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Effects of Insulation Materials and Temperature Gradient on a Brick Cool Room for Vegetable Storage

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Abstract: Modern method of designing engineering systems involves various design techniques. Systems and sub-systems were 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 constructed using brick to serve tomato farmers and merchants to reduce wastage. The room was made of locally available renewable materials: Stabilized cavity laterite bricks were used as walling material. Thatch and air were used as insulation materials at the walls, floor and ceiling. Window-type air conditioner was used to serve as cooling unit. Physical and thermal properties of the room sub-systems were investigated to determine the storage conditions of the cool room. Temperature gradient was used to investigate the insulation cooling performance of the cool room at full load with dried tomato and the room heating when there is energy failure. Results obtained from the data generated indicated that less heat flows through the thatch material compared to air. The temperature of the thatch decreases with increase of thickness (50 – 150 mm). At full load and when cooler unit was put on, about 14.49 hrs was required for the dried tomato to reach the optimum storage temperature. The average heating rate of the cool room when air-conditioner was off was 1.52 ^oC/hr. while within 9.76 hrs., the room temperature equalizes to environmental temperature. That stands was discovered to be a better insulation material for the design. Similarly, the walling arrangement restricts external heat from entering the cool room for a reasonable time before energy was restored.

Keywords: *Cool room, Installation Modeling, Temperature, Vegetable*

INTRODUCTION

Studies conducted by various researchers shows that tomato has been aforemost source of vitamins and minerals to about200million Nigerians (Aminu, 2009, Idah, 2011; FAO, 2015).It was estimated that about 1.95million tons of tomato was reported to have been produced in recent years (Idah, 2011;FAO,2015). However, due to inadequacy of post-harvest storage structures, nearly50% of the produced tomato has been recorded as post-harvest losses (FAO, 2011).

Such losses were even double during market gluts in a bid to control these losses, farmers and produce buyers use traditional means regarded as minimal processing of the tomato by sun drying and storing for out of season usage (Idah*et al.*,2014). Farmers and vegetable marketers store the dried tomato using the available traditional method: lock-up stores, shops and rooms at ambient condition for long periods (Aminu, 2009). These results in deterioration of the product with low appeal that do not attract market due to change in colour, flavour and test.

Deterioration mechanisms in dried foods that affect its quality are usually assumed to be dependent on four parameters: storage facility,period of storage, temperature and moisture content of both the product and the environment (Ozelgin, 2013). 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 cannot address the hazard of the above mentioned parameters (Idah*et al.*, 2014). The evolutions of modern cold storage systems have the means of controlling 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 (Klavinski, 2013; USDA, 2013). The none availability of such storage facilities led to conducting investigation towards the development ofa low-cost coolroom using locally available construction materials that are cheap, available and affordable to most vegetable farmers and value chain stake holders in Nigeria.This study, therefore,was devoted to the effects of insulation materials and environmental condition (temperature) using laterite bricks as walling materials for the coolroomwhile cooling and heating the stored product in the absence of electric energy.

MATERİALS AND METHOD

2.1 Materials

Stabilized laterite soil and cement mixedto produce bricks (at a ratio of 94:6 %) was adopted as walling material (cavity type walls)as suggested by Adriana(2009), Fig 1. Two insulation materials, air and thatch filled in the cavity hole,were used.Dried tomato was considered and used as the test stored material. Thermal and physical properties of these materials were used in determining the insulation and temperatures of the cool room (Fig. 2) located at the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Zaria with latitude 12^{o} 12"N and longitude 07^{o} 37"E at550m altitude. A 2 hpWindow air conditioner served as the cooling media. A 2000 volt stabilizer was attached to the air conditioner in order to regulate the current supplied. The site plan and design of the cool room is given in Appendix 1.

