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THERMAL SIMULATION OF A FLAT PANEL SOLAR INCUBATOR FOR HEN EGGS

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ABSTRACT

Incubators are increasingly used in Burkina Faso in the field of poultry farming in rural and urban areas. They allow poultry farmers to hatch many eggs while minimizing losses. However, the incubators are powered by the electrical network or the photovoltaic system which converts electrical energy (whether alternative or continuous) into thermal energy for heating the eggs.
In order to compensate for this conversion of electrical energy into thermal energy, we decided to design a flat panel solar incubator operating using solar radiation since our country, Burkina Faso, has good sunshine during the year. Both physical parameters such as temperature and humidity are very important in egg hatching.
This work presents the model of the solar incubator with flat plate collector and the temperature profile within it thanks to the resolution of the heat transfer equations with the COMSOL software.

KEYWORDS: Incubator, panel solar, temperature, simulation.

1. INTRODUCTION

The hen egg incubator is where the eggs are incubated and hatched through the use of new technology or artificial equipment [1]. A hen covers her eggs for 21 days to observe their hatching [2]. This is the same normal hatching period when using an incubator [3]. The incubators which have good efficiency are electrical devices that run on alternating current but the vast majority of the population in developing countries is not connected to the electricity grid ([4], [5]). 80% of poultry farmers live in rural areas where they operate their farms using bush lamps to generate heat for egg incubation [6]. This is how energy companies favor the use of renewable energies (photovoltaic or solar thermal) that respect the environment and are accessible everywhere ([7], [8], [9]). Solar energy is an inexhaustible source capable of meeting the temperature conditions of an incubator without any danger to the environment. The incubation temperature of chicken eggs varies from one author to another, but the temperatures are between 36.5°C and 38°C [10].

The objective of this work is the determination of the temperature profiles inside the flat panel solar incubator by solving the heat transfer equations that govern its operation.

2. DESCRIPTION OF THE FLAT PANEL SOLAR INCUBATOR

The flat panel solar incubator (figure 1) consists of a 0.36m² clear window, an absorber (black painted steel plate) of 0.36 m² and a wooden chamber with a volume of 0.396 m^3 can accommodate 360 eggs. Inside the chamber we have honeycombs, a water trough (container containing water) and a chick trough (device to collect newly hatched chicks).

