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THERMOCHEMICAL BATTERY FOR POULTRY EGG INCUBATION

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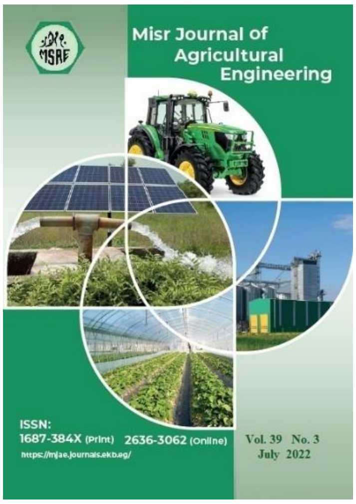


Keywords:
Poultry incubator; Solar energy; Thermochemical battery.

ABSTRACT

The current research aims to identify the possibilities of adopting stored solar energy in thermochemical batteries (TCM batteries) to accommodate optimum thermotolerance of chick embryo development during incubation. A twenty-five-egg capacity TCM incubator was constructed to test the performance of three rechargeable and changeable (self-indicating silica gel, white-silica gel, and natural zeolite) thermochemical batteries in modifying the ambient temperature of the incubated eggs through TCM humidification. And an electrical heating backup unit was used as an emergency thermal compensation unit. The incubated eggs were turned horizontally every hour by an automatic turning mechanism. The overall performance of the TCM incubator was compared with that of a traditional -locally manufactured- electrical incubator. Results showed that the TCM incubator consumed 11.2*kW, while the electrical incubator consumed* 19250*W during the 21 days-cycle of incubation and hatchery. The total heat loss from incubator walls and ventilation was 1.5 W, 9.8 W respectively. The twenty-five incubated eggs released* 3.65*W of metabolic energy. The calculated overall energy efficiency of the TCM self-indicating silica gel - incubator was 53.9% and decreased to 44.4% for natural zeolite cells, while white silica gel cells reached* 37.3%. *The TCM incubator was more efficient in energy consumption by* 41.8% *compared to the traditional electrical incubator at the same operating conditions. The hatchability ratio for the TCM incubator was* 71.4% *and* 80.9% *for the electrical incubator regarding egg fertility ratios were* 56% *and 84% respectively. Using a TCM incubator can significantly reduce power consumption and production costs in the poultry industry.*

1. INTRODUCTION

To deal with the unprecedented global population explosion, agricultural engineering is playing a vital and increasing role to fulfil the food gap from a sustainable view. Poultry production is one of the foremost promising sectors facing increased food demand. Boleli et al. (2016) mentioned that in these last 20 years, the assembly of poultry meat increased by almost 108% (from 54 to 112 million tons), equivalent to a 36% growth of its share in total meat production. to satisfy this high demand for poultry meat, Boleli et al. (2016) suggest that artificial incubators must maximize chick production sustainably. Wikipedia (2022) comes to an agreement that energy is sustainable if it "meets the needs of the present without compromising the ability of future generations to meet their own needs". In such a way determined efforts are being made to utilize renewable energy. In their review, Kousksou et al. (2014) confirmed that energy continues to be a key element to worldwide development. because of the oil price volatility, depletion of fuel resources, global warming, local pollution, geopolitical tensions, and growth in energy demand, alternative energies, renewable energies, and effective use of fossil fuels became way more important than at any time in history.Osanyinpeju et al. (2018) described hatching egg as one of the greatest miracles of nature and its temperature drops to $27°C$ after laying to stop the embryo development until suitable environmental condition established for resuming incubation process. Paras (2020) stated that artificial egg incubation is a complex, costly, and energy-intensive operation, and suggested that innovations in artificial incubator design would improve energy usage. Furthermore, innovative incubators will encourage widespread utilization of unpolluted and renewable energy for the poultry industry with its impact on reducing energy consumption and lower production costs. On the other hand, renewable especially solar energy is a source of unstable energy daily and seasonally needs an efficient storage system. Energy storage is employed to beat the stochastic nature of solar power in industrial applications. Among solar energy storage methods, thermochemical storage (TCM) stores and release thermal energy during a reversible endothermic chemical reaction. TCM is a promising storage material for its energy holding capacity, chemical stability, lower cost, and theoretically endless energy storage expiration time if it's well preserved (Stritih and Kozelj, 2017). The overwhelming majority of poultry hatching eggs are artificially incubated in incubators that must be designed to accurately control the temperature inside the machine to make sure that the temperature of the developing embryo doesn't deviate from 37 to 38 °C which has major impact on hatching success and embryo development (French, 1997). *This work aims* to identify the possibilities of adopting stored solar energy in thermochemical batteries (TCM batteries) to accommodate optimum thermotolerance of chick embryo development during incubation.

2. MATERIALS AND METHODS

An experimental TCM incubator prototype was constructed at the Solar Energy Laboratory, Faculty of Agricultural, Ain-Shams University, Egypt. The TCM incubator was constructed as seen in Figure 1 from:①frame and environmental insulation unit, ②ventilation unit, ③fertile eggs holder and turning unit, ④temperature modification unit (TCM battery charged from solar energy and an electrical heater backup), ⑤humidity modification unit, ⑥electronic measurement, and control unit. All units of the TCM incubator were adjusted to provide the growing chick embryos with optimum growth environmental factors within the accepted tolerance.

① **the incubator Frame and environmental insulation unit:** The TCM incubator frame was constructed from a Styrofoam ($56 \times 39 \times 28.5$cm) container to insulate the incubated eggs from fluctuating environmental conditions and to retain the process within the desired operation factors (Figure 2). The Styrofoam frame contains an access point to ventilation, humidification, measurement, and control units.

② **ventilation unit:** The TCM incubator was ventilated throw three -one-centimeter diameter-holes at the Styrofoam frame by a ventilation 1.68 $Watt$ fan. The ventilation unit was operated automatically according to the egg's incubation stages and the environmental conditions.

③ **eggs tray and turning unit:** The egg tray ($31 \times 31 \times 5$cm) was built to hold 25 eggs Figure 3. An egg turning mechanism operated by a 4 $Watt$ electrical motor at 3~4 rpm, was used to prevent adhesion of the embryo to the inner shell membrane during the incubation stage.

