted to 50% during the period from 1 to 15 days and 75% for days 15 to 18. On day 7, all eggs were removed from the incubators, and their fertility was assessed using candles. On day 19 of incubation, quail chicks were counted and removed from the hatcher.

2.2.1 Evaluated Variables

Three variables were studied:

1. Incubation temperatures (T), °C: Three incubation temperatures of 37, 37.5, and 37.7°C .

2. Turning times per day (R), times/day: The eggs were manually turned every 12 hours, 4 hours and 2 hours, resulting in three turning times per day of 2, 6, and 12 times.

3. Periods for chicks to stay in the incubator after hatching (P), h: Three periods for chicks to stay in the incubator after hatching of 2, 6, and 12 hours were investigated.

2.2.2. Measurements

The number of unhatched eggs, newly hatched quail chicks, and the number of hatched chicks within the first 3 hours of day 19 were counted. The chicks were also checked fordeformities , and the findings were recorded. The following formulas were used to determine the hatching parameters:

$$Hatchability\ percentage\ (\%) = \frac{Number\ of\ hatched\ chicks}{Total\ number\ of\ eggs\ set} \times 100 \quad (1)$$

$$Hatchability\ percentage\ at\ the\ first\ 3\ h\ (\%) = \frac{Number\ of\ hatched\ chicks\ at\ the\ first\ 3\ h}{Total\ number\ of\ chatched\ chicks} \times 100 \quad (2)$$

$$Deformation\ percentage\ (\%) = \frac{Number\ of\ chick\ deformities}{Total\ number\ of\ hatched\ chicks} \times 100 \quad (3)$$

$$Mortality\ percentage\ related\ to\ incubation\ temperatures\ and\ turning\ times\ per\ day\ (\%) = \frac{Number\ of\ dead\ embryos}{\text{Total number of eggs set}} \times 100 \quad (4)$$

$$Mortality\ percentage\ related\ to\ periods\ for\ chicks\ to\ stay\ in\ the\ incubator\ after\ hatching\ (\%) = \frac{Number\ of\ dead\ chicks\ during\ incubation}{\text{Total number of } hatched\ chicks} \times 100 \quad (5)$$

2.2.3. Statistical analyses

Data on hatchability (%), deformation (%) and mortality (%) were edited in MS Excel (Microsoft Corporation, Redmond, WA, USA). The factorial design of the experiment was used to evaluate the performance of the developed machine. The data were statistically analyzed using the method of Stokes et al. (2012) to determine the significant effect of the mentioned variables on the study based on a probability of $P<0.05$. The experiments were conducted three times, and all graphs were drawn using Microsoft Excel 2016.

3. Results and Discussion

3.1. Effect of incubation temperatures (°C) and turning times per day on hatchability (%)

Regarding the effect of incubation temperatures and turning times per day on hatchability percentage, Figure 3 demonstrates a clear relationship. Increasing the incubation temperature up to 37.5°C positively impacted the hatchability percentage, especially when combined with increased turning time per day. The highest hatchability percentage of 95.06±1.32% was achieved with an incubation temperature of 37.5°C and 12 turning times per day. On the other hand, the lowest hatchability percentage of 26.98±1.27% was observed at an incubation temperature of 37°C and 2 turning times per day. The improved hatchability can be attributed to the increased frequency of turning, which prevents the embryo from sticking to the shell during incubation. This finding aligns with the study by Yoshizaki and Saito (2012) who reported a hatchability percentage of 24% under similar conditions.

3.2. Effect of incubation temperatures (°C) and turning times per day on hatchability (%) in the first 3 hours

A direct relationship was observed when examining the effect of incubation temperatures and turning times per day on hatchability in the first 3 hours (Figure 4). The highest mean hatchability percentage in the first 3 hours was 92.22±3.04% achieved with an incubation temperature of 37.5°C and 12 turning times per day. Conversely, the lowest mean hatchability percentage at the first 3 hours was 24.03±3.31% under an incubation temperature of 37°C and 2 turning times per day.

3.3. Effect of incubation temperatures (°C) and turning times per day on deformation (%)

In terms of deformation, Figure 5 illustrates the impact of incubation temperatures and turning times per day. Increasing the incubation temperature up to 37.5°C resulted in a decrease in the percentage of deformities when combined with a higher frequency of turning. The minimum percentage of deformities observed was 3.75±0.52% at an incubation temperature of 37.5°C and 12 turning times per day. Conversely, the maximum percentage of deformities 87.19±1.53% was recorded at an incubation temperature of 37°C and 2 turning times per day.

3.4. Effect of incubation temperatures (°C) and turning times per day on mortality (%)

The relationship between incubation temperatures, turning times per day, and mortality percentage is presented in Figure 6. Direct relationships are evident, with the minimum mortality percentage of 4.94±1.32% observed at an incubation temperature of 37.5°C and 12 turning times per day. In contrast, the maximum mortality percentage of 73.02%±1.27 was recorded at an incubation temperature of 37°C and 2 turning times per day.

