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Modeling Insulation and Temperatures of a Vegetable Cool Room

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Abstract **- Modern method of designing engineering systems involves various modeling techniques. Systems and sub-systems are analyzed using available design related parameters to generate diagnostic information that guides the designer in achieving his design objectives. A cool room for the storage of dried vegetables was proposed by the department of agricultural engineering, ABU, Zaria to serve tomato farmers and merchants. The room was to be made of locally available renewable materials. Stabilized laterite blocks were to be used as walling material and the wall is of cavity type. Two insulation materials, thatch and air were proposed to be applied as cavity filling material and at the floor and ceiling. Window air conditioner was selected to serve as cooling unit. Physical and thermal properties of all the room subsystems were measured and storage conditions were recorded. System level modeling was used to investigate the insulation performance and cooling of the cool room at full load with dried tomato and the room heating when there is energy failure, via MapleSim6.4. After loading the recorded data, models generated indicated that less heat flows through the thatch material compared to air. The temperature of the thatch decreases with increase of thickness (50-150mm). At full load and when cooler unit was put on, it takes 15hrs for the dried tomato to reach the storage temperature; the average heating rate of the cool room when air-conditioner was off is 1.53ºC/hr. And within 9.8hrs the room temperature equalizes to environmental temperature. Thatch stands to be a better insulation material for the design and the walling arrangement curtail external heat from entering the room for a reasonable time before energy is restored.**

1.0 INTRODUCTION

Tomato has been the major source of vitamins and minerals to 100million Nigerians, about 2million tones are reported to have been produced in recent years (Peter, 2011; FAO, 2015). As a result of in-adequacy of post-harvest instruments, between 20-50% of the produced tomato has been recorded as loss (FAO, 2011). During market gluts the losses were said to be severe and in the bid to controlling the losses farmers resolved to minimal processing of the tomato by sun drying and storing for out of season (Olurunda et al., 1990). Farmers and vegetable marketers store the dried tomato using the available traditional method: store, shops and rooms at ambient condition for a period of eight month (Aminu, 2009). At the end of the storage they come' up with tomato that do not attract market due to change in color, flavor and test.
Deterioration mechanisms in dried foods that affect its quality are usually assumed to be dependent on three parameters: time, temperature and moisture (Ozelgin, 2013). The composition of the atmosphere and light they are exposed to may also have an important effect. These parameters constitute a storage condition that sometimes could be more hash to storage of fruits and vegetables in the tropical Africa. Indeed fruits and vegetables are generally handled and stored in cool chain; therefore the existing dry tomato storage method can not address the hazard of the above mentioned parameters (Wilhoit, 2012). Modern cold storage units control the temperature and humidity of agricultural produce using a variety of technologies. Cool-Bot controllers and evaporative cooling are popular methods among small-scale farmers of the developed countries to maintain storage at low costs (USDA, 2013, Klavinski, 2013). An investigation was conducted in the development of a low-cost cool room using locally available construction materials affordable to Nigerian tomato value chain stake holders. In this paper insulation selection and cool room cooling and heating due to electric energy absence were reported.

2.0 MATERIALS AND METHODS

2.1 Materials

6% cement mixed stabilized laterite soil blocks was adopted as walling material (Adriana, 2009), the walls are of cavity type. Two insulation materials, air and thatch to be filled in the cavity hole, are to be tested for the work, dried tomato was considered as the stored material. Thermal and physical properties of these materials (Appendix1) were used in modeling the insulation and temperatures of the cool room. The cool room is located at Department of Agricultural Engineering, Ahmadu Bello University, Zaria latitude 12 º 12" N , longitude 07º 37" E at 550m altitude .
Window air conditioner (2hp) was selected to serve as the cooler and MapleSim 6.4 was the instrumentation software used in this modeling

2.2 Method

2.2.1 Insulation modeling

The two insulation materials as installed within the cavity of the stabilized laterite soil blocks walls were investigated in heat flow and temperature rise using MapleSim 6.4 software. The arrangement of walls and insulation is as shown in the subsystem block diagram (Fig1.0).