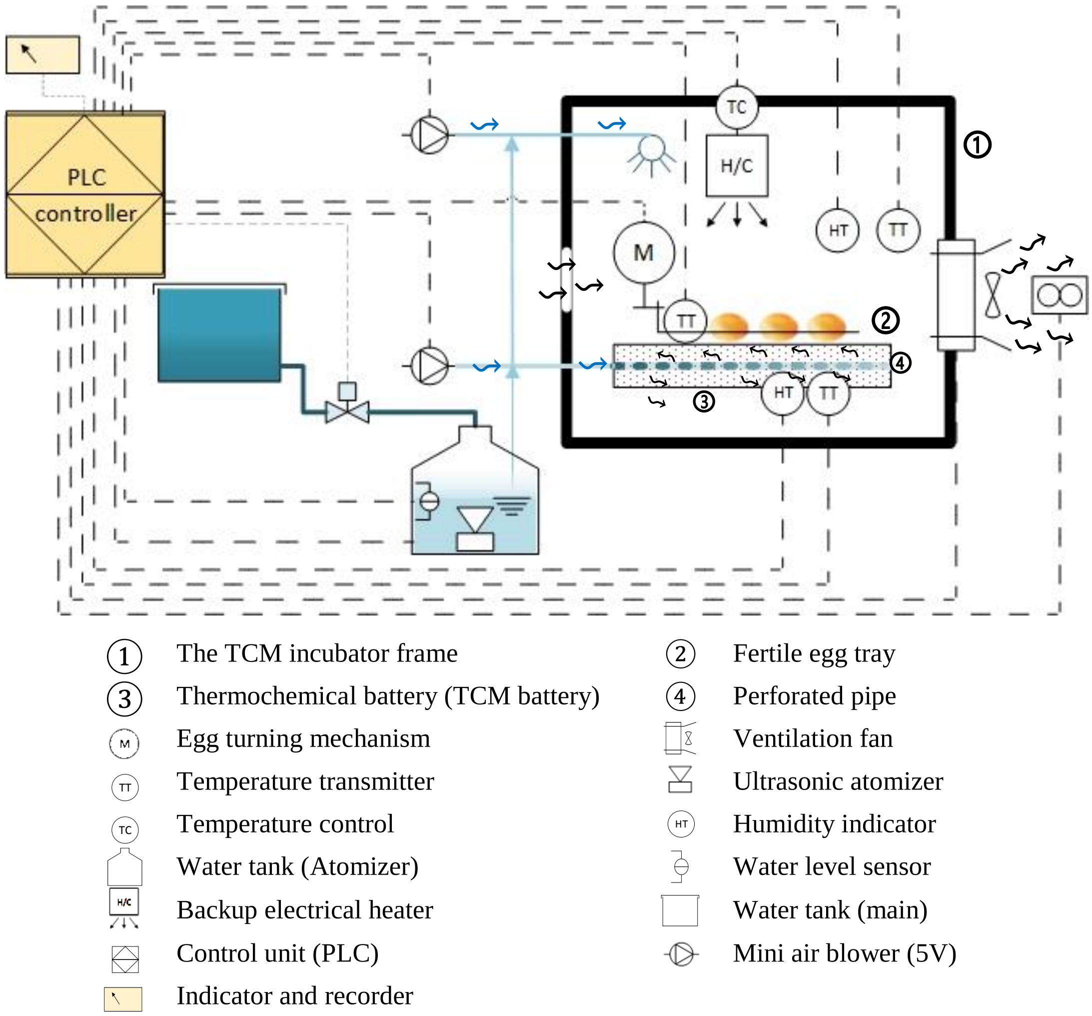


Figure 1. The experimental thermochemical poultry egg incubator main components.

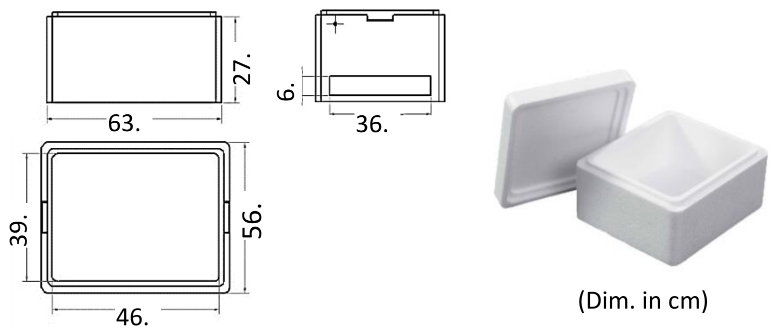


Figure 2. The TCM incubator frame (Styrofoam container).

④ **Temperature modification unit (TCM battery and an electrical heater backup):** The TCM battery was constructed from $(35 \times 35 \times 5\text{cm})$ a topless wooden container to hold a 3.5 kg of TCMs energy storage material. The top of the wooden container was made of an aluminum sheet with a thermal transmission fin as shown in Figure 4.

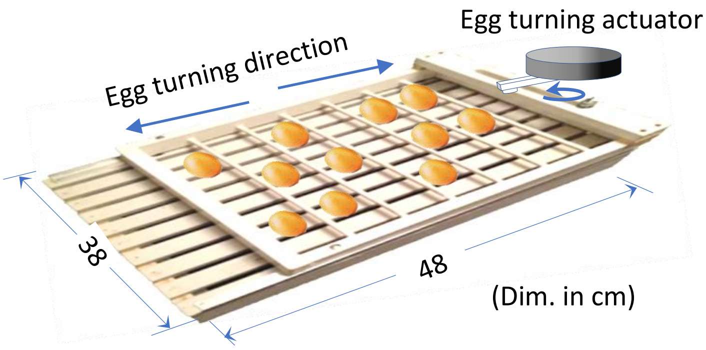


Figure 3. TCM incubator, eggs tray, and turning mechanism.

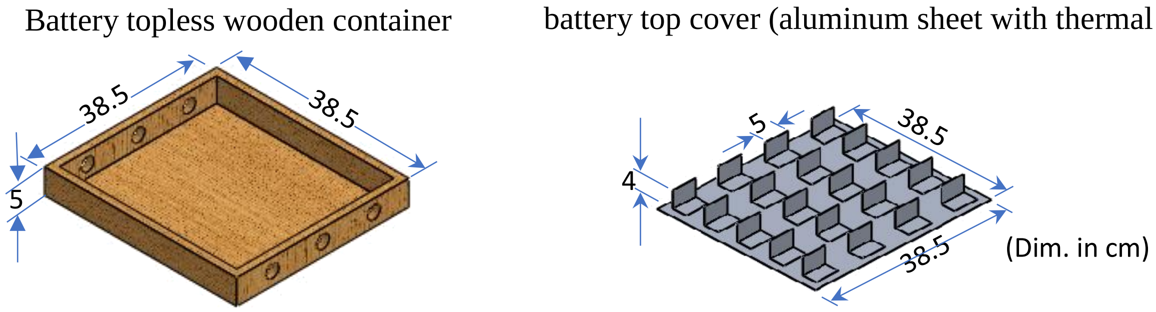


Figure 4. The TCM battery wooden container covered with a finned-aluminum sheet.

Figure 5 illustrates a detailed description of the thermal energy discharging process from the TCM battery (Figure 1-2). To increase the TCM incubator temperature at the desired level, thermal energy was restored from the TCM battery by applying forced humid air generated from an ultrasonic mist generator and flow by a mini air blower through a set of perforated 2.54 cm diameter pipes located inside the TCM battery. A configuration of programable temperature-humidity measurement and control unit were used to restore energy at desired rates and levels.

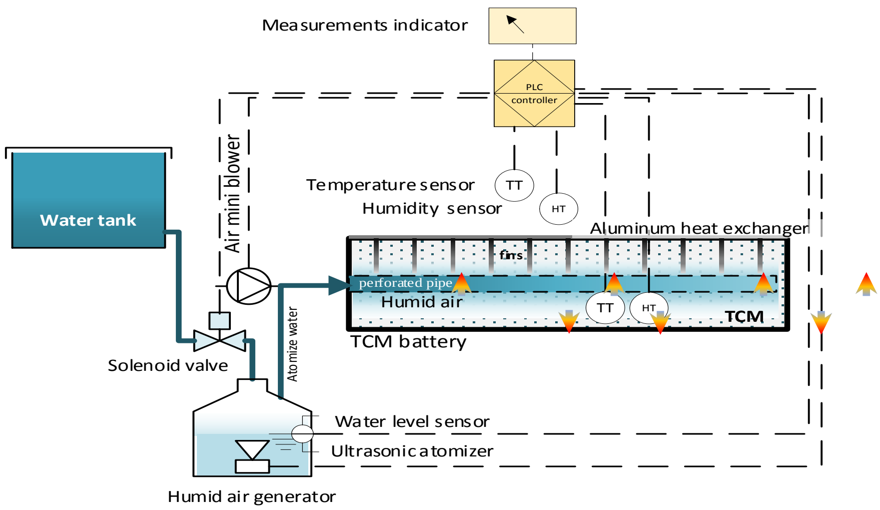


Figure 5. TCM battery discharging process and measurement.