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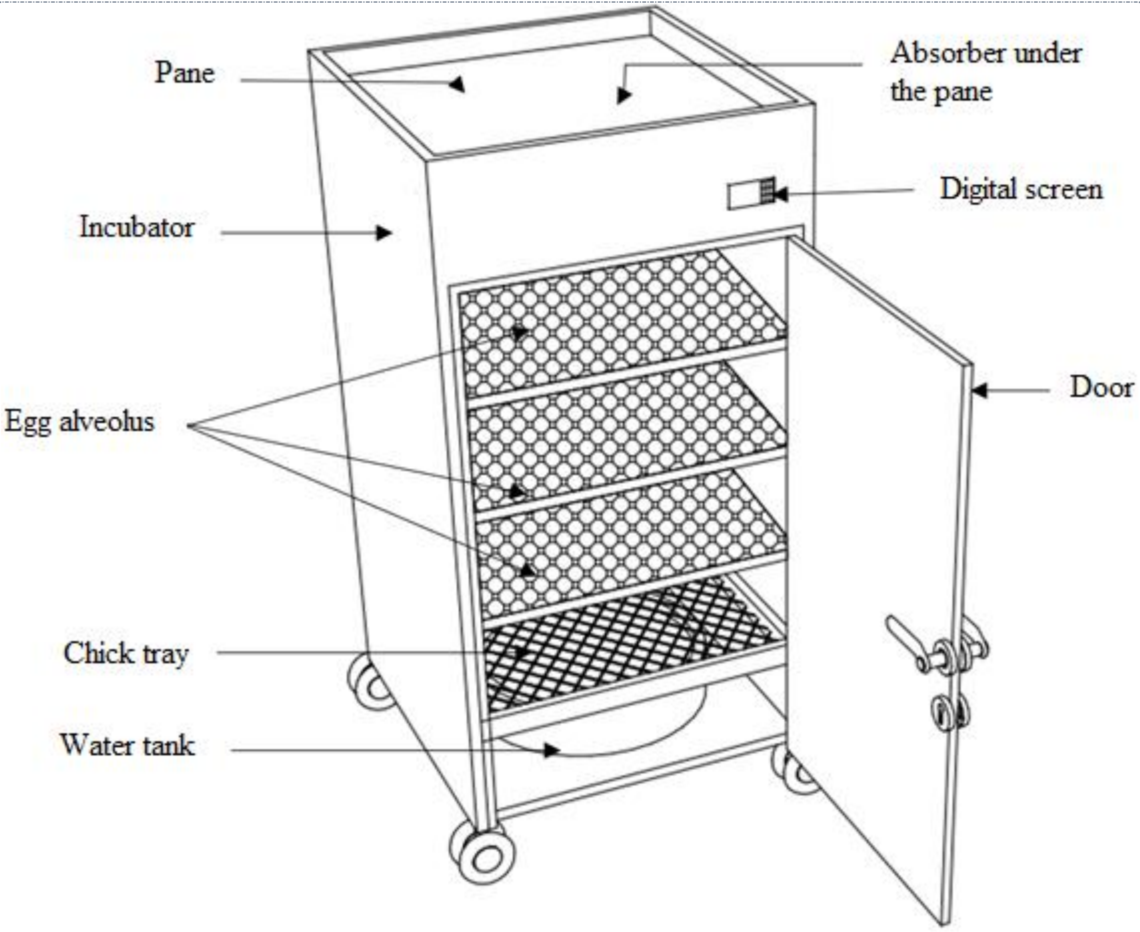

Figure 1. Model of the flat panel solar incubator for hen eggs

Principle of operation

The flat collector receives solar radiation through the glass which heats the absorber by greenhouse effect. This heat is transmitted to the hatching chamber throughout the day. At the level of the glass, we have the three modes of heat transfer namely conduction, convection and radiation. On the absorber, however, we have conduction through the steel plate and convection on its inner face. Finally in the incubation chamber, we retained the convection around the eggs while neglecting the conduction through the eggshells. The different heat exchanges within the device are summarized in Figure 2.

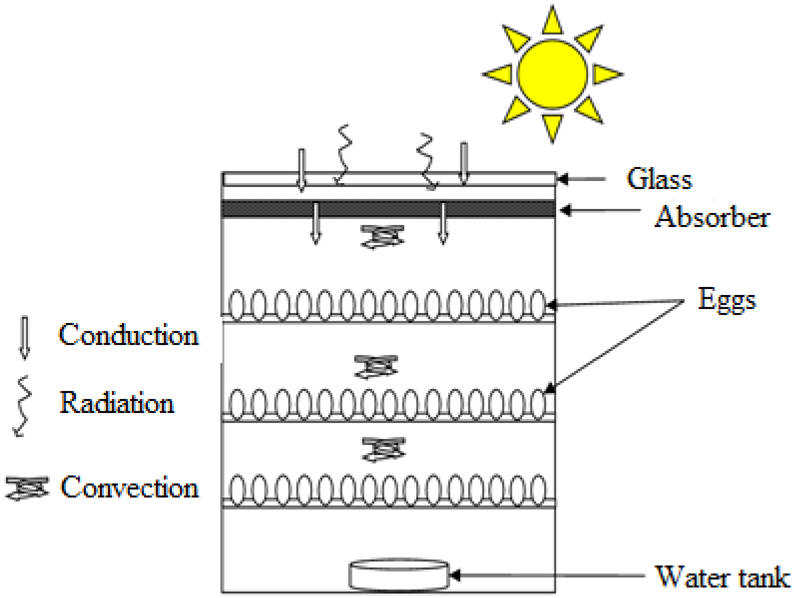

Figure 2. Diagram of heat transfer in the incubator

3. MATHEMATICAL MODELING OF THE FLAT PANEL SOLAR INCUBATOR

The solar radiation and heat transfer equations are used to assess the temperature profiles inside the incubator.