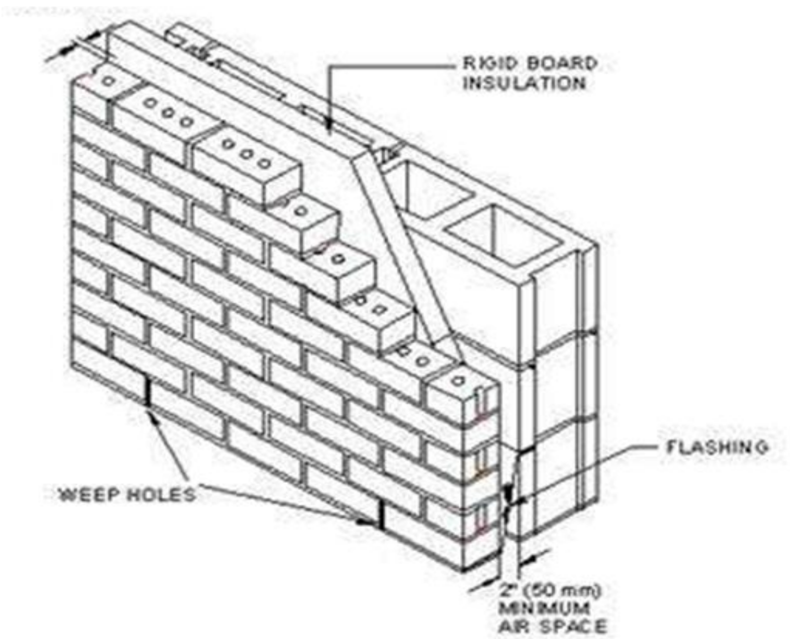

Fig.1 Design of the Cavity Wall

Fig. 2Pictorial view of the constructed rooms

2.2 Method

2.2.1 Insulation Modeling

The two insulation materials were installed within the cavity of the stabilized laterite soil blocks walls were investigated in heat flow and temperature rise using MapleSim 6.4 software. Fig. 3 shows the arrangement of walls and insulation the subsystem block diagram.

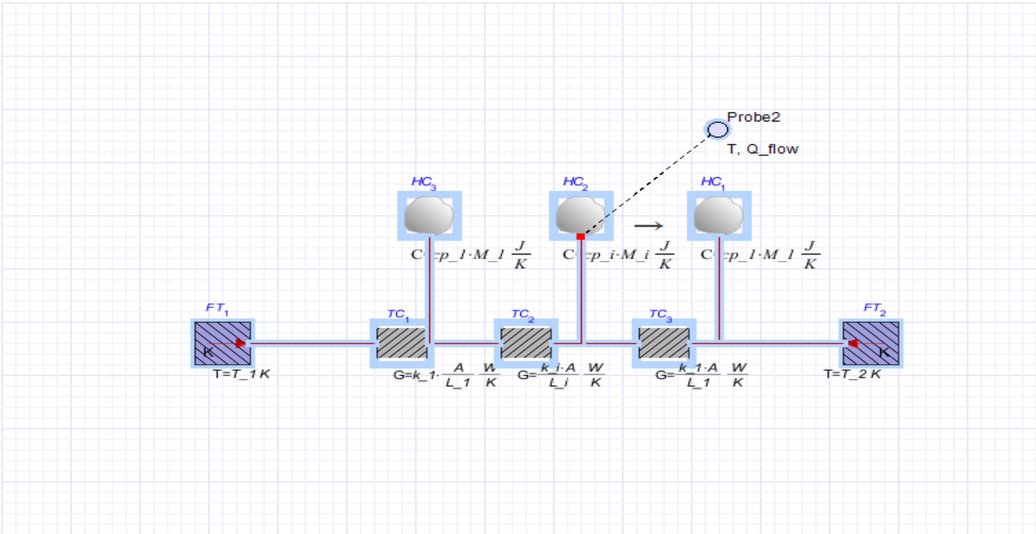

Fig.3Block Diagram of walls and Insulation material

The first icon toward the left of Fig. 3represents the outside environment.Thenext icon represents outside lateritic block wall, then the insulation materials(air or thatch) in the cavity inside lateritic block wall and the inside room environment. The probe2 measures the heat flow and temperatures of the selected insulation materials and the room was cooled by the installed air conditioner.The physical and thermal parameter(shown in Appendix 1) of each component were fed in to the software. A simulation of temperature and heat flow with time was run at 1000 times per minutesat cavity thickness of 50mmto generate the resulting data.This process was replicated further at 80,100, and 150mm thickness of the insulation materials, recording the generated data.