The ultrasonic humid air generator was assembled from a submersible ($250{\sim}300\ mL_{water}/h$) ultrasonic mist generator, and a float-type water level detection sensor. The water level was maintained at a desired $2.1cm$ above the ultrasonic water atomizer (manufacturer instructions) by water supplement from a two-liter storage tank controlled by a solenoid valve and activated according to the water level detection signals. At emergency and battery replacement circumstances, an electrical heater backup unit controlled by a Programmable Logic Control unit (PLC) was used to sustain the temperature at the optimum level for the incubated eggs.

⑤ **The TCM incubator humidity modification unit:** A configuration of 19Watt and $300ml_{water}/h$ ultrasonic atomizer showed in Figure 1-10, relative humidity sensors, air circulation fan, and humid air pipes, and controls were used to maintain the TCM incubator ambient humidity in the range of 55∼75%.

⑥ **Electronic measurement and control unit:** A flowchart of the process measurement and control is illustrated in Figure 6.The TCM incubator and TCM battery were fully controlled through a PLC measurement and controlling unit (Figure 7). The PLC and data storage unit were programmed according to the reviewed data of the egg's incubation process.

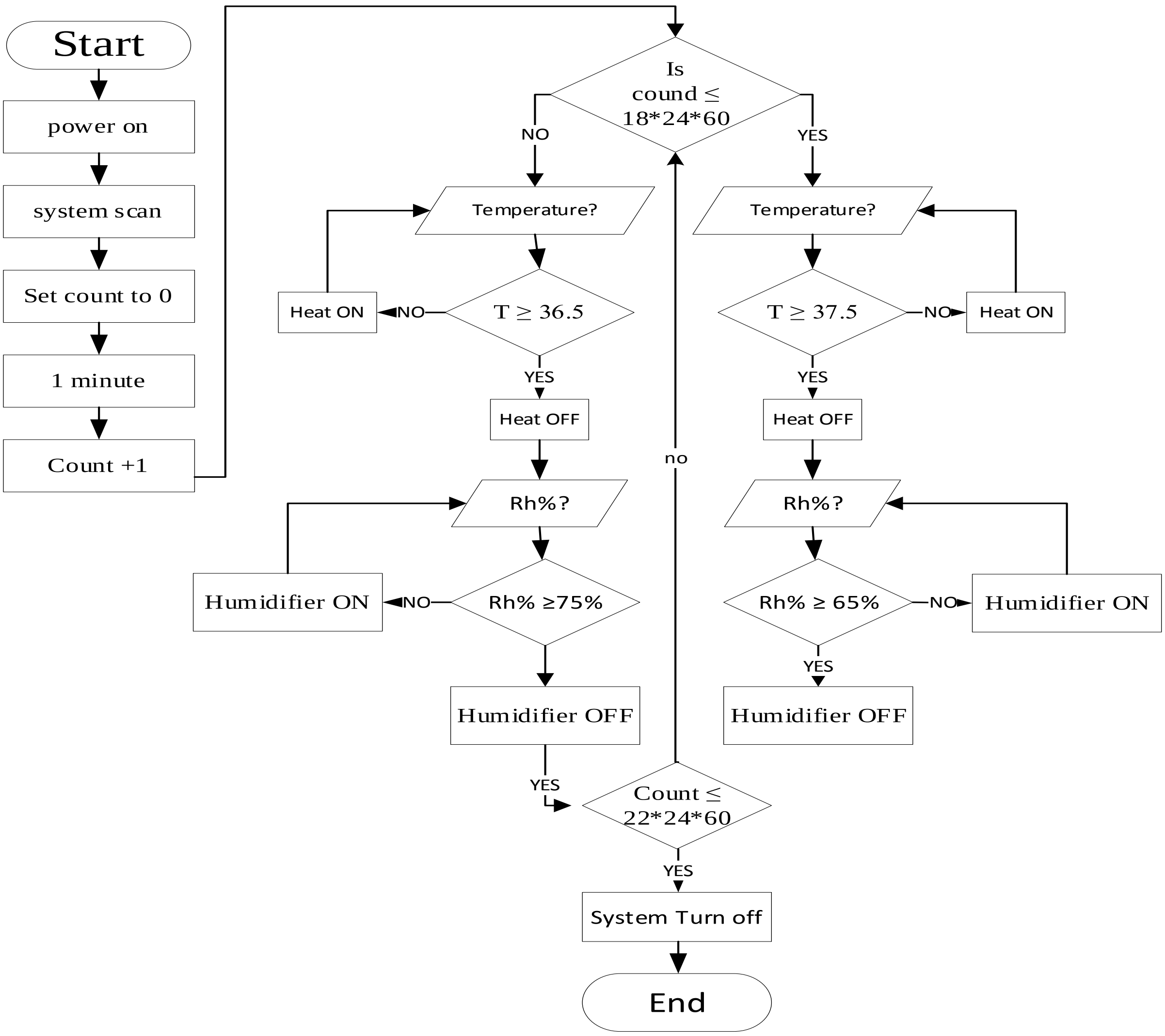
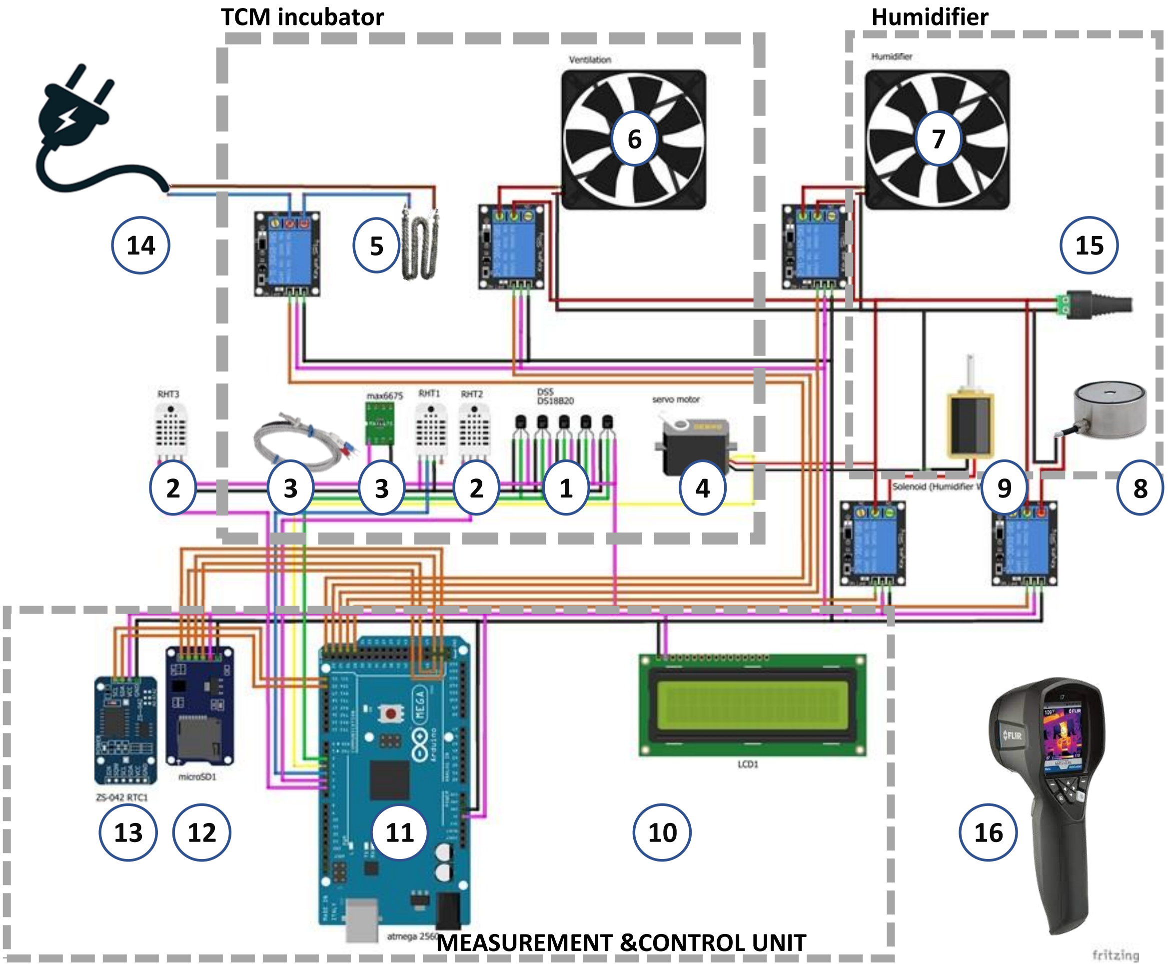