- Equation of solar radiation:

The coordinates of the city of Ouagadougou were used for the estimation of solar radiation.

$$G_{extDir,Bi} = F_{ext,Bi}(i_s).q_{0,s}.FEP_{Bi}(T_{sun}) \quad (1)$$

$$FEP_{Bi}(T) = \frac{15}{\pi^4}\int_{C_2/(\lambda_i T)}^{C_2/(\lambda_i T-1^T)} \frac{X^3}{e^X-1}dX \quad (2)$$

$$G_{extDir,Bi} = G_{extDir,Bi,u} + G_{extDir,Bi,d} \quad (3)$$

- ➢ Equation of thermal transfer

$$\rho C_p\frac{\partial T}{\partial t} + \rho C_p u.\nabla T + \nabla.(-k\nabla T) = Q + Q_{ted} \quad (4)$$

- ➢ Equation of convection

$$q_0 = h(T_{ext} - T) \quad (5)$$

$$h = \begin{cases} \frac{k}{L}\left(0.68 + \frac{0.67Ra_L^{1/4}}{\left(1+\left(\frac{0.492k}{\mu C_P}\right)^{\frac{9}{16}}\right)^{\frac{4}{9}}}\right) & pour\ Ra_L \leq 10^9 \\ \frac{k}{L}\left(0.825 + \frac{0.387Ra_L^{1/6}}{\left(1+\left(\frac{0.492k}{\mu C_P}\right)^{9/16}\right)^{8/27}}\right)^2 & pour\ Ra_L > 10^9 \end{cases}$$

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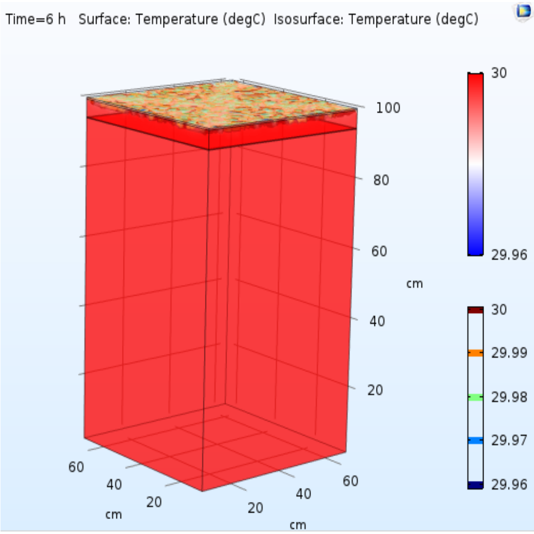
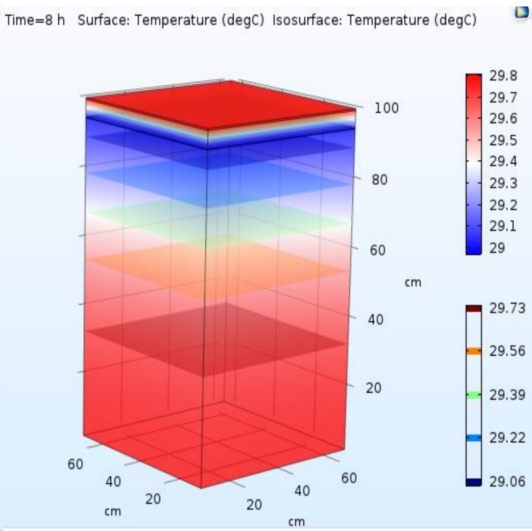
4. RESULTS OF THE SIMULATION

The following results are from a simulation of heat transfer in the flat panel incubator over solar radiation with COMSOL-Multiphysics software. Indeed it is the equations previously cited that allowed us to have these results.



