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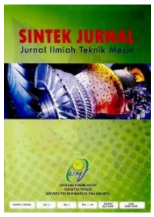

HEAT TRANSFER IN AUTOMATIC DUCK EGG INCUBATOR USING A LIGHT BULB AS THE HEATER

Yanti[1,*], Abd Rohman[1], Ari Patriana[1], Willy Muhammad Fauzi[2], Asep Mustopa[2], Rizki Muh Febrian[1]
[1]Mechatronics Engineering, Universitas Mayasari Bakti, Tasikmalaya, Jawa Barat, 46123, Indonesia
[2]Informatics Engineering, Universitas Mayasari Bakti, Tasikmalaya, Jawa Barat, 46123, Indonesia

[*]E-mail: yanti.aiiasenja@gmail.com

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ABSTRACT

Heat transfer in egg incubator affects the success of egg hatchability. This study aims to determine the heat transfer in an automatic egg incubator with incubator dimensions of 0.38 × 0.35 × 0.45 m. The research method used is an experimental approach by observing heat transfer in an automatic duck egg incubator. The research was conducted by collecting data directly to obtain heat transfer values in automatic egg incubators with a heat source from a light bulb. The incubator temperature was maintained at a maximum temperature of 39°C. Radiation heat transfer that occured in an egg incubator with a surface area of 0.92 m² which was coated with aluminum foil with a material emissivity value of 0.07 and an egg incubator temperature of 39°C (312 K) was 34.6 Watt. The conduction heat transfer that occured on the wall of the egg incubator with the thermal conductivity value of aluminum foil, namely k = 0.034 W/mK, was 34.78 Watt. The results of the study by heat efficiency that occurred in the egg incubator room was 58% obtained a hatching success rate with a hatchability of 75%.

Keywords: egg incubator; hatchability; heat transfer.

1. INTRODUCTION

Egg incubator functions to incubate eggs with heat generated from electric current [1]. The egg incubator is equipped with a temperature control so that it is similar to the mother so that the eggs can hatch [2]. Egg incubators are usually used by duck breeders because ducks do not incubate their own eggs. Duck eggs are left anywhere after the mother duck takes out her eggs [3]. Egg incubator requires a temperature of around 36°C-39°C and humidity around 50-70% for the egg hatching process to be successful [4]. The temperature in the egg incubator that is not suitable for the broodstock will result in insufficient heat needed, this will result in the death of the embryo in the egg [5].

Automatic egg incubator makes it easier for farmers in the process of hatching eggs because breeders do not have to turn the eggs directly. Regular rotation of the rack with angles of 0°, 45°, and 315° indicates that the temperature increase depends on the rotation of the rack, if the distance between the light bulb and the egg is closer, the rate of radiant heat transfer that occurs in the eggshell will be greater, otherwise the farther the distance between the light bulb and the eggshell, the smaller the rate of heat transfer that occurs in the egg [6]. Airflow conditions in the incubator affect the heat transfer and the heat transfer between the egg and its environment affects the temperature of the embryo [7,8]. Janisch's research (2015) shows that incubation temperature affects molecular mechanisms in muscles and other tissues that impact growth after hatching [9]. The right temperature for hatching eggs in an egg incubator is an absolute requirement to get high success hatchability and post-hatching performance [10-14].

Temperature has the strongest influence as it can inhibit, promote, or sustain embryonic development [15-16]. Optimal incubation temperatures result in healthy hatchability with good post-hatch performance [17-18]. High temperatures at the start of incubation can affect bone development during incubation [19], while high temperatures at the end of incubation result in decreased hatchability and quality of post-hatch performance [20]. High incubation temperatures negatively affect chick heart weight and the immune system [21]. In this context, deviations need to be prevented as they can impair embryo development, hatchability, hatchling quality and post-hatching performance [22].

This study aims to determine the heat transfer from a light bulb as the heater in the automatic egg incubator. This research was carried out by adding aluminum foil to the inside of the automatic egg incubator so that the heat inside the egg incubator does not come out much. The use of aluminum foil in the incubator wall is expected to be able to maintain a more stable heat temperature and be able to retain heat longer in the incubator.