Figure 6. Flowchart of the temperature and humidity control inside TCM egg incubator.



Measurement		\`device	range	unit	accuracy
Temperature	②	DHT22	-40~ 80	°C	< ±0.5
Temperature	③	max6675 (K)	0~ 600	°C	±1.5
Temperature	①	DS 18B20	-55~ +125	°C	±0.01
thermal camera	⑯	Flir			
Relative humidity	②	DHT22	0~100	%	±2%
Timer	⑬	RTC (DS1307)			
Data storage	⑫	SD card module			
the programmable logical control unit (PLC)	⑪	ATmega328P			
Servo motor	④	5V DC			
Ventilation fan	⑥	5V DC			
Atomizer	⑧	Ultrasonic			
Solenoid valve	⑨				
Power	⑮	9V DC			
Electrical heater	⑤	220 AC			
Power	⑭	220AC			

Figure 7. TCM incubator and TCM battery measurement and control unit.

A commercial electrical poultry egg incubator model $C2$ (PTO Co., n.d., p. 2) was used to assess the TCM incubator proposed in this work. Figure 8 shows the C2 model electrical incubator with 125 egg capacity, and the egg's automatic tilting mechanism by 45° on opposite sides every hour. The incubator is thermally insulated by a three-layer of especially synthetic fiber. An electronic unit and temperature measurement sensors control the temperature at the desired level by switching on and off the $250W$ electrical heater. A hygrometer was used to monitor the relative humidity for incubation and hatching processes. For ventilation, the incubator's fan forces ambient air through a side entrance and backside-exits hatches.

Analysis of the TCM battery thermal discharging process

In the TCM battery discharging process, a humid airflow in the TCM deploys an endothermic chemical reaction. Then, a thermal energy transfer by conduction occurs between the TCM layers (R_{cond1}) and between the finned-aluminum sheet (R_{cond2}). At last, the thermal energy is transferred to the incubated eggs by convection from the aluminum sheet surface (R_{conv}) as shown in Figure 9. The thermal energy of the TCM battery discharge process was calculated according to Eq.(1)**.**

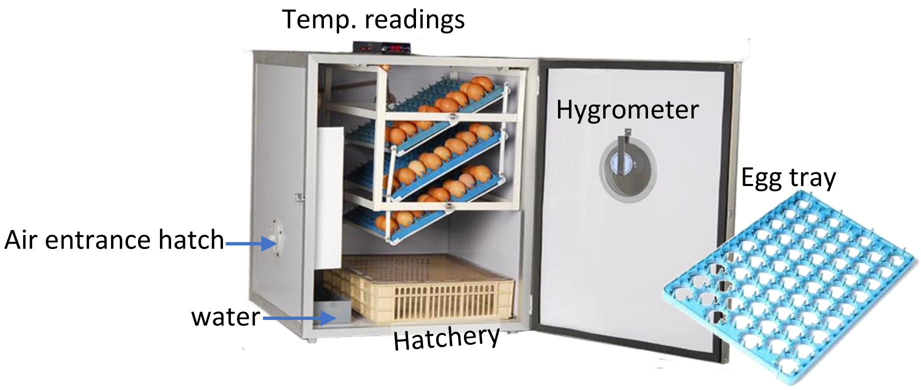


Figure 8.. The commercial electrical egg incubator (model C2, PTO Co., n.d.)

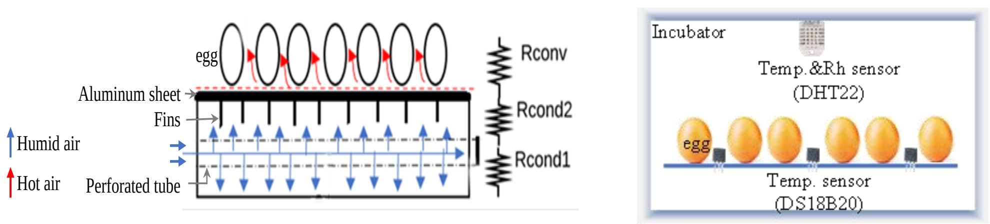


Figure 9 Illustration of the process and measurement of TCM incubator thermal recovery.

$$Q_{out} = h_a A_{al} \left(T_{al} - T_{air}\right) \quad (1)$$

where Q_{out} is the heat released from discharging TCMs process (W), h_a is the convection heat transfer coefficient ($W/m^2 °C$), A_{al} is the surface area of aluminum sheet (m^2), T_{al} and T_{air} are the temperature surface of the aluminum sheet and the air temperature inside the incubator (°C).

forced convection heat transfer (h_a) and Re were calculated as in (Eqs. 2 and 3).

$$h_a = \frac{N_u \ K_{air}}{l_c} \quad (2)$$

where N_u is the Nusselt number, K_{air} is the air thermal conductivity ($W/m°C$), and l_c is the characteristic length (m).

$$Re = \frac{u_\infty \, l_c}{\upsilon} \tag{3}$$

where Re is the Reynolds number, u_∞ is the air velocity (m/s), l_c is the characteristic length (m), and υ is the air kinematic velocity, (m^2/s).

Total energy consumption in the egg incubation process was calculated by Eq. (4) according to Victor (2015); Demissie (2020); and Osanyinpeju et al. (2016).

$$Q_t = \; Q_a + Q_e + Q_v + Q_s \tag{4}$$

where $\mathrm{Q_t}$ is the total heat required for incubation (kJ), $\mathrm{Q_a}$ is the heat required to raise the temperature of incubator air (kJ), $\mathrm{Q_e}$ is the heat required to raise the temperature of the egg from ambient temperature to incubation temperature (kJ), Qv is the heat loss by ventilation (kJ), and $\mathrm{Q_s}$ is the heat losses throw the walls of the incubator (kJ).

The required thermal energy for the incubator ambient temperature was calculated according to Woldegiorgis and Meyyappan (2018) as seen in Eq. (5).

$$Q_a \;=\; M_a \, C_p \, (T_f - T_i) \tag{5}$$

where M_a is the mass of air (Kg), C_p is the specific heat of the air ($kJ/kg°C$), T_i is the initial air incubator temperature ($20°C$), and T_f the final incubator temperature or the incubation temperature ($38°C$).

