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Analysis Study on Influence of Temperature and Humidity During Incubation of Chicken Eggs Via Altair Hyperstudy

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ABSTRACT – Temperature and humidity levels during incubation are crucial determinants of the duration of incubation. Inadequate monitoring during the incubation process extends the incubation period and hinders the embryonic development of the chicks. This study examines the incubation period and optimises the temperature and humidity parameters during incubation. The chicken eggs were placed into an automatic incubator at temperatures of 36.5℃, 37.5℃, and 38.5℃. The relative humidity was monitored at 50%, 55%, and 60%. The turning frequency was set at every three hours, and the eggs were automatically turned for a duration of six seconds. Finally, the incubation period was analysed using Altair HyperStudy software in order to obtain the ideal period for incubating a chicken egg. The exhibition demonstrated that the development of chicken embryos reached a sufficient level of maturity. The results showed that the optimum 38.5℃ temperature was accomplished, as well as a 60% relative humidity (RH) was retained during the analysis. This resulted in an incubation period of 18 days for the chicken eggs. The analysis through ANOVA and RSM shown that the incubation temperature and humidity are inversely proportional to incubation period.

KEYWORDS: Incubation Period, Temperature, Humidity, Chicken Egg

1.0 INTRODUCTION

An incubator is essentially an enclosed device with a fan and heater designed to keep the eggs warm during the 21-day incubation period. The average size of egg is the best to choose for the incubator. It is because a double-yolk may be contained within the eggs if the size chosen is too large, yet if a smaller size of egg is utilized, the yolk may not be there at all. The optimal settings can be provided to ensure that the egg incubates and hatches in correct development growth with the aid of an incubator. It will recommend incubation temperatures and humidity levels that are optimal for the correct development of chicken eggs, but this will not guarantee complete success.

In a nutshell, the incubator can replace the natural role of the broody hen. Another reason incubator can be advantageous is that they can hatch a large number of chicken eggs at once, which is far more reliable than hens. Unfortunately, the successful rate of hatchability cannot be proven using an incubator because there are several factors that influence egg hatchability. In general, chicken eggs are supposed to hatch on the 21st day, but when using an incubator, the eggs may hatch too early or too late due to several factors that have a significant impact on the hatchability of the eggs. For example, temperature and relative humidity during the incubation phase are critical in ensuring that the eggs hatch on the 21st day. As previously indicated, one of the most important variables influencing egg quality is environmental circumstances. An optimal temperature and relative humidity must be established, particularly during the 21-day incubation phase.

The incubation time of chicken eggs refers to the period during which an egg is placed in an incubator and a chick hatch. The incubation time may vary depending on various factors, such as the temperature and humidity levels during incubation. Therefore, RH and temperature are essential factors affecting embryo development, hatchability, as well as post-hatch performance. Current research conducted by [1] has reported that chick quality as well as

post-hatch performance is influenced by incubation conditions, such as incubation temperature and humidity. An automatic incubator can be utilized for the purpose of enhancing productivity, quality, and safety, while also preventing wastage in comparison to natural incubation. Additionally, it has the capability to save a significant amount of time and reduce labor costs. Based on the findings of [2], it has been observed that natural incubation results in a reduced number of chicks. This can be attributed to the fluctuations in humidity and temperature. The incubation period for chicken eggs is approximately 21 days on average. This aligns with [3] results, describing that these eggs will stay for 21 days in incubators, followed by the hatching of the chicks.

However, it is important to note that the actual duration may vary between 19 and 23 days. During incubation, the crucial stage necessitates the control and observation of temperature and humidity, as these parameters hold significance in influencing both the incubation period and hatchability. The ideal temperature for most chicken eggs is approximately 37.5°C, accompanied by a relative humidity of approximately 50-55%. Previous research has shown that eggs were incubated at a 37.8°C temperature as well as a 56% RH for the entire 21-day incubation period [4].

A suggestion has been made that the incubator's humidity setting must continuously rise, starting from 53% RH and reaching 66% RH [5]. A more recent study has confirmed the existence of sensors capable of overseeing humidity levels by regulating and anticipating each egg's humidity loss [6]. A previous study has reported that chicks hatched from eggs subjected to a 45% RH during incubation exhibited lower weight at hatching in contrast to chicks from eggs incubated at 55% RH. The findings revealed that chicks hatched from eggs with a 55% RH incubation experienced more significant reductions in both body weight as well as water content during heat exposure compared to their counterparts from eggs incubated at 45% RH [7].

Based on the previous study, eggs were incubated at the optimum 37.7°C temperature as well as at a 60-65% humidity level [8]. In addition to the work of [9], who found that the hatchability was achieved at 37.2°C in an incubator with a relative humidity of 53% for the incubation period of 21 days. The study reported by [10] demonstrated that the eggs were left at a 37.8°C temperature as well as a 56% RH throughout the entire incubation period. The previous findings by [11], who discovered that chicken eggs incubated at 38°C as well as 60% humidity successfully hatched. Another study has reported that the highest percentages of hatchability were observed for the 53% relative humidity (RH) [12].