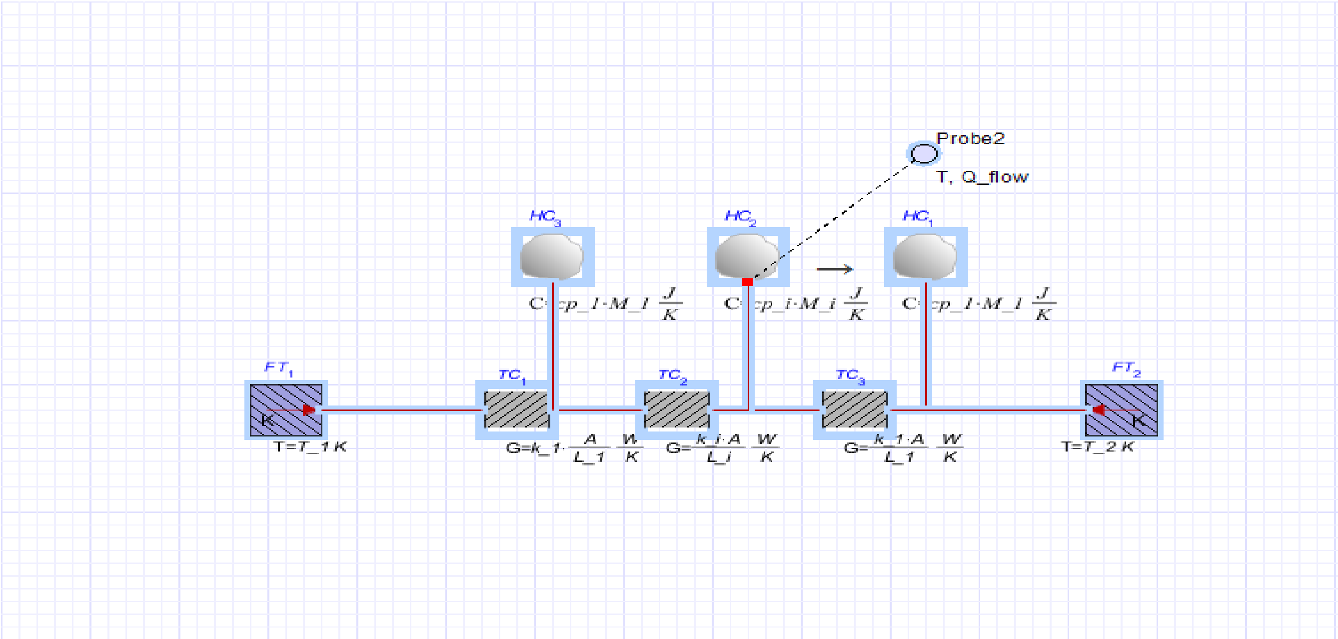

Fig.1.0 Block Diagram of walls and Insulation material

From left the first icon represents outside environment, the next represents outside lateritic block wall, then the insulation materials(Air or Thatch) in the cavity, the inside lateritic block wall and the inside room environment. The probe2 measures the heat flow and temperatures of the selected insulation and the room was cooled by an Air Conditioner (window type).The physical and thermal parameter of each component (Appendix 1) was fed in to the software. A simulation of temperature, heat flow with time was run at 1000 times per minutes at cavity thickness of 50mm and models were generated, models were further generated at insulation thicknesses of 80,100,150mm.

2.2.2 Cool Room Temperature Modeling

Similarly the cool room heating when there is energy failure and the cooling after dried Tomato was loaded and Air Conditioner thermostat was set at 20°C were model using thatch as insulation material with same lateritic soil block (fig2.0). The parametric data of the room contents (Appendix 1),the four walls,ceiling and floor were loaded in to the software,prob2 measures the roomtemperatures per second. Simulations were run at 1000 times per minute speed and models were generated.