(a)



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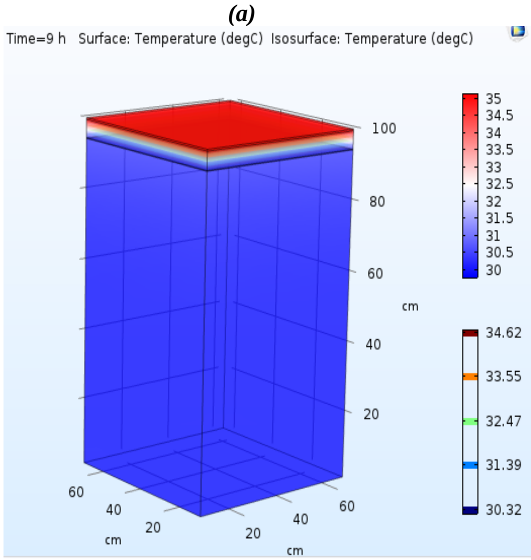

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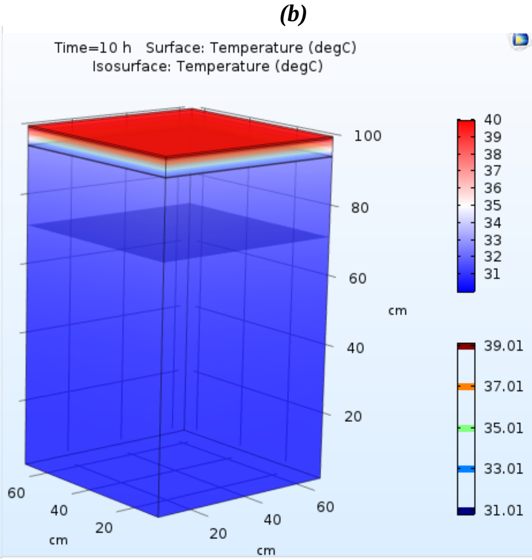

(d)

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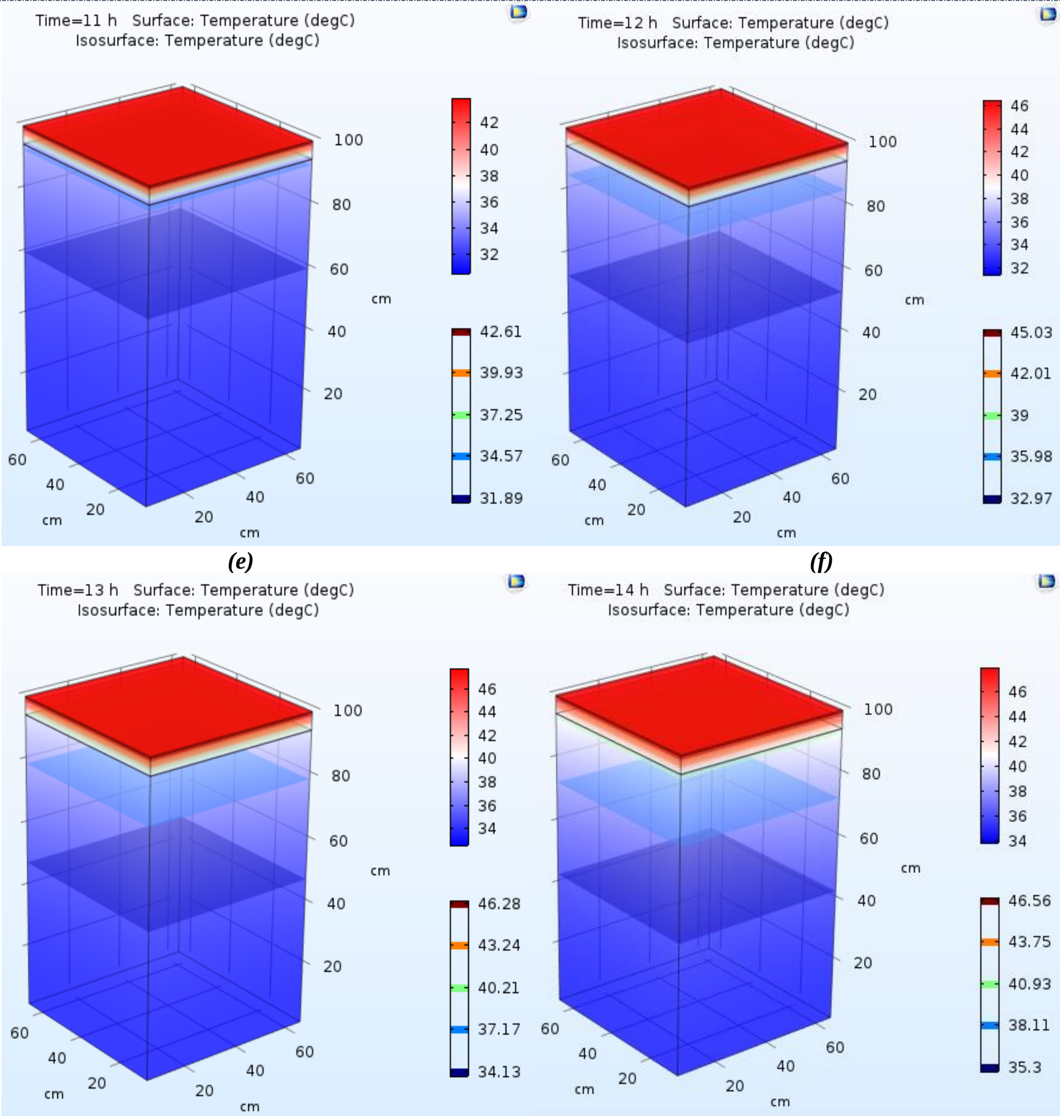

