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Full Length Research

Development of hot spring fed incubator for duck eggs

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The development of hot spring heat source incubator for duck eggs was deemed necessary to design the utilization of hot spring as heat source for incubating duck eggs, to reduce the use of electricity. This study addressed issues such as replacing conventional source of energy with geothermal energy in Los Baňos, Laguna, Philippines for incubation of eggs (ducklings, *ballot* and *penoy*). The experimental design used was two factors at three levels (2 × 3): ventilation opening (30, 45 and 60°) and number of evaporating pans (3, 4 and 5 pans) and each run had duration of 23 h. Sampling of the average temperature and relative humidity showed an average of 100 samples per hour. The data were analyzed using surface response regression to select the run within optimal conditions. The surface response and multiple regression revealed that the optimal setup was with the ventilation opened at 30° and 5 evaporating pans in the incubator. The optimal conditions were the mean temperature and relative humidity of 37.5°C at the top tray and 49.6% at the bottom tray as predicted by the mathematical model using trial version of Design of Experiment (DoE) 10.0.

Key words: Hot spring, incubator, heat source, geothermal, energy, duck eggs.

INTRODUCTION

Los Baños is a city located in the province of Laguna, Republic of the Philippines. Los Baños is the location of the Miyon Volcano which is a source of geothermal energy. Geothermal energy is the heat contained in the solid earth and in its internal fluids. It can be stored as sensible or latent heat (Clauser, 1988). In Los Baños, geothermal energy is in the form of hot spring and these hot springs are mainly utilized for hot spring resorts. In 2014, there were 42 hot spring resorts registered in Los Banos. Because of the hot spring resorts, Los Banos is also recognized as a tourist destination. The hot springs are mostly located in the barangays (villages) of Lalakay, Tadlac, Bambang and Baybayin. These hot spring resorts are estimated to consume large volume of groundwater which could result in over-extraction and decrease in ground water quantity. The groundwater is significant for domestic, agricultural, commercial and industrial uses in urban and rural development (Jago-on et al., 2017). In Laguna Provience, large scale duck egg production is observed in the municipalities of Los Baños and Victoria

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Table 1. Agricultural applications of hot spring.

Temperature (°C)	Process
20	Fish farming
40	Soil warming, biodegradation and fermentations
50	Mushroom growing
60	Animal husbandry, greenhouses by combining space and hotbed heating
70	Refrigeration (lower temperature limit)
80	Space heating (buildings and greenhouses)
90	Drying of stock fish
100	Drying of organic materials, washing and drying of wool
120	Most multi-effect evaporation, concentration of saline solution
130	Evaporation in sugar refining
140	Drying farm products at high rates and canning of food

due to its proximity to the Laguna de Bay (Atienza et al., 2015).

Hot springs can also be used for agricultural and industrial purposes within a temperature range of 20 to 140°C (Table 1). The temperature of 40°C can be used for soil warming, biodegradation and fermentation but these processes cannot suit the agricultural process of Los Baňos. In a study by Taplah et al. (2018a), it was determined that the hot spring at 41.5°C can be used for the incubation of duck eggs which is a major industry in Baranggay Malinta, Los Baños, Laguna Province, Philippines with coordinate 14° 10’ 55.91” N and 121° 13’ 36.49”E.

Over the period of incubation, continual vaporization of water through incubation amount is typically 12% of the fresh egg's weight (Ar et al., 1991). The change in phase of liquid to vapor at incubation temperature is approximately 580 cal/g of water lost (Schmidt-Nielson, 1975). For radiation in the incubator among the internal wall of the incubator, the egg and other eggs, the radiation can be negligible because the temperature of the surface of the internal wall and the surface of the eggs is within 1 and 2°C. The convective heat flow during incubation is important in the incubator because of the medium of heat flow from the heat source to the egg. In order to calculate the convective heat flow, the thermal conductivity of the egg and the air which is the boundary layer of air around the egg must be established. It can be determined that the boundary layer around the egg is approximately 100 times greater than the barrier to heat loss (Sotherland and Rahn, 1987); therefore, the thermal conductivity of the egg can be negligible.