The required thermal energy for the incubated eggs ($\mathrm{Q_e}$) was calculated according to Eq.(6) (Scott Turner, 1991).

$$Q_e = \; n \, M_e \, C_p \, (T_{ie} - T_{oe}) \tag{6}$$

where n is the number of eggs, M_e is the weight for the egg as an average of $60g$, C_p is the specific heat of egg (3.23 $kJ/kg°C$) as mentioned in (ASHREA Handbook-Refrigeration, 2014), T_{ie} is the egg temperature inside the incubator ($°C$), and T_{oe} is the egg temperature outside the incubator ($°C$).

The warming rate expressed about the egg temperature raising from room temperature to incubation temperature with the time. It can be calculated from Eq. (7).

$$egg\ warming\ rate = \frac{(T_{oe} - T_{ie})}{time} \tag{7}$$

Lourens et al. (2006) found that the heat production rate from embryos due to the metabolic activities is $137mW$ for small eggs and $155\,mW$ for big ones. In this work, the design calculations were made upon the embryo producing $146mW$ as an average of metabolic energy.

The optimum incubator gas concentrations and levels of oxygen, carbon dioxide, and relative humidity achieved by the ventilation process are vital to the embryo's development and hatching success. Incubator's ventilation time intervals depend on the stage of the incubation process and the development of the embryos. Ventilation time intervals were covered by many researchers. Daud et al. (2019) suggest ventilating incubators once every two hours, while Mauldin (2002) and Osanyinpeju et al. (2016) recommend ventilating every three hours, or every four hours as Woldegiorgis and Meyyappan (2018) mentioned. Ventilation heat losses (Q_v) were calculated according to Eq.(8).

$$Q_v = V\, \rho_a\, C_p\, (T_i - T_o) \text{ and } \rho_a = \frac{M_a}{V} \tag{8}$$

where V is the air volume changed (m^3), ρ_a is the density of outlet air (Agidi et al., 2014), C_p is the air specific heat capacity ($kJ/kg°C$), and t_i, t_o is the air temperature inside and outside the incubator (°C).

The heat losses from the incubator frame (Q_s) (Eq. (9)), by conduction (Eq. (10)), radiation (Eqs. (11) and (12)), and from ventilation as forced convection (Eqs.(14) and (15)) were calculated (Figure 10).

$$Q_s = \frac{T_{\infty 1} - T_{\infty 2}}{\sum R_{th}} = \frac{T_{\infty 1} - T_{\infty 2}}{R_{rad} + R_{conv} + R_{cond}} \tag{9}$$

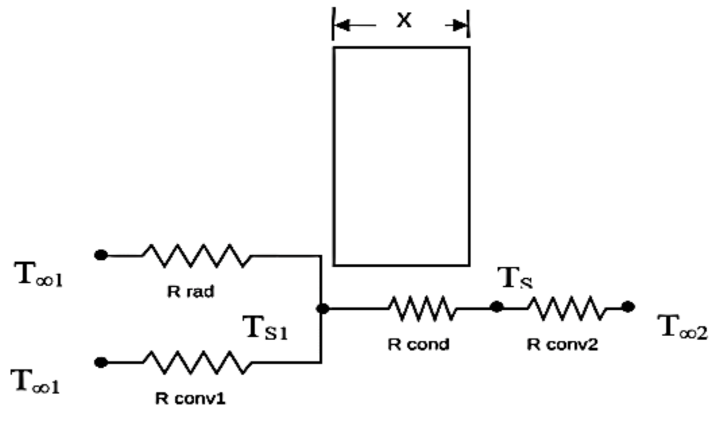
where $T_{\infty 1}$ is the ambient temperature ($°C$), $T_{\infty 2}$ is the air temperature inside the incubator ($°C$), R_{rad}, R_{conv} and R_{cond} are the thermal resistance by radiation, convection, and conduction (°C/W).

$$Q_{frame} = k\, A \frac{\Delta T}{L} \tag{10}$$

where Q_{frame} is the heat lost by conducting through the frame (W), k is the thermal conductivity of wood (W/m °C), ΔT is the temperature difference between the inner and outer surface of the frame (°C), L is the thickness of frame (m).

$$R_{rad} = \frac{1}{h_{rad}\, A} \tag{11}$$

where R_{rad} is the thermal resistance by radiation ($°C/W$), h_{rad} is the radiation heat transfer coefficient ($W/m^2°K$), and A is the surface area of the incubator wall (m^2).



where X	is the thickness of the incubator wall (m)	$T_{\infty 1}$	is the ambient temperature
T_{S1} and T_{S2}	is the outer and inner frame surface temperature (°C),	$T_{\infty 2}$	is the air temperature inside the incubator (°C),
R_{rad}, R_{conv} and R_{cond}	are the thermal resistance (radiation, convection, and conduction), (°C/W)		

Figure 10. Thermal losses through the incubator frame Diagram.

$$h_{rad} = \varepsilon\, A_s\, \delta\, (\, T_{s1} +\, T_{sur})(T_{s1}^2 + T_{sur}^2) \tag{12}$$

where $\boldsymbol{\varepsilon}$ is the surface emissivity, $0 \leq\, \boldsymbol{\varepsilon}\, \leq 1$, A_S is the surface area (m^2), δ is the Stefan-Boltzmann constant ($\boldsymbol{\delta} =\, 5.67 \times 10^{-8}\, W/m^2\, °K^4$), T_s is the surface temperature, and K. T_{sur} is the surrounding temperature (°K).

$$R_{eq} = \left(\frac{1}{R_{conv} + R_{rad}}\right)^{-1} and\ R_{conv} = \frac{1}{h\ A} \tag{13}$$

where R_{conv} is the thermal resistance by convection (°C/W), h is the convection heat transfer coefficient ($W/m^2\ °C$), and A is the surface area (m^2).

$$h_1 = \frac{N_u\ \ K_{air}}{l_c} \tag{14}$$

where N_u is the Nusselt number, K_{air} is the air thermal conductivity ($W/m°C$), and l_c is the characteristic length (m).

$$R_{e=}\frac{u_\infty\ l_c}{\upsilon} \tag{15}$$

where Re is the Reynolds number, u_∞ is the air velocity (m/s), l_c is the characteristic length (m), and υ is the air kinematic velocity, (m^2/s).

The costs of the total energy consumption (TEC) during incubation processes were calculated according to (Eqs. (16) and (17)).

$$Total\ operating\ cost = total\ power\ consumption\ \times cost\ of\ unity \tag{16}$$

$$Energy\ saving\ = \frac{Electrical\ \ incubator_{TEC}\ - TCM\ incubator_{TEC}}{traditional\ incubator_{TEC.}} \tag{17}$$

where the total power consumption in kW.h, and the cost of unity in EGP/ kW.h

The TCM incubator hatchability and fertility ratio were used to assess the performance of the TCM incubator compared to the traditional electrical incubator (Eqs. (18) and (19)) according to Osanyinpeju et al. (2016); Dalangin (2019); and Uzodinma et al. (2020).

$$Hatchability\ ratio\ = \frac{total\ number\ of\ eggs\ hatched}{total\ number\ of\ fertile\ eggs} \times 100 \tag{18}$$

$$Fertility\ ratio\ = \frac{total\ number\ of\ fertile\ eggs}{total\ number\ of\ incubated\ eggs} \times 100 \tag{19}$$

3. RESULTS AND DISCUSSIONS

Experiments were conducted to select the optimum TCM battery material (Silica gel self-indicating, white Silica gel, and Natural Zeolite) that can provide the developing chick's embryo with the required and steady thermal energy. Results in Figure 11 showed that the self-indicating silica gel releases steady energy than the white silica gel and the natural zeolite. Also, self-indicating silica gel stores more energy in less material volume compared to white silica gel and natural zeolite. TCM battery from self-indicating silica gel can provide the developing embryo with the required thermal energy within the acceptable thermal tolerance.