2. RESEARCH METHOD

The research method used is an experimental approach by observing heat transfer in an automatic duck egg incubator using a light bulb as a heater. The heat inside the incubator is observed using sensors installed inside the incubator. The incubator has dimensions of 0.38 x 0.35 x 0.45 meters. The light bulb used is a light bulb with a power of 5 watts. The parameters measured to observe heat transfer are environment temperature and temperature inside the incubator.

The research instrument included an egg incubator unit with the use of aluminum foil on the inner wall and the measuring instrument was a digital thermometer. In this study, an egg incubator unit with an automatic sliding rack was used. The number of eggs used in the study were 10 duck eggs obtained directly from the breeders.

This research included testing to determine the rate of heat transfer that occured in the incubator chamber of the automatic duck egg incubator using a light bulb. The research was carried out by collecting data directly to obtain the temperature value or degree of heat in the egg incubator and the ambient temperature given from the glow of a light bulb. Data collection on the egg incubator was carried out by measuring the room temperature of the egg incubator marked with code T1 and the ambient temperature value with code T2 after the temperature inside the egg incubator was stable at a maximum temperature of 39^{o}C.

Heat transfer is influenced by the dimensions of the egg incubator/hatching chamber, namely the surface area of the egg incubator. The hatch area can be determined by equation (1):

$$A = 2(p.l) + 2(p.t) + 2(l.t) \quad (1)$$

Where A = hatchery area (m^2), p = hatchery length (m), l = hatchery width (m), and t = hatchroom height (m).

The calculation of heat transfer by radiation in the egg incubator is determined by equation (2):

$$\dot{Q}_e = \sigma .\ A .\ \varepsilon .\ T^4 \quad (2)$$

Where $\dot{Q}_e$ = Radiation heat transfer rate (Watt), ε = Emissivity of the material, σ = Stefan Boltzman constant 5.67 x 10^{-8} W/m^2 K^4, and T = Surface temperature (^{o}C).

The power generated from the use of light bulbs is determined by equation (3):

$$P = V.I \quad (3)$$

Where P = power (Watt), V = voltage (volt), and I = electric current (A)

Conduction heat transfer on the surface of the wall of the egg incubator is determined by equation (4):

$$\dot{Q}_k = \frac{k}{d} A\ (T1 - T2) \qquad (4)$$

Where $\dot{Q}_k$= Conduction heat transfer rate (Watt), k = thermal conductivity, and d = wall thickness (m).

3. RESULTS AND DISCUSSION

The heat transfer process in the egg incubator occurs from the heating source to the entire egg incubator room. Heat transfer is the process of transferring heat energy due to a temperature difference. Heat energy will move from a higher media temperature to a lower media temperature. The heat transfer process will continue until there is a temperature equilibrium in the two media. Each material has a different thermal conductivity and emissivity. Thermal conductivity is an intensive quantity of a material which indicates its ability to transmit heat energy. Emissivity is the ratio of the energy radiated by a given material to the energy radiated by a black body at the same temperature. Emissivity shows a measure of the ability of an object to radiate the energy that is absorbed.

Heat transfer is influenced by the dimensions of the egg incubator/hatching chamber, namely the surface area of the egg incubator. The surface area of the egg incubator/hatching room was calculated by equation (1) and the results are shown in Table 1.

Table 1. The values of the dimensions of the hatching chamber

Dimensions	Values
Length (m)	0.38
Width (m)	0.35
Height (m)	0.45
Surface area (m^2)	0.92

The distance between the light bulb and the egg affects the rate of heat transfer. The closer the distance between the light bulb and the egg, the greater the rate of radiation heat transfer that occurs in the egg, conversely, the farther the distance between the light bulb and the egg, the smaller the rate of heat transfer that occurs in the egg.

The inside of the egg incubator was covered with aluminum foil which functioned as a heat barrier. The radiation heat transfer rate in the egg incubator with a temperature of 39°C and a surface area of 0.92 m^2 and the emissivity value of aluminum foil is ε = 0.07 was calculated by equation (2).