The optimum incubation temperature for most poultry species is 37 to 38°C and small deviations from the optimum temperature can have a major impact on the hatchability and development of the embryo (Wilson, 1991). Although, the optimum temperature of incubating poultry species is 37 to 38°C, the temperature, relative humidity and length of incubation may vary from avian species. Majority of the ducks grown in the Philippines are the Mallard and about 90% of the eggs produced are used to process *balut* (Chang and Villanoz, 2008). Deep body temperatures for the domestic duck were 41.5 to 42.5°C (King and Farner 1961) while deep body temperatures for Mallard were about 41°C (Caldwell, 1971).

In the Philippines, fertilized duck eggs are incubated for a period of 14 to 18 days then steamed or cooked for about 20-30 min and commonly known as *balut* in Asian countries such as Bangladesh, Cambodia, China, Indonesia, Laos, Malaysia, Thailand and Vietnam. The byproducts of *balut* include the following:

Penoy: Incubated duck eggs which did not develop since the yolk are scattered. *Penoy* are usually extracted from the incubator during candling after 5 days of incubation. They are steamed or boiled and usually sold alongside with *balut*.

Century eggs: The duck eggs that contain dead embryos. It is baked and sold together with byproducts of *balut* (BAS-SRTC, 1998).

By the end of the first quarter of the 21th century, the supply of oil will reach its peak and will begin to decline as predicted by energy experts. The increase in the demand and reduction in the supply will lead to a significant increase in the price of oil. However, this increase in the price of oil will cause a chain reaction which may lead to the replacement of conventional sources of energy by non-conventional sources consisting mainly of the renewable or alternative energy sources such as biomass, biogas, wind, hydro, solar and geothermal energy (Fanchi, 2005).

This study was deemed necessary to design and optimize a hot spring incubator for duck eggs to eliminate the use of heating coil with the hot spring heat exchanger to maintain optimum incubating temperature and relative humidity. The results of this experiment can be used by duck farmers in areas with access to hot springs to build full size incubators for duck eggs using renewable energy (geothermal energy) as heat source. This study addresses the issues such as replacing conventional source of energy with non-conventional, renewable or alternative source. Since it reduces operational cost of incubating duck eggs, it can help to increase the profits of small scale farmers.

METHODOLOGY

Conceptual framework

The small scale hot spring as heat source incubator (Figure 1) was designed with double walls, adjustable ventilation opening and water supply valve control. The water header is to maintain a constant water flow through the heat exchanger in the incubator while setting the other two factors (ventilation opening and number of evaporating pans) at different levels. The two fans at the top of the incubator were to blow continually for the circulation of the air while the turning of the eggs was about 6 times a day. The turning of the eggs was powered by an electrical motor and controlled by a Programmable Logic Control (PLC) to reduce the human effort.

Considering the design of the tray spacing, the dimension of the duck egg with the maximum major dimension was used for the computation. Insufficient tray spacing may cause the tray above to crush the eggs when tilted at 45°. As in Figure 3, the maximum height of the egg is not the actual height to consider in the computation. The added height of the tray and tray holder were also considered in excess allowances. The space between trays at inclination, c´ was based on Equation 1 by French (1997):

$$c' = cos\Theta(h + c) - h \qquad (1)$$

The turning frequency numerically improved fertile hatchability (Elibol and Brake, 2008). For ease of the experiment, the eggs in the trays were connected to an automatic timer that would tilt the trays 45° from the horizon alternating from left to right or vice versa every 6 h. The tray rack was connected to a transmission system. The transmission system served as a speed reducer of the electrical motor. The speed was reduced as shown in Figure 2.