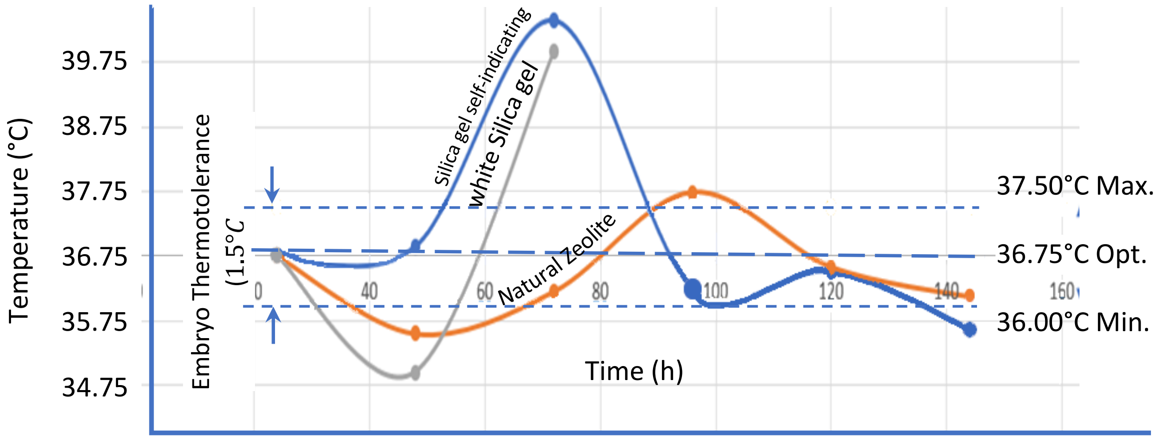
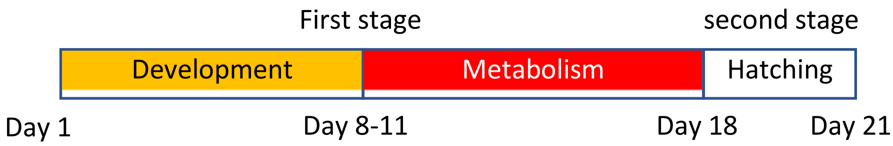


Figure 11. thermotolerance of different TCM battery materials (Silica gel self-indicating, white Silica gel, and Natural Zeolite) during the energy discharging process.

Results of the thermal performance showed that the average temperature inside the TCM incubator and the traditional electrical incubator for the first stage (incubation stage $from\ day\ one\ to\ day\ 18$) was $35.6 \sim 37.7°C$ and $38.1 - 38.3°C$, respectively.



And, for the second stage (hatching $from\ day\ 18\ to\ 21$) was $36 \sim 37.5\ °C$ and $38.3 \sim 38.4\ °C$, respectively at an average ambient temperature of $23.5 \sim 29.5\ °C$ as shown in Figure 12.

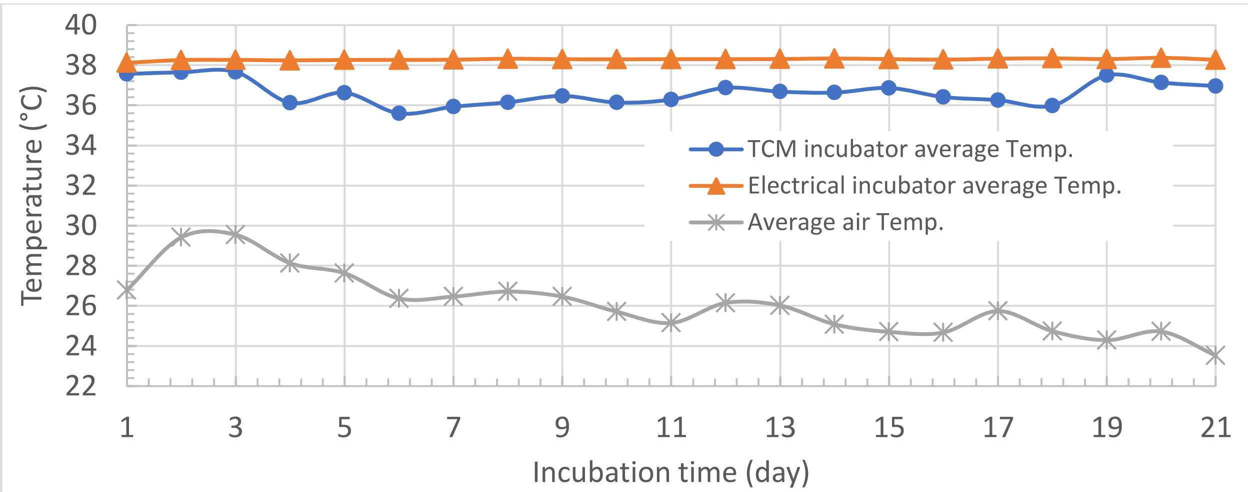


Figure 12. The average atmospheric temperature inside TCM and electrical incubator.

The average egg's ambient temperature inside the TCM incubator and traditional electrical incubator for the first stage was $35.1 \sim 37.6°C$ and $37.9 \sim 38.5°C$, respectively. And for the second stage was $36.4 \sim 37.0\ °C$ and $38.0 - 38.4\ °C$, respectively at an average ambient temperature of $23.5 \sim 29.5\ °C$ (Figure 13).

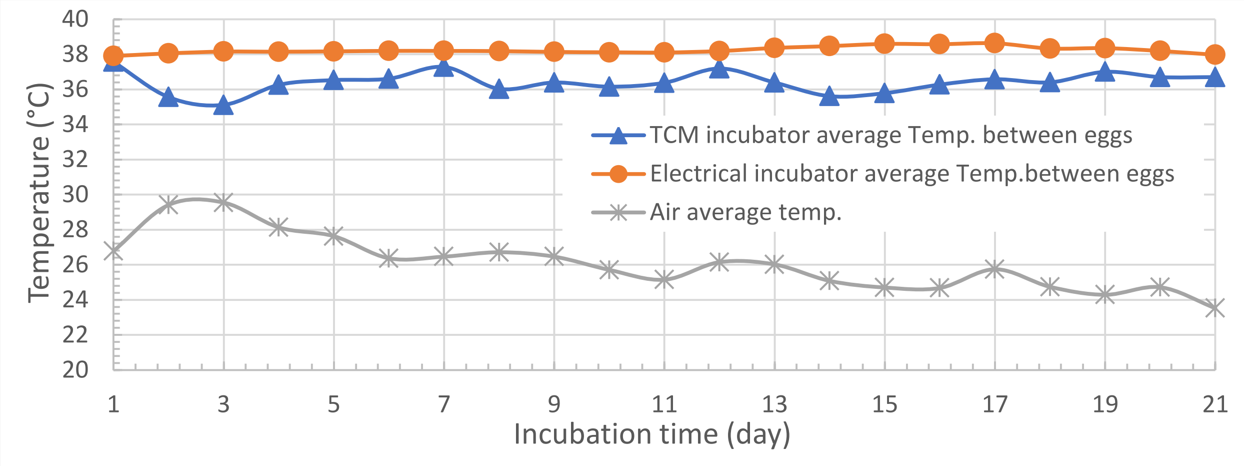


Figure 13. The average temperature between eggs in TCM and traditional incubator

According to the obtained results shown in Figure 13, the TCM battery was able to accommodate the optimum thermotolerance of chicks' embryo development ($\pm 1.5°C$) during incubation and keep the egg's temperature at desired range from 36.4 to 37.0 $°C$. In the traditional electrical poultry incubator, thermal performance was much more stable due to the nature of the steady electrical power supplement.