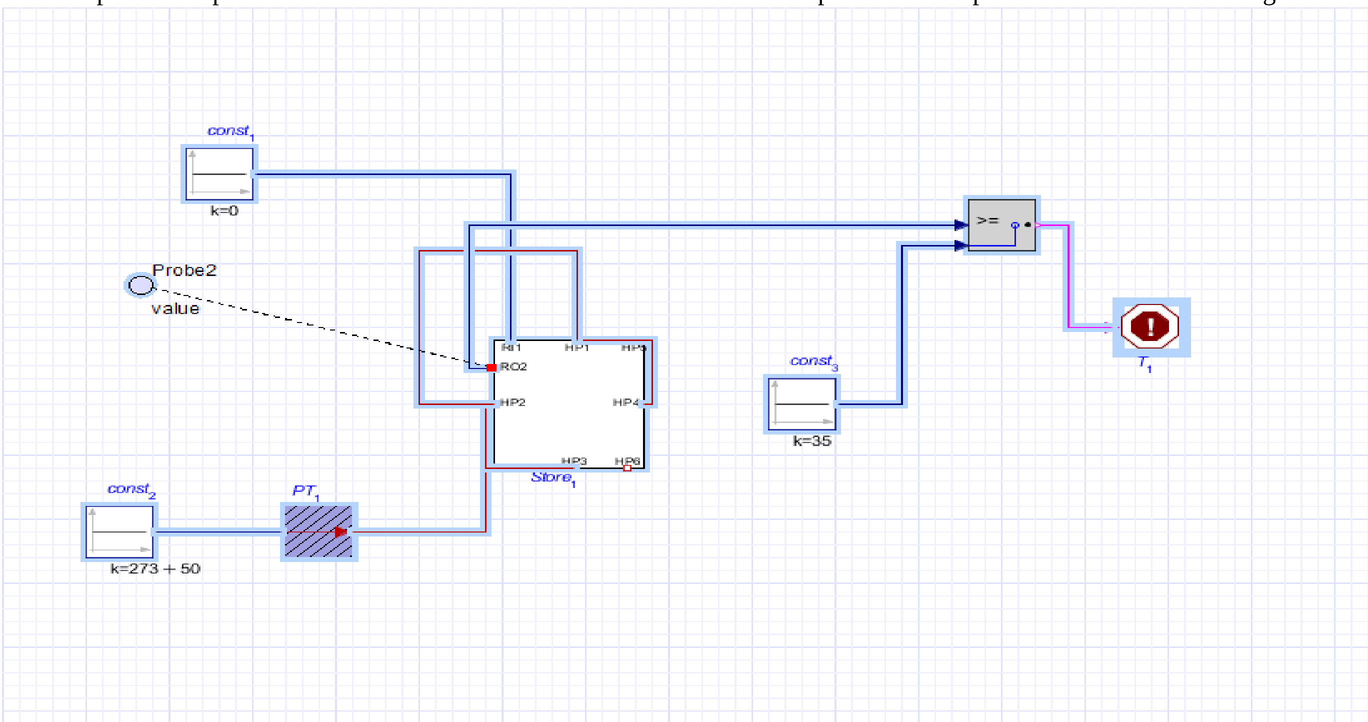

Figure2.0. Block diagram of the Coolroom

3.0 RESULTS AND DISCUSSION

3.1 Insulation Model

The heat flow model for the two insulation materials, air and thatch were generated and presented in Fig3.0. Curve leveled thatch represents the heat flow through the thatch material and curve leveled air represents the heat flow through the air as positioned in the cavity of the room wall. From the model, less heat flows through the thatch material compared with the air at the same time. The model predicted that after 14500sec (4hrs) the heat flow was close to zero in the thatch material, where as heat continue to flow in air insulation. Further investigation on the effect of change of thickness (50-150mm) of the thatch insulation within the wall at the same room condition on the mean insulator temperature reveals that the more the insulator thickness the less the temperature (fig4.0).