(e) *(f)*

(g) *(h)*

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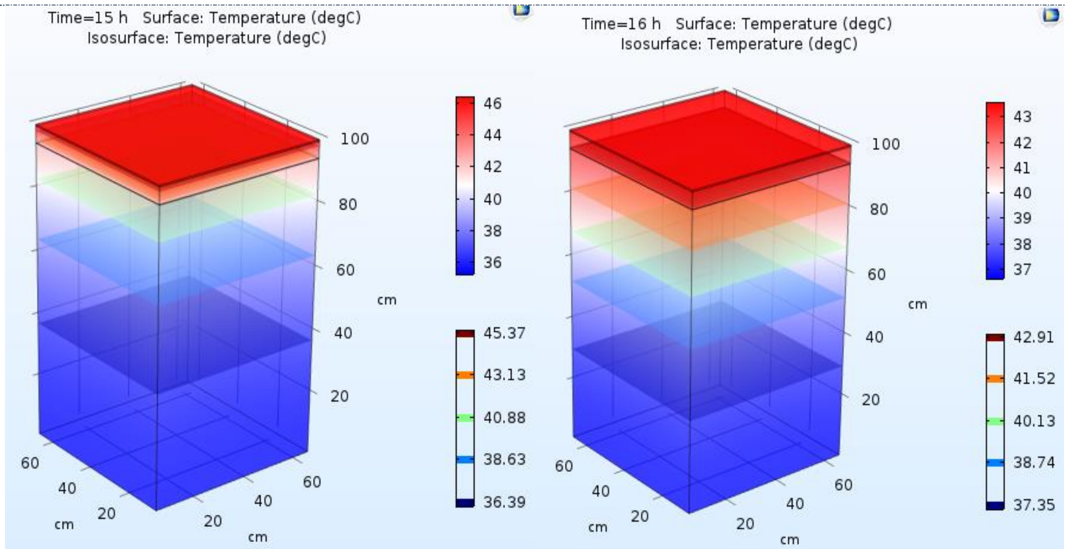
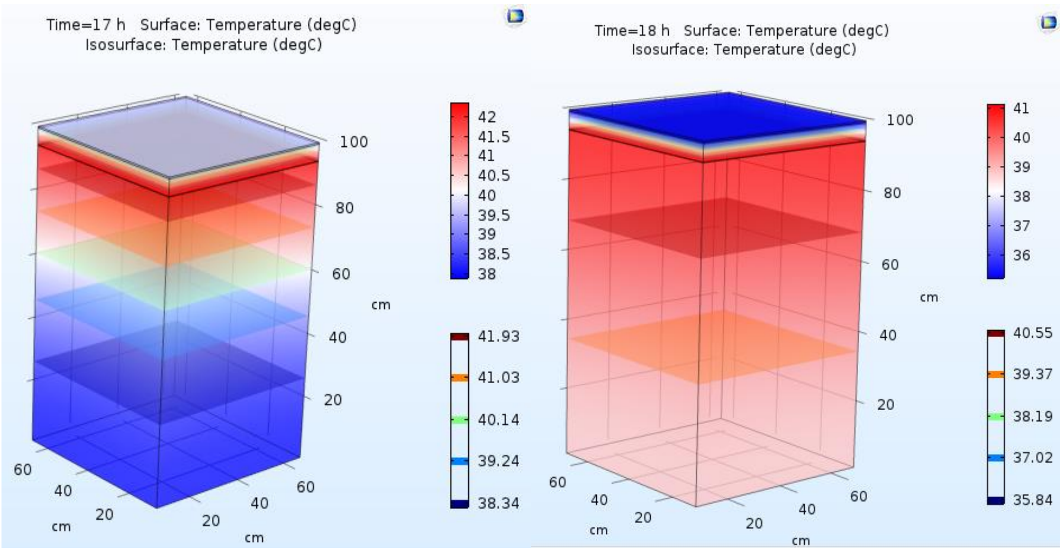