In a similar manner, it was found by [13] that optimal chick performance was accomplished at a 53% RH. It was suggested that issues with chick quality might arise from excessive or insufficient RH levels during the incubation process. In this study, the temperature and relative humidity in an automatic incubator were analysed and optimized as they are the most important parameters that affect the incubation period, egg hatchability, embryonic growth, and the chick weight at hatch. It is possible to obtain more optimal combinations of incubational temperature and relative humidity by analyzing their relationship and subsequent impacts on the incubation period. This can lead to improvements in embryo development and chick performance in the future.

2.0 METHODOLOGY

The setup for experimental is performed as shown in Figure 1. The parameters that are evaluated in this investigation are temperature and humidity. The temperatures and humidity are expressed in three levels: 36.5°C, 37.5°C, and 38.5°C. The relative humidity used are 50%, 55%, and 60%. The humidity is controlled by the volume of water, air flow, temperature and speed of the fans. It keeps the egg from losing too much of moisture during the incubation process. Meanwhile, the frequency at which the eggs are turned is set to be constant, occurring every 3 hours, with each egg being turned for approximately six seconds. The ideal incubation time for chicken eggs, as well as the optimum temperature and relative humidity, were determined by considering all the parameters. Next, the setup of the design of the experiment was performed. The full factorial design method was used for the DOE in this study. The total

number of experiments that were performed is nine, (3^2). Experimental data are taken and represent as shown in Table 1. The fitting procedure was performed using least square regression, which predicts the best result. Following that, optimization was performed to determine the best temperature and humidity for incubating chicken eggs. The response surface was created from the DOE results using the least-squares regression (LSR) fitting approach.

(a)

(b)

Figure 1. Experimental set up using an automatic incubator (a) Inside view of the incubator, and (b) Outside view of the incubator

Figure 1. Experimental set up using an automatic incubator (a) Inside view of the incubator, and (b) Outside view of the incubator

Number of Experiments	Temperature [^{0}C]	Relative Humidity [%]	Incubation Period [days]
1	36.5	50	23
2	36.5	55	21
3	36.5	60	20
4	37.5	50	22
5	37.5	55	21
6	37.5	60	19
7	38.5	50	21
8	38.5	55	19
9	38.5	60	18

Table 1. Experimental datasets

Number of Experiments	Temperature [^{0}C]	Relative Humidity [%]	Incubation Period [days]
1	36.5	50	23
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4	37.5	50	22
5	37.5	55	21
6	37.5	60	19
7	38.5	50	21
8	38.5	55	19
9	38.5	60	18

3.0 RESULT

ANOVA, or analysis of variance, is a statistical technique employed to determine if there is a significant difference in the means of two or more groups. The feature provided by Altair HyperStudy Software compares the samples of incubation period to assess the impact of individual parameters on the duration of the incubation period. The present analysis was conducted with a 95% confidence level, corresponding to a 0.05 significance level. The statistical significance of a design variable is reflected to be more definite when its F-value is high. According to the results of the ANOVA test, the variable with the utmost statistical significance (112.15) in relation to the incubation period is humidity. This is followed by the temperature which is recorded the lowest statistical significance (49.85). If the P-value of this model is below 0.05, it indicates the statistical significance of the design variable. A P-value below 0.05 is preferred as it has a better probability of observing a result that is obtained from the experiment. According to Table 2, the P-value for humidity is 4.17 x 10-5, which has the highest probability when compared to temperature.

The analysis results presented in Table 2 indicates that the variables of humidity (H) and temperature (T) are statistically significant factors that affect the incubation period for chicken eggs. This is obvious from the obtained P-values, which are less than 0.05. Hence, the suggested model for the incubation period offers a sufficient explanation for the correlation between the design variable as well as the incubation period response, as it accounts for about 96% of the experimental variability in the dataset. Based on the analysis, the humidity has the greatest influence on the incubation period, while temperature has the least contribution to the analysis.

However, interestingly, this contradicts a study that was conducted by [14] which stated that the temperature plays a crucial role in egg incubation, significantly impacting the development of the embryo, hatchability, as well as post-hatch performance. In general, chicken eggs are sensitive to incubation temperatures and humidity. Lower incubation temperatures generally cause the chicken eggs, or embryos, to be delayed, whereas higher incubation temperatures accelerate growth and development. Equation 1 represents the regression equation that has been developed for the incubation period. Regression equations are utilized to ascertain the relationship between temperature and RH as well as their influence on the chicken eggs' incubation period. The equation response surface is developed, and the incubation period can be predicted by using this equation within the limits of testing, generated by Altair HyperStudy.