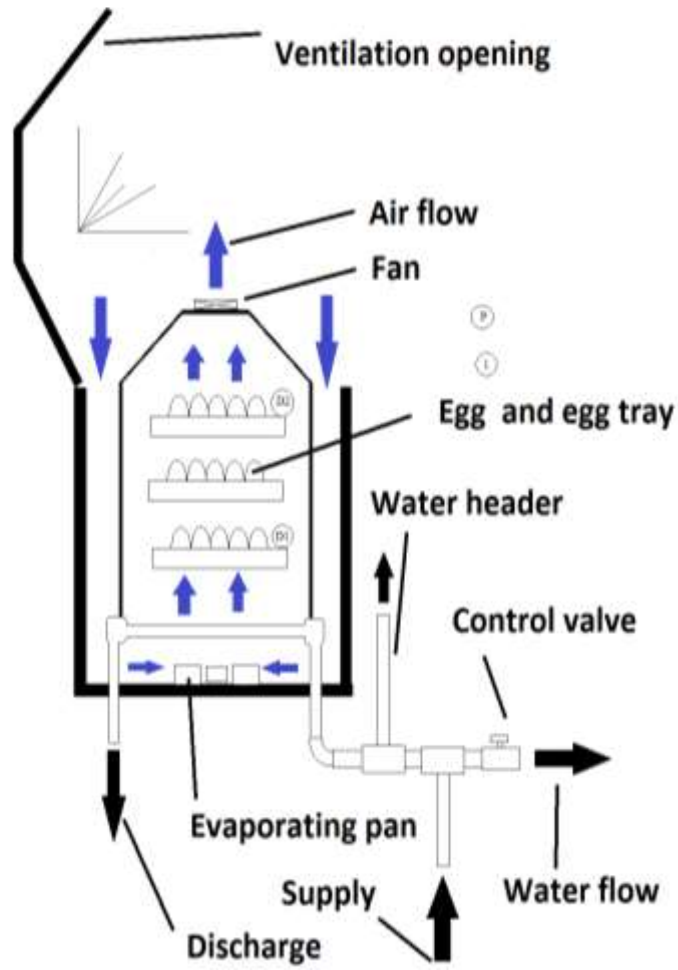

Figure 1. Schematic diagram of hot spring incubator.

Experimental design

The final design used was a completely randomized design (CRD) of 2 factorial design with 3-level. This was a complete factorial of the design with 0 center points on the block. The factors considered in the experiment for variations are shown in Table 2 with three levels. The factors were number of evaporating pans and ventilation opening. The three levels for evaporating pans were 3, 4 and 5 which were placed at the bottom of the hot spring incubator. The evaporating pans were to mainly maintain the optimal relative humidity within the duck eggs incubator with hot spring heat source. On the other hand, the ventilation opening was to maintain an optimal temperature within the incubator at three levels (30, 45 and 60°) since the average temperature of the hot spring was 41.49°C with the standard deviation of the hot spring being 0.0021°C (Taplah et al., 2018a) which is above the optimal incubating temperature.

The experimental runs were in the random sequence as listed in the Table 3 with further research conducted separately to verify the optimal run with three replicates. The reading was logged every 1 h for at least 23 h from 16:00 to 15:00 the next day instead of 16:00 to 16:00 the next day. The next run started at 15:00h and the first temperature was logged approximately 1 h after the temperature had stabilized. The reason for the 23 h data log per run is to continuously run the experiment. For the next 23 h run, the incubator was loaded and the temperature stabilized within an hour before logging the temperature and relative humidity. The sampling of the temperature and relative humidity were logged by averaging 100 samples per hour. For this experiment, each run covered the period of 23 h. The reason for the 23 h per run was to observe the change in the temperature during both extremities of the high and low atmospheric conditions during the day and night, respectively.

The data collected were analyzed using the surface response method and multiple regression analysis to predict the temperature and relative humidity at the optimum setting using Design of Experiment (DoE) version 10.0.