(i) *(j)*



(k) *(l)*

Figure 3. Temperature profile during the day

We observe a variation in air temperature between 30°C and 40°C from 6 a.m. to 6 p.m. With an initial ambient temperature set at 30°C, the air temperature inside the incubator is close to this value for up to 8 hours. It is from 9 a.m. that we notice an increase of 2 to 3°C in the air temperature inside the incubator and close to the absorber. At the same time the air near the base of the incubator has a temperature of around 30°C. As the solar radiation increases, we also observe an increase in the temperature inside the incubator to reach a maximum temperature of 42°C. From 40 cm and 95 cm height of the incubator, the temperature is between 34°C and 43°C from 11 a.m. to 3 p.m. while from 0 cm to 40 cm height, we have temperatures between 32°C and 38°C. Then between 4 p.m. and 6 p.m., in the zone close to the absorber (95 cm and 40 cm in height of the incubator), the temperatures vary from 38.73°C to 41.80°C while in the lower part (0 cm to 40 cm in height), the temperatures are between 37.5°C and 39.37°C.

We notice that the temperatures are lower or higher than the recommended temperatures 37.0°C to 38.0°C for a chicken egg incubator ([11], [12], [13], [14]).

In addition, exposure of the egg to a temperature of 46.1°C for 3 hours or 48°C for 1 hour on the 16th day of incubation is fatal for the embryo [15]. However, for work similar to ours, using a flat solar collector, the finding is practically the same with high temperatures when the solar irradiation is high [4]. On the other hand, with photovoltaic solar incubations, there is the possibility of controlling the temperature between 36°C and 39°C ([1], [10], [16],[17], [18]).

5. CONCLUSION

This simulation study allowed us to evaluate the temperature profiles in the flat panel solar incubator. The temperatures recorded inside the hatching chamber vary from 30°C to 37°C between 6 a.m. and 11 a.m., from 36°C to 42°C between 11 a.m. and 3 p.m. then from 40°C to 38.5°C between 3 p.m. and 6 p.m. The variation in temperature between 30°C and 42°C is due to the variation in solar radiation and has negative repercussions for the hatching process. Thus, we have to find solutions in order to have temperatures around 37 to 38°C during the day. One of the solutions is the introduction of fans in the model.

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