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Table 2. ANOVA Test for Incubation Period

Variables	*Degree Freedom (DOF)*	*Sum of Squares*	*Mean Squares*	*F-value*	*p-value*
Temperature, T	1	6.00	30.58	49.85	4.04e-04
Humidity, H	1	13.50	68.81	112.15	4.17e-05
Error	6	0.72	0.61		
Total	8	20.22			

$$P = 74.444 + (- 1.0000 * \quad + (— \ 0.3000 * \ H\text{^}1)\, T\text{^}1) \qquad (1)$$

where,
P is the Incubation Period, in days
T is the temperature, in degree Celsius
H is the relative humidity, in percentage

As shown in Figure 2, the 3D graph response surface depicts the relationship between two design parameters on the incubation period. This feature aids in gaining a better understanding of the parameters' impact (temperature as well as RH) on the chicken eggs' response during incubation. The 3D response surface graph makes determining the optimal incubation period easier. Once two parameters are chosen to be plotted in the 3D response surface graph, the medium level is chosen as the constant parameter. Figure 2 depicts the graph design created using data from the full factorial DOE. Furthermore, the trade-off occurs provided that the number of captured graphs equals the product of the number of responses as well as the number of parameters, achieved by pairing two parameters while keeping one constant at a medium level. Figure 2 displays the response of the incubation period to variations in temperature and relative humidity. Based on the 3D graph, it can be observed that there is a negative trend on the incubation period in relation to temperature as well as RH. As the temperature and RH decrease, the duration of the incubation period rises.

From the findings, the optimum incubation period occurs when the temperature used is 38.5 ˚C, the relative humidity applied is 60% and the incubation period is 18 days. The trend in Figure 2 illustrates that the impact of relative humidity and temperature on incubation period is inversely proportional. When the relative humidity is decreasing, the incubation period also decreasing. When a relative humidity of 50% is applied, the obtained incubation period ranges from 21 to 23 days. Furthermore, when a relative humidity of 60% is applied, the incubation period ranges from 18 to 20 days. In addition to that, the relative humidity applied inside the incubator also has a significant impact on the quality and hatching rate of the eggs. When a temperature of 36.5˚C is used, the incubation period spans from 20 to 23 days. However, when a temperature of 38.5 ˚C is applied, the incubation period ranges from 18 days to 21 days, apart from any other considerations. Based on the previous study, eggs were incubated at the optimum 37.7°C temperature as well as at a 60-65% humidity level [8].

Furthermore, this finding is corroborated by another study, which stated that eggs were subjected to a 21-day incubation period at 37.5ºC with a 60% RH [15]. On the contrary, a prior investigation demonstrated that an elevated 39.5°C temperature as well as 65% humidity, extended the incubation period to 21 days [16]. The recommended duration for hatching chicken eggs is 18 days, influenced by a 38.5˚C temperature as well as a 60% RH. Nevertheless, there are reports of successful incubation at a 37.8°C temperature as well as a 55% RH, and they hatched on day 21 [17].

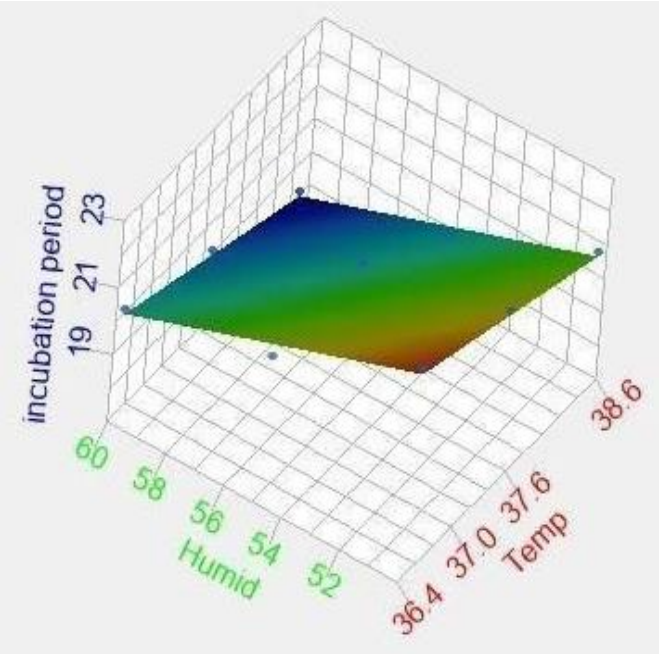

Figure 2. 3D response surface of temperature and relative humidity for incubation period

To conclude, dehydration inside the chicken eggs can be caused by inadequate RH levels during the incubation or hatching phases or from an extended duration between hatching and the eggs being taken out of the hatcher. The prominent effects that can be clearly seen during the process of incubating chicken eggs are the environmental conditions, namely temperature and humidity.

3.0 CONCLUSION

The major impact on the incubation period of the eggs is the relative humidity. The highest incubation period that is gained is 23 days, while the lowest is 18 days. The 23-day incubation period can be achieved by applying a 36.5℃ temperature as well as a 50% RH throughout that period. During the incubation period, the optimum temperature was 38.5 ˚C with 60% relative humidity for 18 days. The relationship between temperature and relative humidity with the incubation period is inversely proportional. In general, higher temperatures contribute to shorter incubation periods, along with an increase in relative humidity. To improve and offer recommendations, in future studies, increase the range of parameters and levels used in the full factorial approach to obtain more precise data, particularly for the incubation period of chicken eggs. Parameters such as turning frequency and storage temperature could be included in the next study so that those parameters can be investigated further, particularly the effect of incubation period.

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