This response surface approach utilizes elementary statistical information on the basic variables (mean values and standard deviations) to increase the efficiency and accuracy (Bucher and Bourgund, 1990). The application of response surface methodology in the optimization of analytical methods follows theoretical principles and steps for its application with multivariate statistical technique (Bezerra et al., 2008). Response surface method is widely used to alleviate the computational burden of engineering analyses (Kaymaz and McMahon, 2005). The multiple regression analysis is highly general and very flexible data analysis system. The multiple regression analysis may be used for quantitative variable, the dependent (Y) and independent variable (X) to predict the factor of interest (Cohen et al., 2003).

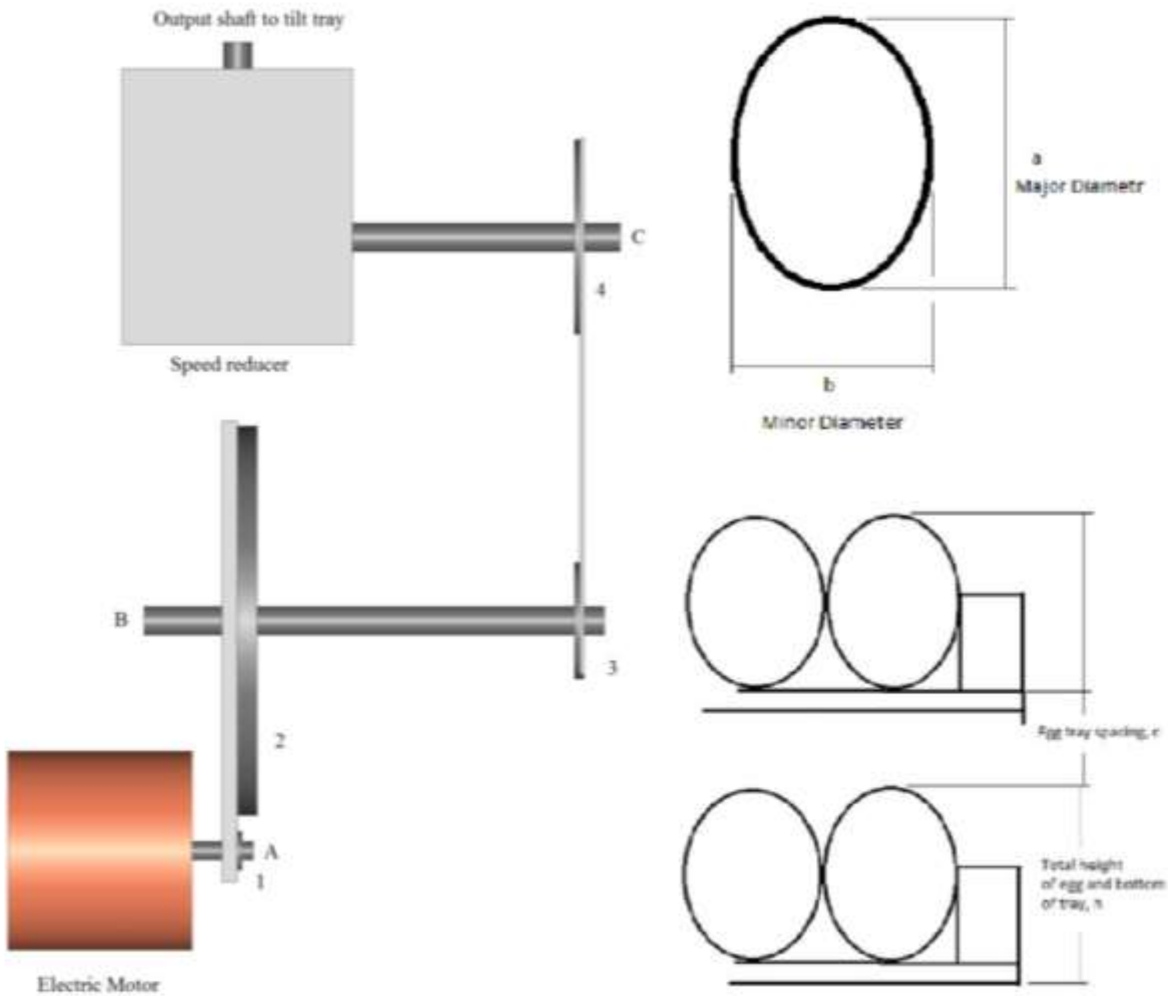

Figure 2. Power transmission for turning the eggs.