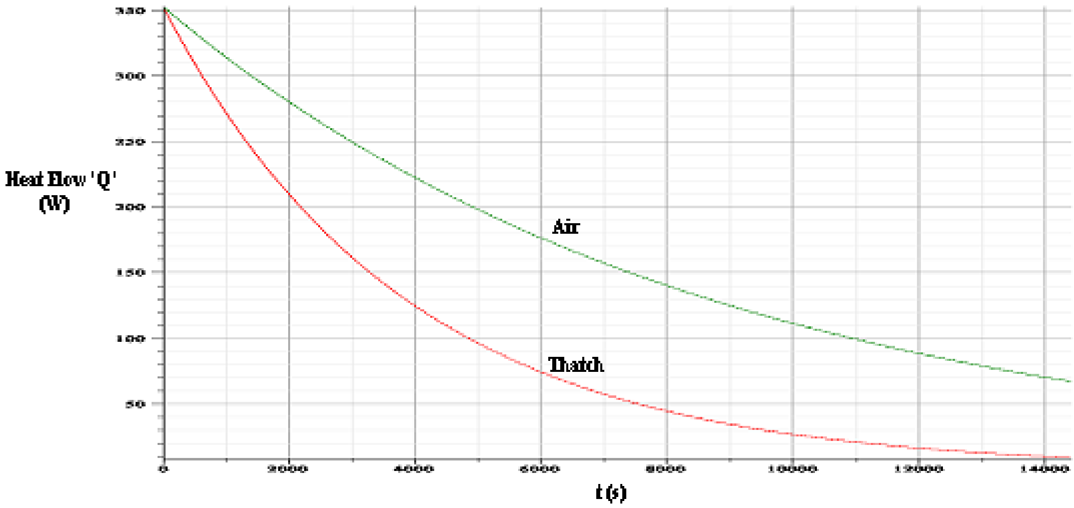

Figure3.0: Heat flow Model of the thatch and air insulation

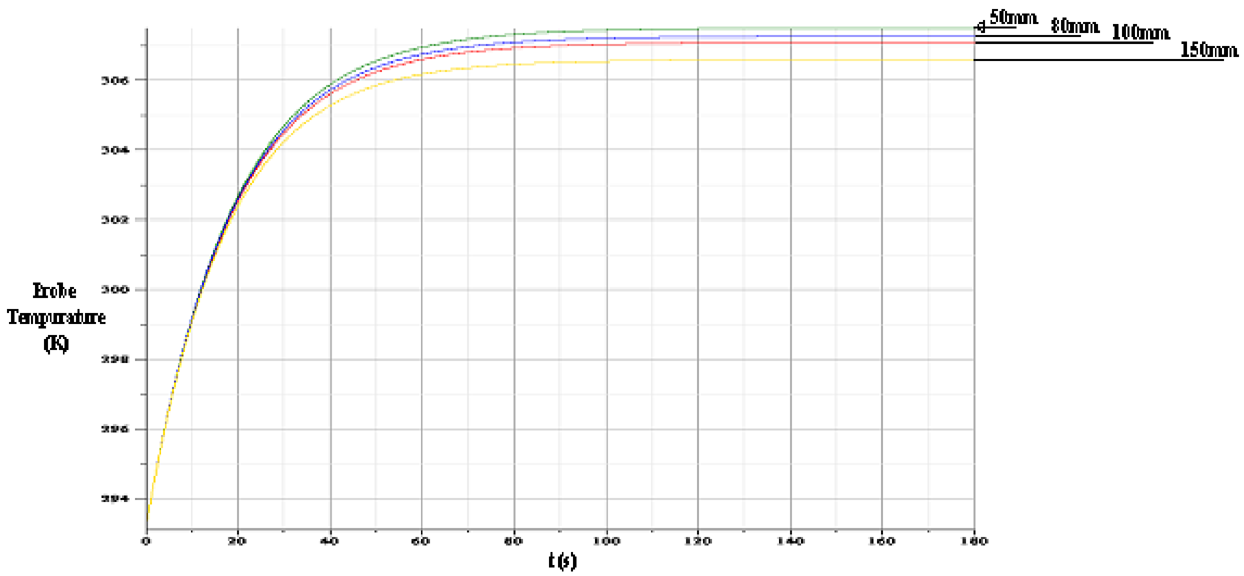

Figure4.0: Thatch insulation temperatures Model (at various thickness(50-150mm))