2.2.2 Determination of Cool Room Temperature

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 determined using thatch as insulation material with same lateritic soil block(Fig.4). The parametric data of the room contents (Appendix 1),the fourwalls,ceilingand floor were loaded into the software. Probe 2 measures the room temperatures per second.

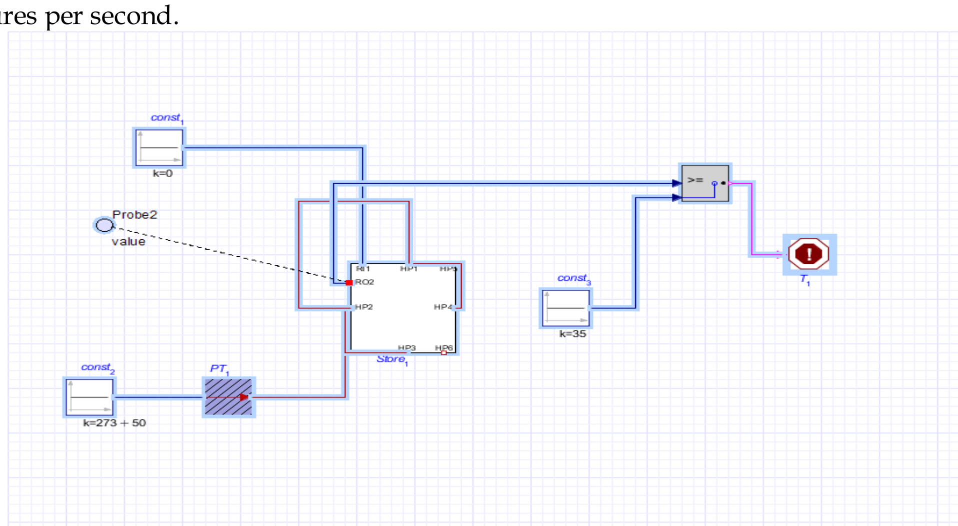

Fig.4Block diagram of the Coolroom

2.2.3 Working Principle of the Cool Room

The working principle of the cool room includes the loading of the dried vegetables (sliced tomatoes) at different moisture levels. These materials were packaged in 0.01mm thick polypropylene food grade film at 500g each and re-packaged in carton (10pieces) for the room's storage as suggested by Gordon (2013). The packages were labeled according to the moisture levels and loaded on a wooden pallet in each room. Storage temperatures of 20^{o}C and 25^{o}C were selected according to Bilge *et al.* (2012) and set on the air conditioner in each room accordingly and closed for experimentation.

RESULTS AND DISCUSSION

Effects of Insulation Materials

The heat flow model for the two insulation materials (air and thatch) were generated and presented in Fig. 5. 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. It was observed that less heat flows through the thatch material compared with the air at the same time. The study discovered that after 14,500sec (4hrs); the heat flow was close to zero in the thatch material, whereas heat continues 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 revealed that the more the insulator thickness the less the temperature (Fig.6).