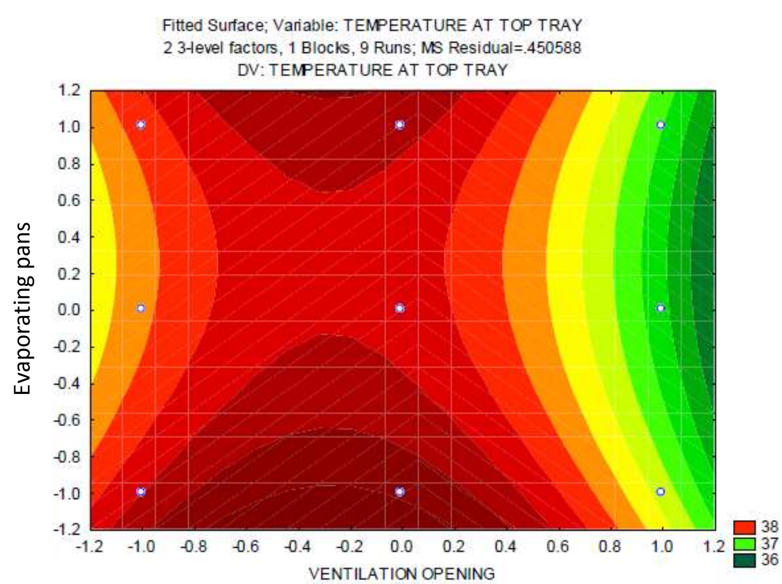

Figure 3. Surface response for temperature at the top tray.

Table 2. Experimental factors and levels.

Factor	Unit	-1	0	1
Evaporating pans (A)	No. of pans	3	4	5
Ventilation opening (B)	Degree	30°	45°	60°

Table 3. Design layout for two factorials with three levels.

Run	A	B
1	-1	1
2	1	1
3	0	1
4	1	0
5	1	-1
6	-1	0
7	0	-1
8	0	0
9	-1	-1

RESULTS AND DISCUSSION

Experimental results

Temperature analysis

All the data on temperature gathered at the top tray during the experiment were subjected to multiple regression to determine the mathematical model to predict the temperature on the two dimensional surface response as shown in Figure 3. The surface response of the temperature within the incubator was with the combinations ventilation opening (30°, 45° and 60°) and evaporating pans (3, 4 and 5 pans). The reason for using only the temperature at the top tray is that the independent variables have a higher effect on the temperature with the correlation coefficient. The mathematical model was derived from the surface response to multiple regression analysis as shown in Equation 2.

$$t = 38.1435 - 0.5521x - 1.10174x^2 - 0.1920y + 0.3785y^2 \quad (2)$$

Where, t is the temperature at any combination of x and y on the multiple regression analysis; x is the effect of the ventilation opening on the temperature at any level, and y is the effect of the evaporating pans on the temperature at any level.

Relative humidity analysis

All the data on relative humidity gathered at the top tray during the experiment were also subjected to multiple regression to determine the mathematical model to predict the temperature on the two dimensional surface response of the relative humidity with the combinations ventilation opening (30°, 45° and 60°) and evaporating pans (3, 4 and 5 pans) as shown in Figure 4. The reason for using only the relative humidity at the bottom tray is that the relative humidity is at a minimum at the bottom tray. Therefore, if maintained within optimum range, the trays above would also be maintained. The mathematical model was derived from the surface response to multiple regression analysis as shown in Equation 3.

$$RH = 46.1991 + 0.677x + 0.8368x^2 + 1.1354y + 2.1285y^2 \quad (3)$$

Where, RH is the relative humidity at any point with the combination x and y on the multiple regression analysis; x is the effect of ventilation opening on the relative humidity at any level, and y is the effect of the evaporating pans on the relative humidity at any level.