3.2 Coolroom Temperature Model

When outside environment temperature was at 35°C and the room temperature was set at 20^{0}C, at the coolroom load condition, time taken to cool the dried tomato to the set temperature is shown in the model (figure 5.0). It took the dried tomato 15.0hrs to cool from the environment temperature to the set storage temperature. And from the cool room heating model (Fig.6), the room will heat-up to environmental temperature in 9.78hr (1.53^{0}C/hr) when there was energy failure. The room temperature will rise to 25°C within 3hrs; this indicated that the cool room at the simulated storage condition can tolerate 4hrs electric energy failure. Electric energy supply failures are a phenomenon in Nigeria.

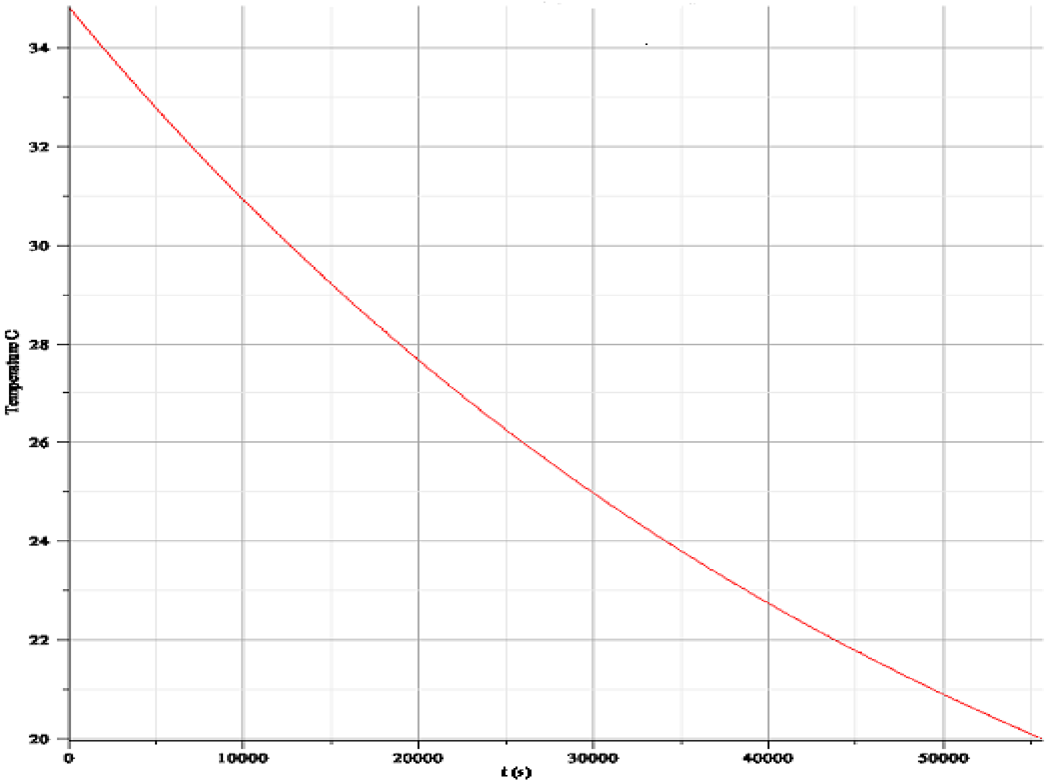

Figure5: Cool room cooling Model

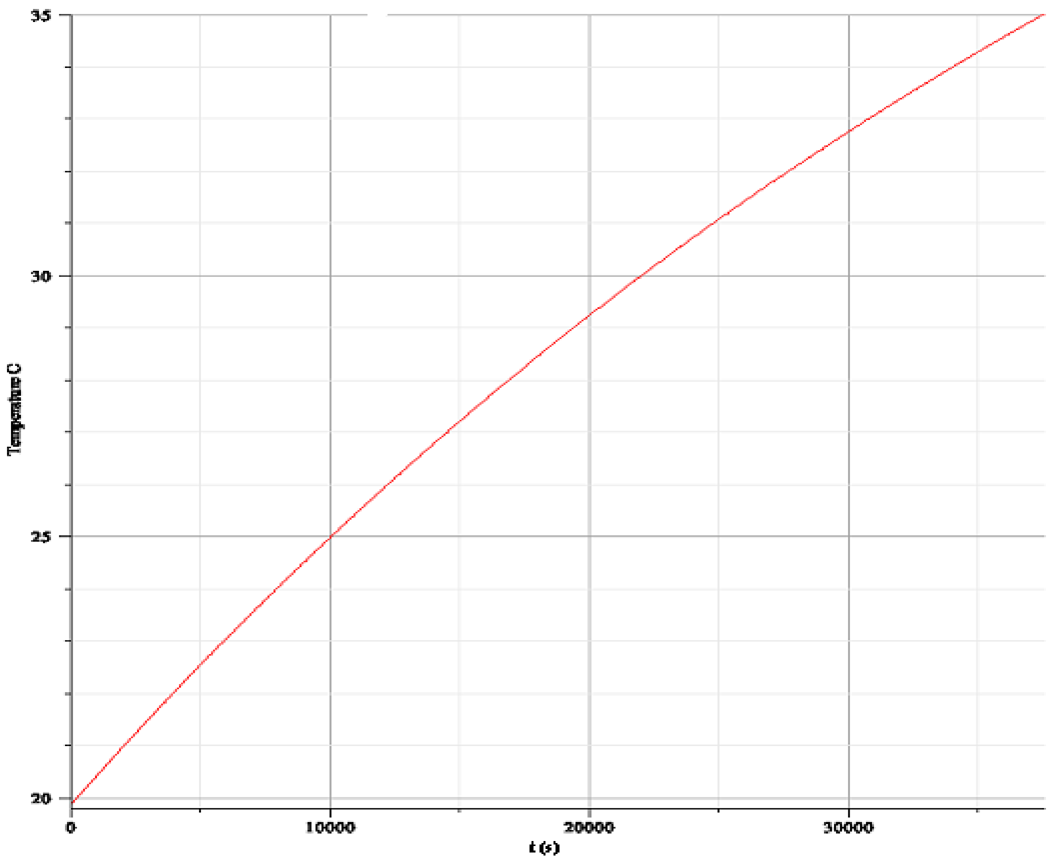

Figure6: Cool room heating Model

4.0 CONCLUSIONS AND RECOMMENDATION

4.1 Conclusion

Insulation and temperatures of the vegetable cool room were investigated for design purposes using the lamped parameter modeling technique; the following conclusions are hereby drawn:

1. Based on the generated models, less heat flows through the thatch material compared to the air as installed in the cavity of the cool room wall. Therefore the thatch stands to be better insulation material than the air.