Relative humidity inside a poultry egg incubator is one of the most affecting factors on hatchability. During the incubation stage, the developing embryo requires relatively low ambient humidity (55~65%). On the other hand, during the hatching stage, the embryo requires highly ambient humidity (65~75%) for hatching. Obtained results from relative humidity measurements inside the TCM incubator and traditional electrical incubator during the incubation stage were 55.7~61.5% and 57~65.5%, respectively. On the second stage (hatching), the relative humidity inside the TCM incubator and traditional electrical incubator was 61.4~69.4% and 59~62.3%, respectively as showed in Figure 14.

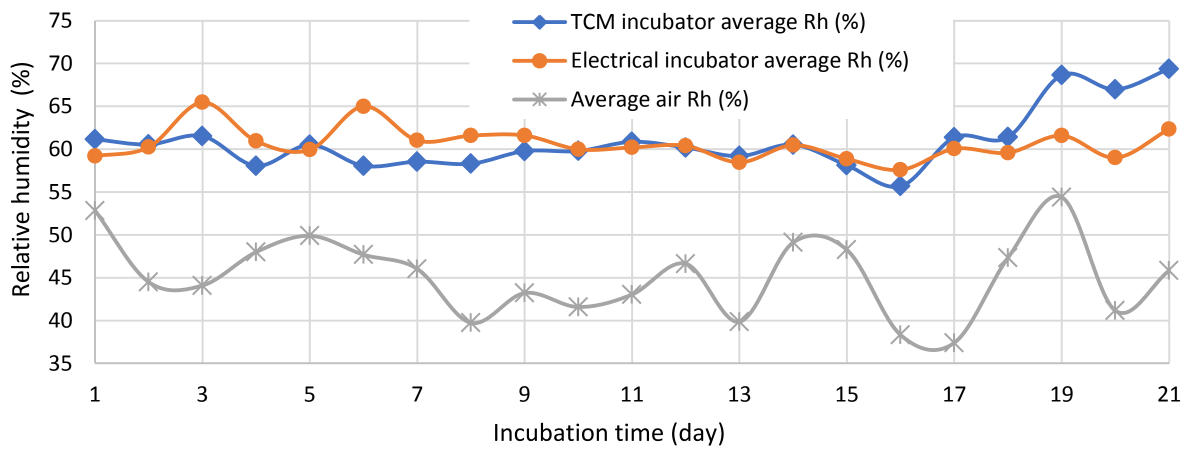


Figure 14. The average relative humidity inside TCM and electrical incubator.

TCM incubator, using humidity measurement and ultrasonic water mist generator controlled by PLC, gives a steady performance within the desired/programable relative humidity ratio on incubation stage and especially in hatching stage. While the tested traditional electrical incubator with an open water tank working as a passive humidifier performed less due to lack of control and low performance.

Biocompatibility measurement for the incubated twenty-five eggs in the TCM and traditional electrical incubator was conducted. Eggshell temperature (EST) in the incubation process differs according to the embryo develops from the differentiation, growth, and maturation phases. Incubated EST is vital to embryo development, hatchability, and mortality as much as for assessing the TCM incubator efficiency and process. (Lourens et al., 2005) in his study concluded that the highest hatchability and best post-hatch performance was observed when eggs were incubated at a constant EST ($37.8°C$). Figure 15, illustrates the average EST measured by the thermal camera in the TCM incubator proposed in this study compared to the electrically powered incubator. In the mid and late incubation and hatching stages, EST was a sum of the ambient temperature from the TCM battery and metabolic energy of the growing embryo (Figure 16).

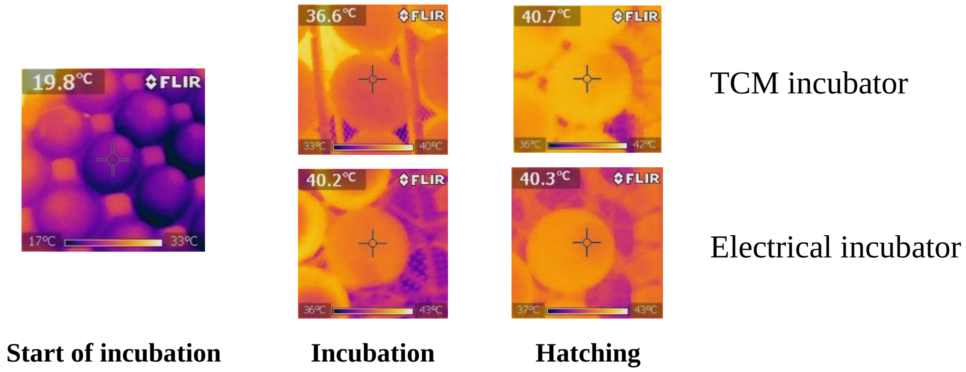


Figure 15. Thermo-image of eggshell at the start, incubation, and hatching stages.

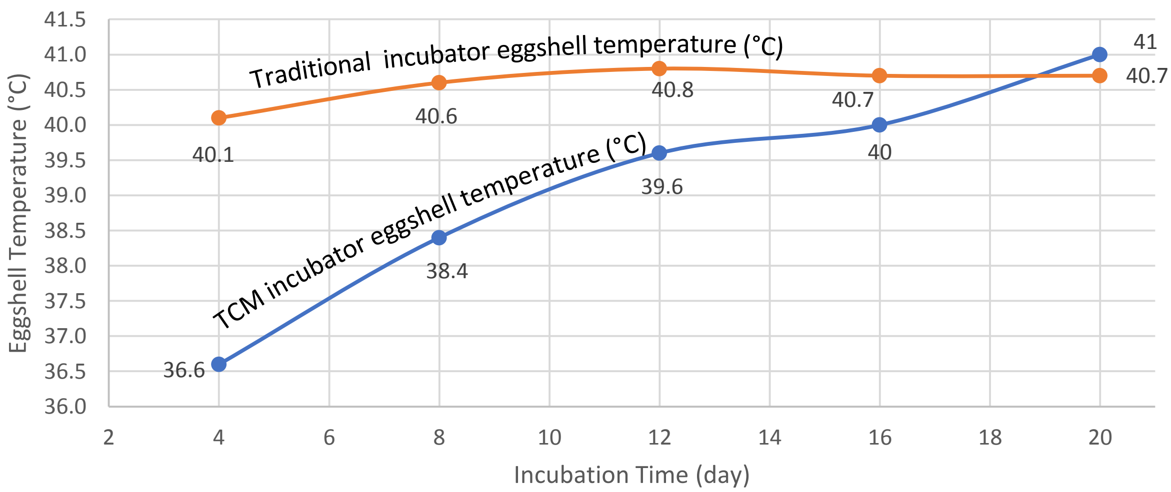


Figure 16. Relationship between average eggshell temperature in the TCM and the electrical egg incubator.