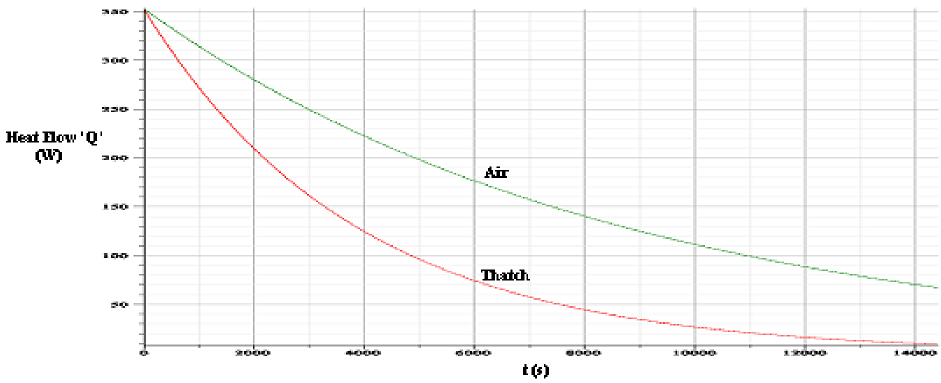

Fig.5Heat flow through the thatch and air insulation

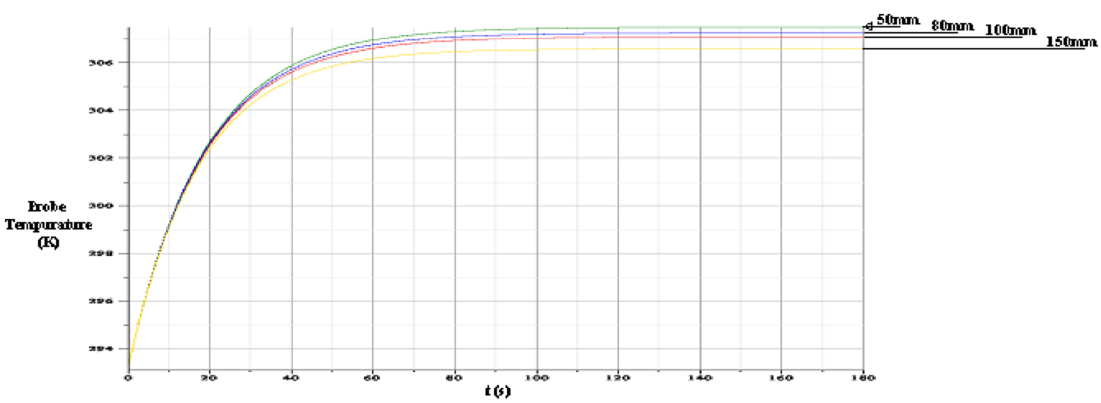

Fig.6 Thatch insulation temperatures (at various thicknesses,50 – 150 mm)

Effects of Temperature on the Cool room

When outside environment temperature was at 35ºC and the room temperature was set at 20⁰C at the coolroom load condition, time taken to cool the dried tomato to the set temperature is shown in Fig.7. It took the dried tomato 15.0 hrs. to cool from the environment temperature to the set storage temperature.From the cool room heating (Fig.8), the room will heat-up to environmental temperature in 9.78hr (1.53⁰C/hr) when there was energy failure. The room temperature rose to 25ºC within3hrs.This indicated that the cool room at the storage condition could tolerate 4hrs electric energy failure,erratic power supply is a commonphenomenon in Nigeria.