2. The temperature of the thatch insulation turns to be decreasing with increase of the wall cavity thickness.
3. At full load and when cooler unit was put on, it takes 15hrs for dried tomato to reach the storage temperature.
4. When the electric energy was cut-off, the average heating rate of the cool room was 1.53ºC/hr.

4.2 Recommendation

Thatch which is a renewable material is strongly recommended to be used as insulation material in the appropriate vegetable cool room construction.

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APPENDIX 1

Wall

Inner wall thickness 110mm

Outer wall thickness 110mm

Wall material Stabilized laterite soil (6% cement)

Wall material conductivity 0.523W/mºK

Wall cavity depth 50mm, 80mm, 100mm and 150mm

Wall surface area 5.0m^2

Air

Cp air 1.005kJ/kgºK

Air density 1.127 kg/m^3

Air conductivity 0.025W/mºK

Thatch

Conductivity 0.07W/mºK

Density 123kg/m^3

Room

Volume 1.5 x 2.0 x 2.4m

Cooler Air conditioner (2hp window)

Inside set temperature and RH 20ºC, 60%

Environmental temperature and RH 35ºC, 80%

Wooden shelves

Single florescence bulb

Dried Tomato

Quantity 500kg Cp Dried tomato 3.978kJ/kgºC

Density 204kg/m^3