Duck egg air cell temperature averaged 36.3°C (SD = 2.5, N = 1655) during the 24 days of incubation and the brood area temperature reported for the domestic duck was 39.5°C probably approximating the Mallard (Caldwell and Cornwell, 1975). The average incubating temperature was 38.9°C.

The multiple regression analysis showed the predicted temperature and the relative humidity within the incubator, it revealed that evaluation of the combination of ventilation opening and evaporating pans, at point -1, 1 (combination of ventilation opened at 30° and 5 evaporating pans), had average temperature and relative humidity of 37.78°C at the top tray and 49.62% at the bottom tray as predicted by the mathematical model closest to the average incubating temperature.

In a further research by Taplah et al. (2018b), the economic analysis and verification of the surface response regression analysis of the hot spring heat source incubator with manual turning mechanism was the most feasible over the automatic turning hot spring heat source incubator and the conventional incubator for duck eggs. This study used both the undiscounted and discounted measures to evaluate the feasibilities. The mean average temperature and the variance were 38.39°C and 0.057, respectively

This study also contradicts reduction in the consumption of electrical power. On a full scale extraction of hot spring for incubation, the incubator could have the

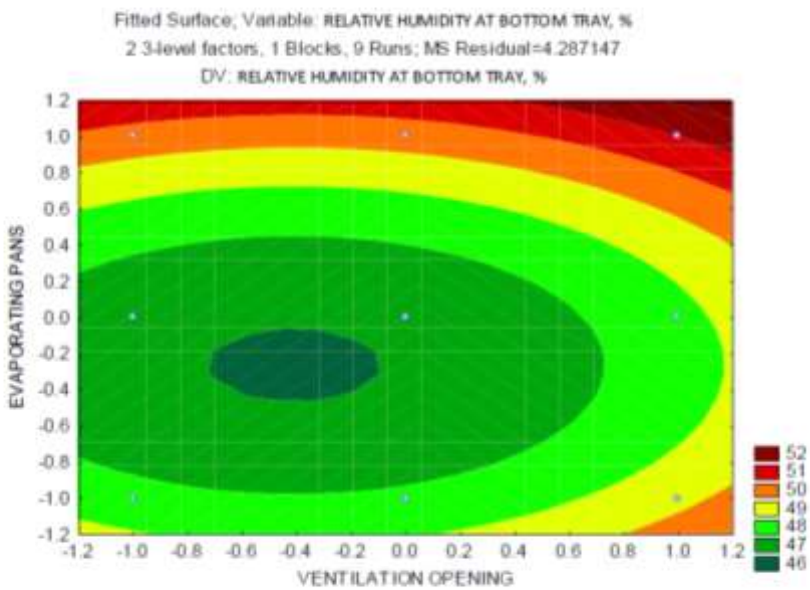

Figure 4. Surface response for relative humidity at bottom tray.

capacity or more than 4000 eggs per outlet which could result in the total capacity of 12000 eggs.

Conclusion

There should also be further experiment on the developed incubator using temperature control sensors (thermostat to open or close the ventilation to maintain the optimum incubation temperature). Other means of maintaining the optimum incubation temperature should also be tested. For example, controlling the flow rate of the hot spring incubator or using an exhaust fan for cooling.

Other designs like separating the heat exchanger from the incubator to enlarge the size of the incubator instead of limiting the dimension to the size of the heat exchanger should also be experimented. The hot spring water fed incubation can also be designed using a natural draft instead of a forced draft incubator. Further study is recommended for the development of hot spring water fed natural draft incubator to completely eliminate the use of electricity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Ar A, Girard H, Rodeau JL (1991). Oxygen uptake and chorioallantoic blood flow changes during acute hypoxia and hyperoxia in the 16 day chicken embryo. Respiration Physiology **83(3**):295-312.