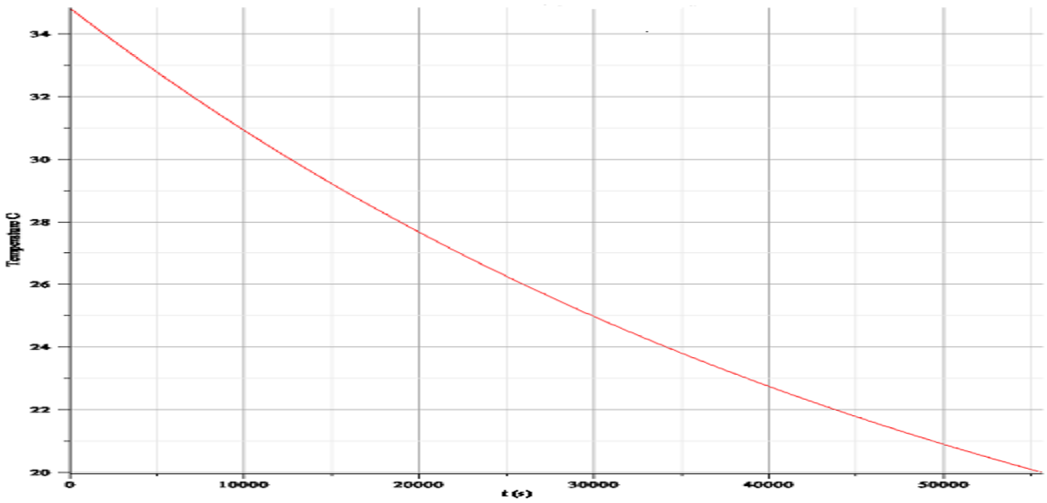

Fig.7Cool room cooling Model

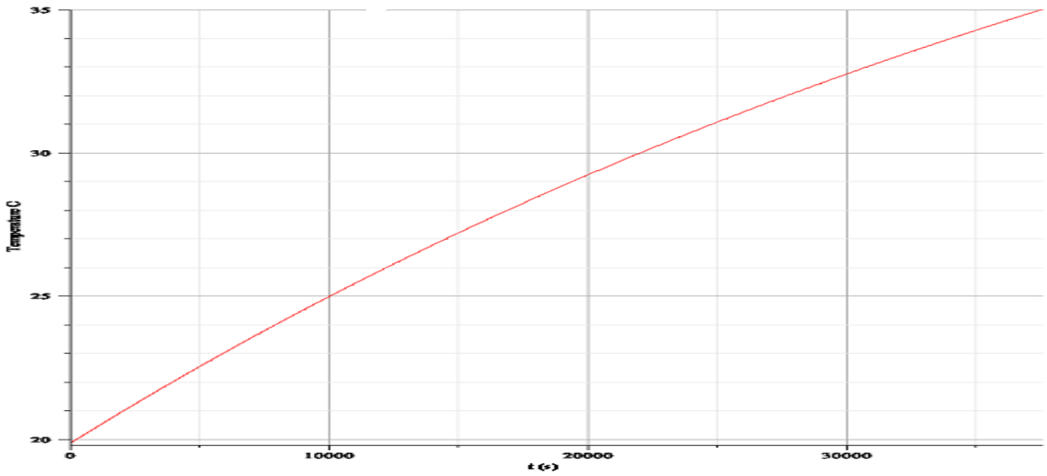

Fig. 8 Cool room heating Model

Tomato dried and stored in the cool room at 20 °C and 25 °C had no significant moisture content difference at 0.05level but significant difference exists with its control. The farmer dried Tomato showed similar trend but the farmer dried Tomato turn to be drier and exhibits impurities due to the environmental conditions of the drying area (Fig. 9).The product of the developed cool room(Fig. 10) is, therefore, more hygienic and qualitative than that of the traditional method of drying that is common especially in the northern part of Nigeria where farmers sun-dry their products either by the roadside or within their farms.

Such products were noted to contained so much dirt's and impurities that reduce their quality and eventually hazadious and of less economic values.

Fig. 9 Tomatoes dried and stored traditionally in the open space

Fig. 10 Product of Tomatoes dried and stored in the developed cool room

CONCLUSIONS

The effects of insulation materials and temperatures of the vegetable cool room were investigated for design purposes in order to maintain and preserve the market value of the vegetables. The following conclusions are hereby drawn:

i) Based on the results obtained, it was observed that less heat flows through the thatch material compared to the air as installed in the cavity of the cool room wall. Therefore the thatch was better insulation material than the air.
ii) The temperature of the thatch insulation turns to be decreasing with increase of the wall cavity thickness.
iii) At full load and when cooler unit (air conditioner) was put on, it takes 15hrs for dried tomato to reach the storage temperature.
iv) When the electric energy was cut-off, the average heating rate of the cool room was 1.53^{o}C/hr.

CONTRIBUTION TO KNOWLEDGE

This study has established a system of vegetable storage using locally available insulation materials at controlled temperatures to in order to reduce wastages incurred by farmers and merchants. This would as well add value of the produced for increased income.

DECLARATION OF CONFLIT OF INTERST

The authors declare no competing interest

ACKNOWLEDGEMENT

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REFERENCES

Adriana Mauricio Perez-Pena. (2009). Interlocking Stabilized Soil Block, appropriate earth technology in Uganda.United Nation Human Settlement Programme

Aminu A. and Shehu A.M. (2009).Tomato Commodity Chain Analysis in Kano River Irrigation Project,Nigeria. A Study Commissioned by the Agricultural Development in Nigeria (ADENI) Project, Frenvh Embassy/NAERLS, ABU-Zaria Nigeria

Bilge A., Dilek D. K. and Neriman B. (2012).Use of factorial experimental design for analyzing the effect of storage conditions on color quality of sun-dried tomato. *Science Research and Essays*, 7(4): 477 – 489

FAO .2011. Global food loses and food waste. International Network on Post-harvest Operation

FAO-STAT.2015. Tomato Production in Nigeria

Gordon L.R. (2013). Food Packaging Principles and Practice. CRC Press, Taylor and Francis Group 6000 Broken. Sound Packway NW, Suite 300 Boca Raton, FL33487-2742.