Results showed that the number of fertile eggs in the TCM incubator and traditional electrical incubator were 14 and 21 eggs, respectively. While the number of infertile eggs in TCM and traditional electrical incubators were 11 and 4 eggs, respectively. No early death of fertile eggs was observed in the TCM incubator, while one early death was observed in the traditional incubator. Four late death of fertile eggs was observed in the TCM incubator and three in the traditional electrical incubator. The number of hatched eggs in the TCM and the traditional electrical incubator was 10 and 17 eggs, respectively. The hatchability and fertility ratio were calculated from (Eqs. (16) *and* (17)) illustrated in Figure 17. The calculated Hatchability and fertility ratio for TCM incubators and traditional electrical incubators were 71.4, 80.95, and 56, 84%, respectively.

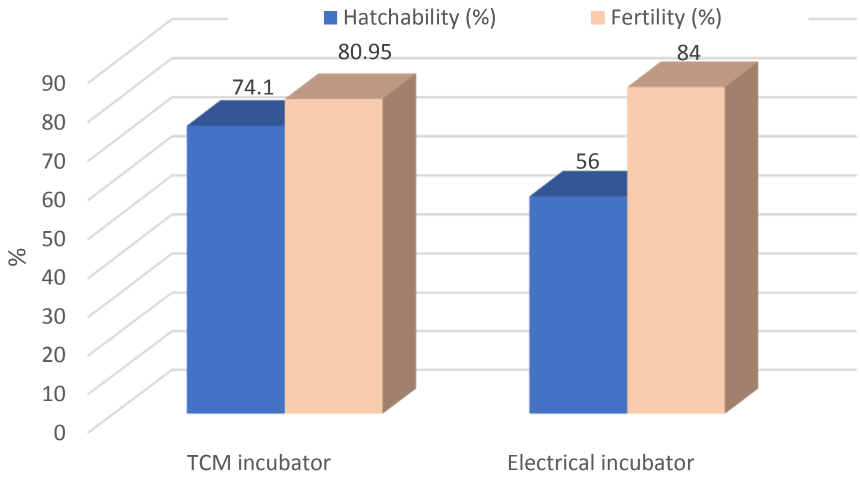


Figure 17. The ratio of hatchability and fertility in TCM and electrical incubator.

TCM incubator power consumption and costs

Measured energy consumption and traditional electrical incubator for 21 days was 11.2 kWh for TCM incubator and 19.25 kWh for the traditional. The TCM incubator consumed less power than the traditional incubator by 41.8% (Eq. (15)). The total cost for TCM and traditional electrical incubator was 7.28 and 12.51 EGP, respectively at a unity cost of 0.65 EGP as cited in the official website of the Egyptian Ministry of Electricity and Energy (Eq. (14)).

4. CONCLUSIONS

- The poultry industry is one of growing production can close the world food gap with consideration of the environmental impact and production sustainability. Poultry production can use renewable energy as a way for sustainability. Renewable energy can be widespread in the presence of an effective energy storage method.
- Using TCM batteries charged by renewable solar energy in the most demanding energy sectors is the most relevant method to overcome environmental crises and climatic changes that emerged from the intensive use of fossil fuels. This combined with several times higher stored thermal energy density compared to sensible and latent storage makes thermochemical materials (TCM) a promising alternative for mid and long-term heat storage.
- TCM battery materials Silica gel blue indicator, white silica gel, and natural zeolite were tested to choose the optimum performance of energy storage and release in the

way that fits the egg incubation process. Energy analysis showed that Self-indicating blue silica gel was suitable for embryo development with optimum embryonic thermotolerance ($1.5°C$) during incubation, energy storage capacity, battery size, and lower cost.

- TCM incubator automation with the programable logic control (PLC) has a positive impact on controlling energy release from the TCM battery according to the embryo development stage and the environmental conditions which lower the total energy consumption and production cost by 41% and 51%, respectively compared to the commercial electrical egg incubators.

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استخدام البطاريات الكيموحرارية بحاضنات الدواجن

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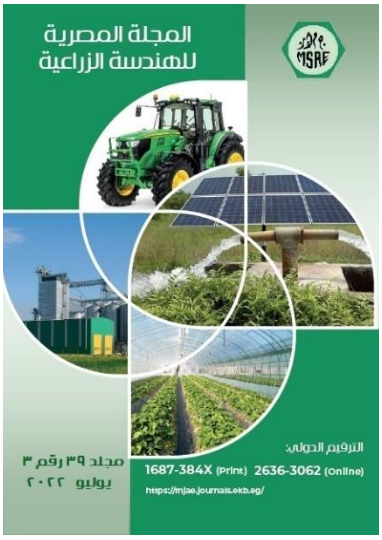

الكلمات المفتاحية:
تفريخ الدواجن؛ الطاقة الشمسية؛ البطاريات الحرارية.

الملخص العربي

يهدف هذا العمل إلى تقصي إمكانية اعتماد الطاقة الشمسية المخزنة في البطاريات الكيموحرارية المتنقلة والقابلة لإعادة الشحن للعمل ضمن النطاق الحراري الأمثل لنمو الأجنة بوحدات تفريخ الدواجن. أُنشأت حاضنة ذات سعة خمس وعشرين بيضة لاختبار أداء ثلاثة أنواع من البطاريات الكيموحرارية المتمثلة في مركبات السيليكا جل ذات الدليل اللوني الأزرق، السيليكا جل البيضاء، والزيوليت الطبيعي. أُجْرِيَت التجارب باسترداد الطاقة الشمسية المخزنة بالبطاريات الكيموحرارية - للحفاظ على درجات حرارة تحضين البيض ضمن حدودها المثلي- بترطيب مادة تخزين الحرارة.

أظهرت نتائج أداء الحاضنة التي تعمل بالبطاريات الكيموحرارية استهلاك للطاقة بمقدار ١١٢٠٠ واط خلال فترة التحضين البالغة ٢١ يوم بكفاءة استهلاك للطاقة الحرارية ٤١,٨% أعلى من وحدة التحضين التقليدية محلية الصنع والتي تعمل على الطاقة الكهربية وتستهلك ١٩٢٥٠ واط عند نفس ظروف التشغيل. نتج عن نمو الأجنة ٣,٦٥ واط من الطاقة الحرارية الحيوية، بينما فُقِدَ ٩,٨ واط بعمليات التهوية، و١,٥ واط من خلال جُدر الحاضنة بالحمل والإشعاع إلى الوسط المحيط. وبلغت كفاءة استرجاع الطاقة من البطارية الكيموحرارية من مادة السيليكا جل ذات الدليل اللوني الأزرق نحو ٥٣,٩%، وفى بطارية الزيوليت الطبيعي ٤٤,٤%، بينما بلغت كفاءة الاسترجاع ٣٧,٣٪ عند استخدام السيليكا جل البيضاء. بلغت نسبة الفقس – للبيض المحضن بنسبة ٥٦% قابلية للفقس- بالحاضنة التي تعمل على الطاقة الشمسية المخزنة نحو ٧١,٤% بينما بلغ نسبة الفقس – للبيض المحضن بنسبة ٨٤% قابلية للفقس- بالحاضنة التقليدية التي تعمل على الكهرباء بنحو ٨٠,٩%. خلص البحث إلى إمكان استخدام الطاقة الشمسية المخزنة في بطاريات بصورة كيميائية للعمل ضمن وحدات التفريخ مما ينعكس إيجابيا على كل من عمليات الإنتاج الداجني بخفض التكلفة والحفاظ على البيئة.