Atienza M, Rodriguez DPGM, Babilonia DR, Guimary M, Rebancos C (2015). Food safety study of duck eggs produced along Laguna Lake areas, Philippines. Journal of Nutrition and Food Sciences S3:005.

Bureau of Agricultural Statistics- Statistical Research and Training Center (BAS-SRTC) (1998). Improvement of methodology on production survey for duck. BAS-SRTC Project. https://ageconsearch.umn.edu/bitstream/12904/1/wp040001.pdf

Bezerra MA, Santelli RE, Oliveira EP, Villar LS, Escalaira LA (2008). Response surface methodology (RSM) as atool for optimization in analytical chemistry. Talanta 76(5):965-977.

Bucher CG, Bourgund U (1990). Fast and efficient response surface approach for structural reliability problems. Structural Safety 7(1):57-66.

Caldwell PJ (1971). Nest microclimate and nesting behavior in the Mallard (*Anas platyrhynchos*) at Delta, Manitoba. Unpublished M.S. thesis, Gainesville, University of Florida.

Caldwell PJ, Cornwell GW (1975). Incubation behavior and temperature of the Mallard duck. American Ornithological Society. 28-08-2017 14:08 UTC. The Auk 92(4):706-731.

Clauser C (1988). Handbook of Terrestrial Heat Flow Density Determination. Dordrecht: Kluwer Academic Publishers pp. 143-165

Chang HSC, Villanoz R (2008). Technical and socio- economic constraints to duck production in the Philippines: A productivity analysis. International Journal of Poultry Science 7(10):940-948.

Cohen J, Cohen P, West SG, Aiken LS (2003). Applied multiple regression/correlation analysis for the behavioral sciences (3rd ed.). Mahwah, NJ: Erlbaum.

Elibol O, Brake J (2008). Effect of egg position during 3 and 14 days of storage and turning frequency during subsequent incubation on hatchability of broiler hatching eggs. Poultry Science 87:1237-1241.

Fanchi JR (2005). Energy in the 21th Century. World Scientific Publishing Co. Pte. Ltd.

French NA (1997). Modelling Incubation Temperature: The Effects of Incubator Design, Embryonic Development, and Egg Size. Poultry Science 74:124-133.

Jago-on KAB, Siringan FP, Balangue-Tarriela R, Taniguchi M, Reyes YK, Lloren Lloren R, Peňa MA, Bagalihog E (2017). Hot spring resort development in Laguna Province, Philippines: Challenges in water

use regulation. Journal of Hydrology: Regional Studies 11:96-106.
Kaymaz I, McMahon CA (2005). A response surface method based on weighted regression for structural reliability and analysis. Probabilistic Engineering Mechanics 20:11-17.
King JR, Farners DS (1961). Energy metabolism, thermoregulation and body temperature. in Biology and comparative physiology of birds, (A. J. Marshall, Ed.). New York, Academic Press 2:215-288.
Schmidt-Nielson K (1975). Animal physiology. New York: Cambridge University Press 715 p.
Sotherland PR, Rahn H (1987). On the Composition of Bird Eggs". The Cooper Ornithological: The Condor 89(1):48-65.
Taplah AJ Jr, Cabahug JMC, Manuel LJR, Quilloy EP, Bato PM (2018a). Evaluating the use of hot spring for agricultural process in Los Baňos, Laguna, Philippines. International Journal of Water Resources and Environmental Engineering 10(1):1-8.
Taplah Jr AJ, Suministrado DC, Amongo RMC, Paras Jr FO, Elauria JC, Tokpah DP (2018b). Economic analysis of duck eggs incubation using hot spring as heat source. Journal of Development and Agricultural Economics 10(2):38-44.
Wilson HR (1991). Physiological Requirements of the Developing Embryo: Temperature and Turning In: S. G. Tullett, (ed.) Avian incubation. Butterworth-Heinemann, London 9:145-156.