3.5. Effect of incubation temperatures (°C) and staying period (h) on mortality (%)

Furthermore, the study examined the effect of incubation temperatures and staying period on mortality percentage (Figure 7). The results demonstrate a direct relationship, with the minimum mortality percentage of 9.32±0.06% observed at an incubation temperature of 37.5°C and a staying period of 12 hours. Conversely, the maximum mortality percentage of 34.64±7.48% was recorded at an incubation temperature of 37°C and a staying period of 2 hours. It is worth noting that quail chicks are particularly sensitive to temperature, and a longer stay in the incubator after hatching contributes to reduced mortality rates.

In summary, the results indicate that the hatchability percentage decreases, the deformation percentage increases, and the mortality percentage increases when the incubation temperature deviates from the optimal 37.5°C. These findings are consistent with Rashid (2014), who reported significantly higher hatchability at an incubation temperature of 37.5°C. Additionally, maintaining a minimum of 12 turning times per day is crucial for preventing deformities and ensuring successful hatching, as explained by Ramli et al. (2017). The deformation percentage is also influenced by the temperature, with higher temperatures leading to increased deformities. The combination of optimal temperature and an adequate number of turning times significantly impacts the hatchability percentage.

Overall, these results provide valuable insights into the optimal incubation conditions for quail eggs, highlighting the importance of temperature control and turning frequency for achieving higher hatchability rates, minimizing deformities, and reducing mortality.

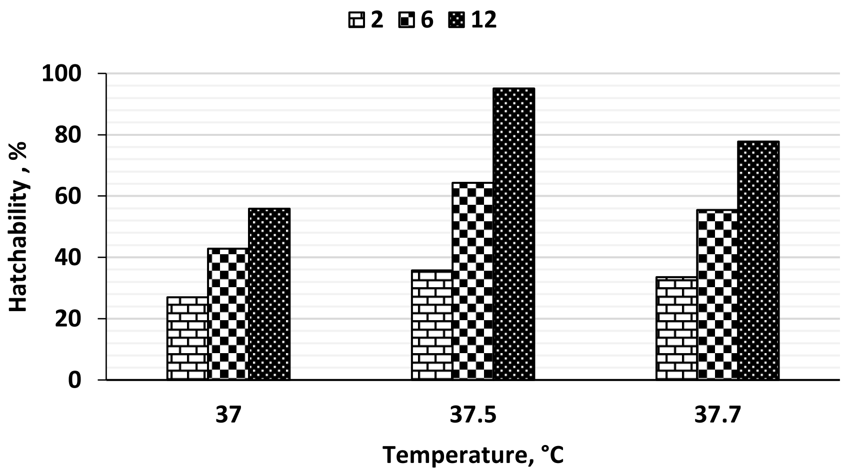


Figure 3. Effect of incubation temperature (°C) and turning time per day on the mean percentage of hatchability (%).

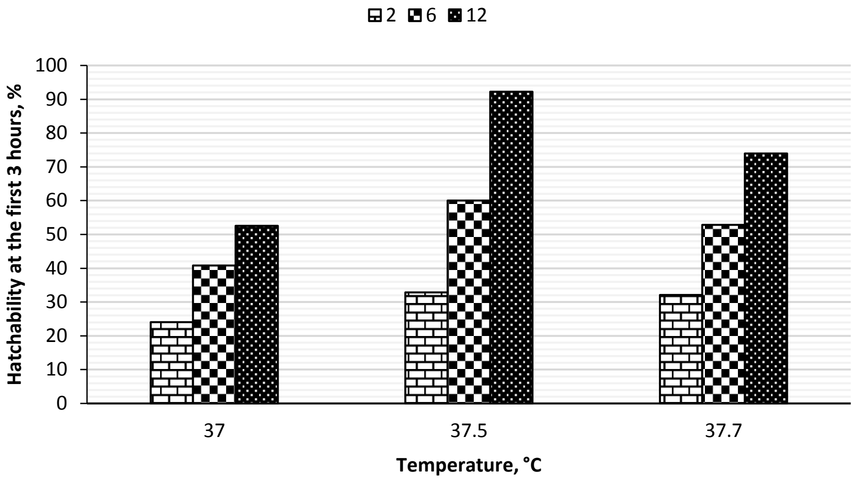


Figure 4. Effect of incubation temperature (°C) and turning time per day on the mean percentage of hatchability (%) in the first 3 hours.

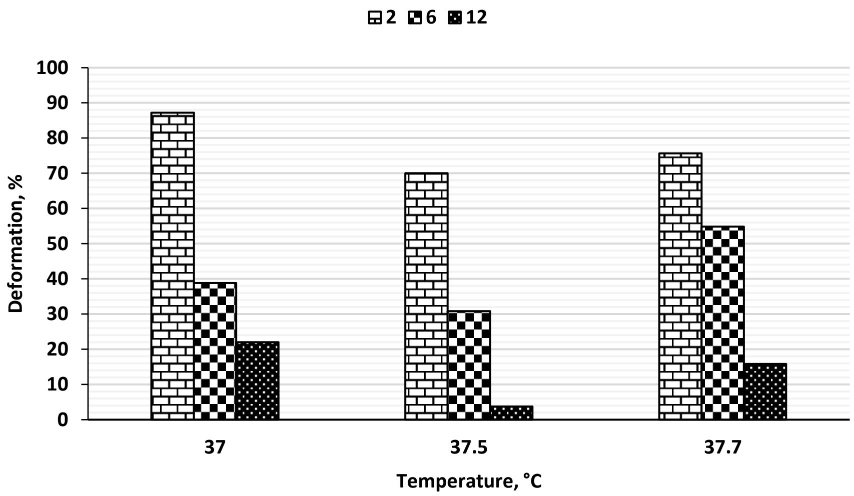


Figure 5. Effect of incubation temperature (°C) and turning time per day on the mean percentage of deformation (%).