$\dot{Q}_e = \sigma.\ A.\ \varepsilon.\ T^4$
$\dot{Q}_e = 5.67\ x\ 10^{-8}.\ 0.92.\ 0.07.\ 312^4$
$\dot{Q}_e$= 34.6 Watt

Radiation heat transfer that occured in the egg incubator with a surface area of 0.92 m^2 and covered with aluminum foil with a material emissivity value of 0.07 was 34.6 Watt.

The power generated from the use of light bulbs with a current strength of 0.27 amperes and a voltage of 220 volts was calculated by equation (3)

$P = V.I$
$P = 220\ x\ 0.27$
P = 59.4 Watt

The wall material used for the egg incubator was wood with a thickness of 9 mm and coated with aluminum foil with a thermal conductivity of aluminum foil, namely k = 0.034 W/mK. The conduction heat transfer rate that occurred on the egg incubator wall was calculated by equation (4).

$\dot{Q}_k = \frac{k}{d} A\ (T1 - T2)$
$\dot{Q}_k = \frac{0.034}{0.009} x 0.92 x (312 - 302)$
$\dot{Q}_k$ = 34.78 Watt

Therefore, the heat load of the egg incubator room covered with aluminum foil with aluminum foil thermal conductivity of k = 0.034 W/mK was 34.78 Watt.

The heat efficiency that occured in the egg incubator room was the ratio of the heat load in the egg incubator (Qout) to the heat load given to the egg incubator (Qin). Heat efficiency was calculated by equation (5).

$\eta = \frac{Qout}{Qin} x100\%$
$\eta = \frac{34.78}{59.4} x100\%$
$\eta = 0.58x100\%$
$\eta = 58\%$

Thus, the heat efficiency that occurred in the egg incubator room was 58%.

The number of eggs hatched in the study were 10 duck eggs. After 24 hours in the egg incubator, there were 2 infertile duck eggs so they were removed from the egg incubator. There are 8 fertile duck eggs in the incubator and after 28 days, 6 eggs can hatch. The percentage of hatching eggs in the egg incubator can be calculated by equation (6).

$$Hatchability = \frac{\Sigma numberofhatchedducks}{\Sigma numberoffertileeggs} \times 100\%$$
$$Hatchability = \frac{6}{8} \times 100\%$$
$$Hatchability = 75\%$$

So the hatchability of egg incubators using automatic sliding racks was 75%. The percentage of eggs that hatch from the total number of fertile eggs is called hatchability. Hatchability can be used as a parameter of the success of the egg hatching business. The higher the hatchability obtained, the higher the profit of the hatching business, while the low hatchability will cause the profit obtained to be smaller. Yuni's research shows the results of the hatchability analysis at a temperature of 39°C - 40°C is 58.88% [23]. The incubation period with too high a temperature causes the amount of egg shrinkage. Shrinkage of egg weight inhibits embryo development which has an impact on hatchability. This is because the liquid in the egg functions to dissolve nutrients for embryonic development to experience greater heat expenditure through evaporation and it is very likely that the embryo fails to hatch due to dehydration caused by large evaporation.

4. CONCLUSION

Egg incubator using an automatic sliding rack provides convenience in the process of turning eggs. The timer installed in the egg incubator functions as a regulator of the sliding rack motor. The automatic sliding rack is effective for rotating the position of the eggs on the egg rack for a set time so that the egg heating process becomes more even. The walls of the egg incubator are made of wood covered with aluminum foil with a thickness of 9 mm. The heat efficiency that occurs in the egg incubator covered with aluminum foil is 58%. From the research results with the incubator room temperature setting to a maximum of 39°C, the hatching success rate was obtained from 8 fertile eggs which were incubated, 6 eggs hatched with a hatch presentation reaching 75%. The use of light bulbs as heaters in an automatic duck egg incubator can transfer heat into the incubator and maintain an optimal temperature for duck hatching.

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