John Wilhoit.2012. Mid-Atlantic Fruits and Vegetable Convention.Biosystems and Agricultural Engineering Department,University of Kentucky.

Idah P. A. (2011). Quality change in Dired Tomato Stored in Sealed Polythene and open Cotainer. Journal of Agricultural Engineering and Technology

Idah P.A., Objemihi, O. I., Adeboye 0.A. and Olaniyan, A.M, (2014). Assessment of Osmotic Pre-Drying Treatment on Drying Rates of Fresh Tomato Fruits.*Nigerian Journal of Technological Development,* 11(1): 22 – 26

Klavinski, R (2013). Michigan State University MSU Extension, *7 Benefits of Eating Local Foods*. Michigan State University Extensions, 13 Apr. 2013

Ozilgen.M.(2011). Handbook of Food Process Modelling and Statistical Quality Control. CRC Press ,Tylor and Francis Group Newyork

USDA.Department of Agriculture.*Farm Size and the Organization of U.S. Crop Farming*.By James M. MacDonald, PenniKorb, and Robert A. Hoppe. USDA, Aug. 2013

Wilhoit, (2012).Modeling Insulation and Temperature of a Vegetable Cool Room.

APPENDIX 1

A. Design of the Cool Room

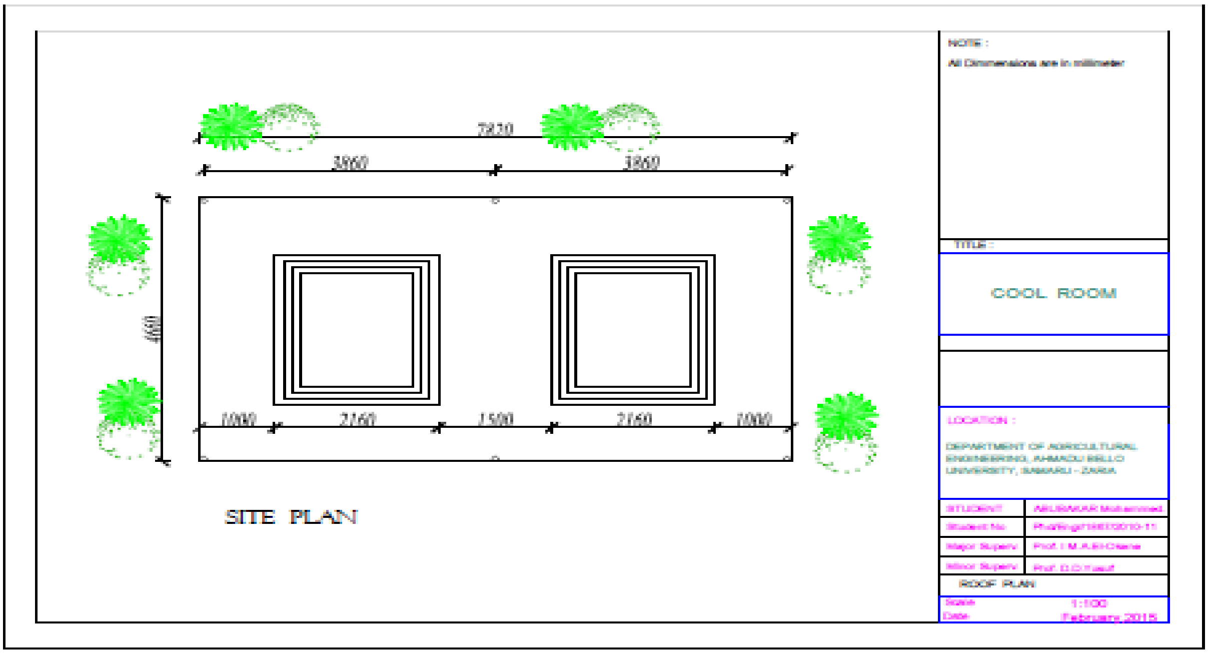

Fig.A1 Site plan of the cool room

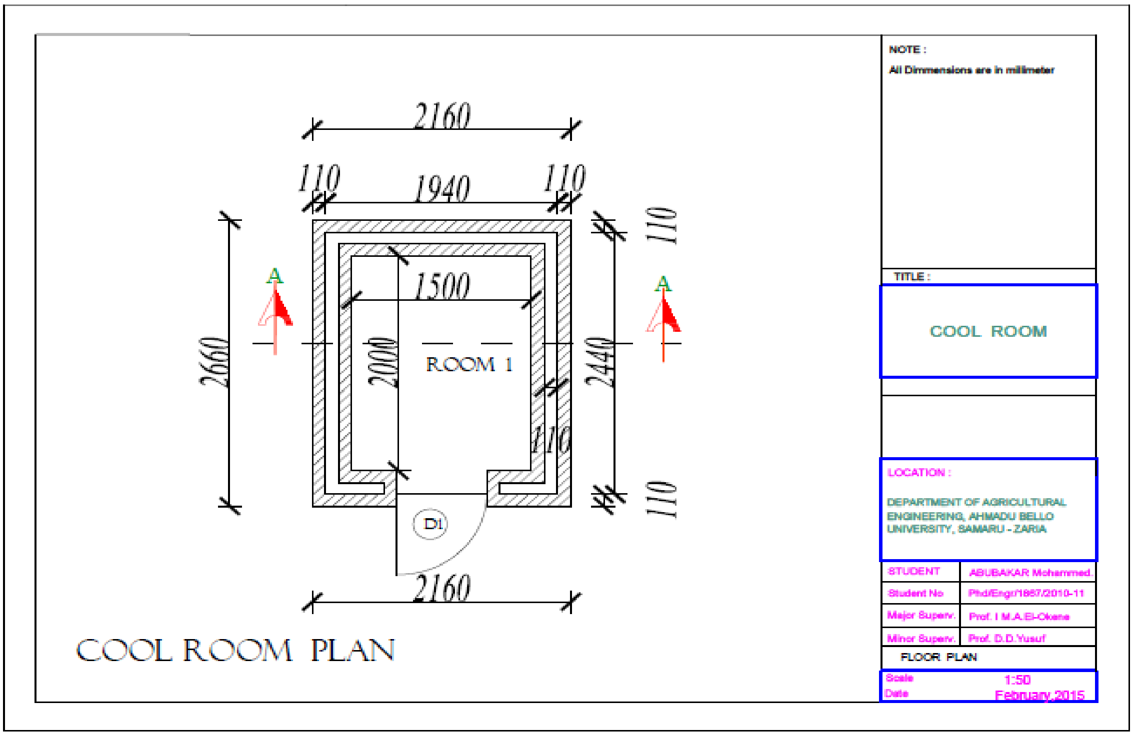

Fig. A2 Plan of the Cool Room

APPENDIX 2

Wall

Inner wall thickness 110mm
Outer wall thickness 110mm
Wall material Stabilized laterite soil (6% cement)
Wall material conductivity 0.523W/m°K
Wall cavity depth 50mm,80mm,100mm and 150mm
Wall surface area 5.0m^2

Air

Cp air 1.005kJ/kg°K
Air density 1.127 kg/m^3
Air conductivity 0.025W/m°K

Thatch

Conductivity 0.07W/m°K
Density 123kg/m^3

Room

Volume 1.5 x 2.0 x 2.4m
Cooler Air conditioner (2hp window)
Inside set temperature and RH 20°C, 60%
Environmental temperature and RH35°C, 80%
Wooden shelves
Single florescence bulb

Dried Tomato

Quantity 500kg Cp Dried tomato 3.978kJ/kg°C
Density 204kg/m^3