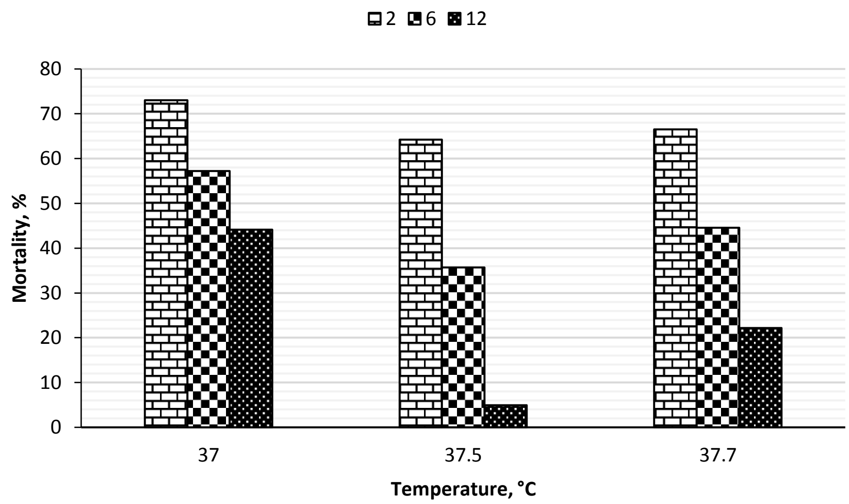


Figure 6. Effect of incubation temperature (°C) and turning time per day on the mean percentage of mortality (%).

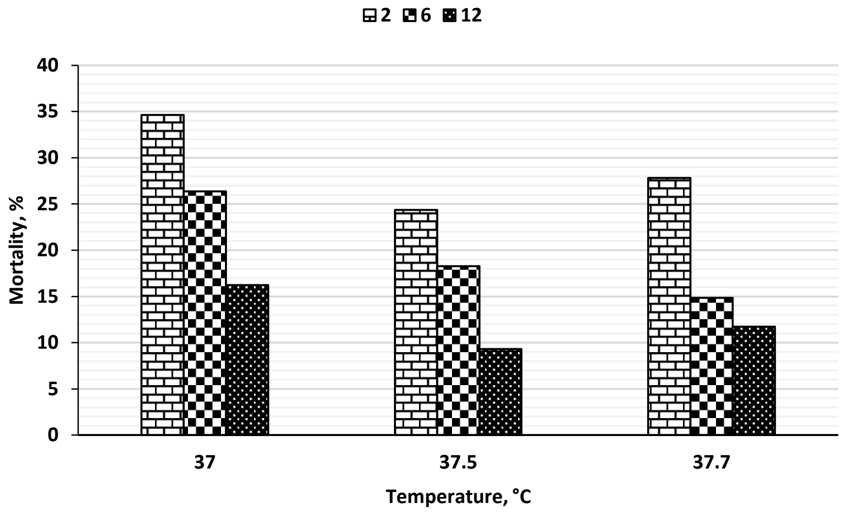


Figure 7. Effect of incubation temperature (°C) and staying period (h) on the mean percentage of mortality (%).

4. Conclusion and Recommendations

In conclusion, the study highlights the critical role of optimal incubation temperatures and turning times per day in achieving higher hatchability rates and minimizing deformities and mortality in quail eggs. The results demonstrate that hatchability decreases, deformation increases, and mortality rates increase when the incubation temperature deviates from the optimal 37.5°C. Consistency in turning the eggs, with a minimum of 12 times per day, is crucial for successful hatching and reduced mortality. Moreover, the deformation percentage is dependent on maintaining the optimal temperature, while the hatchability percentage is influenced by both temperature and the frequency of turning.

Based on the findings of this study, the following recommendations can be made:

1. Maintain an incubation temperature of 37.5°C for optimal hatchability, while avoiding temperatures lower or higher than this range.

2. Implement a turning schedule of at least 12 times per day to prevent the embryo from sticking to the shell and thus improve hatchability.

3. Ensure a longer staying period in the incubator after hatching to minimize mortality rates, as quail chicks are particularly sensitive to temperature during handling.

4. Monitor and control the incubation temperature and turning times per day rigorously to achieve consistent and optimal conditions for successful hatching.

5. Further research should be conducted to explore the impact of other factors, such as humidity and egg positioning, on hatchability, deformity rates, and mortality in quail eggs.

By implementing these recommendations, poultry farmers and hatchery operators can enhance the hatchability and overall quality of quail chicks, leading to improved production efficiency and profitability.

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