LAUTECH Journal of Engineering and Technology 9 (2) 2015: 44 – 49

DEVELOPMENT OF MICROCONTROLLER - BASED STORAGE CHAMBER FOR WATERMELON FRUITS (CITRULLUS LANATUS) GROWN IN NIGERIA

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ABSTRACT

Watermelon fruits rapidly deteriorate after harvest because of its short shelf life of about 10 days, after which it loses its nutritional value. Hence, the development of a microcontroller based storage chamber for watermelon fruits. The chamber is a combination of the cooling, power supply, microcontroller circuit, and sensors units for controlling the atmospheric parameters. The storage chamber was designed to keep the atmospheric conditions at temperature of 10℃-15℃, relative humidity at 90%, oxygen and carbon dioxide concentrations at 2% and 3% respectively. The chamber with an area of 1456cm^2 and a height of 41cm was designed to store 20kg of water melon. The cooling unit incorporated a compressor of 0.1hp. An ATmega328P microcontroller programmed in C++ was developed with the Isis Proteus software for the design and simulation. The microcontroller was interfaced with the DHT11 sensor, valves, power supply and a liquid crystal display. Cooling test was carried out on the system and a temperature of 1^{o}C and humidity of 90% was recorded at a time of 55 minutes. An average voltage of 4.07V was measured at the microcontroller interface with the sensor when temperature and humidity level were 12℃ and 90% respectively. Tests were carried out on the system and the result was a controlled environment characterized by temperature of range 10^{o}C -15^{0}C and 90% relative humidity. The relationship between temperature and humidity with time and output voltage respectively were determined using Matlab software. The results showed that the chamber will increase the shelf life of watermelon fruits

Keywords: Watermelon, Storage chamber, Microcontroller, Postharvest, Shelf life, Cooling

1 Introduction

Cold storage of fruits and vegetables was used extensively by our ancestors to keep food after the harvest season. Several hundred years ago, man has been practicing the gathering of fruits and vegetables during seasons of abundance for use in seasons of scarcity. These two seasons were linked by storage technology Nigeria produced approximately 200, 000 tonnes of water melon as at present and there is estimated 40% losses after harvest which occur at every stages of postharvest period. Considerable quantities of watermelon fruits are lost between harvest and consumption. Watermelons are cultivated for commercial purposes in the Northern part of Nigeria which include Kano, Jigawa, Kastina, Zamfara, Sokoto, Kaduna, Bauchi, Gombe, Taraba and few south western states. Watermelons are delicious summertime treats enriched with enough Vitamins A, B6, and C, lots of lycopene (linked with heart health, bone health, and prostate cancer prevention), antioxidants, amino acids and β-carotene content which has a needed diuretic effect in the body system. There’s even a modest amount of potassium, low sodium and fat-free. To obtain the best flavor, watermelons must be harvested at the right stage of maturity. Once harvested,

proper storage that prolongs their storage life for as long as possible should be put in place(Jauron,2003). In order to reduce the losses, postharvest technologies which delay senescence but maintains fruit quality must be employed. Existing technologies must be improved and alternative technologies must be sought. Modern storage methods for horticultural produce are based on refrigeration and environment control (Ashrae, 1993). These include mechanical refrigerated storage, controlled atmosphere and low pressure storage system (Peter et al., 2010). This research focused on understanding the biological and environmental factors involved in watermelon fruit deterioration and the use of postharvest techniques that delay senescence and maintain the best possible quality technologies for boosting the safety of watermelon fruits. Watermelons are made of living tissues which are susceptible to continuous changes after harvest. While some changes are desirable, most are not from the consumers' standpoint. Postharvest changes in watermelon fruits cannot be stopped, but they can be reduced to within certain safe limits. Senescence is the final stage in the development of plant organs, during which a series of irreversible events leads to breakdown and death of the plant cells (Akande and Ojekemi, 2013). The processes in this research keenly prevent this.Fresh horticultural crops like watermelon have their own morphological structure (roots, stems, leaves, flowers, fruits, and so on), in composition, and in general physiology. Thus, its requirements and recommendations for maximum postharvest life must be carefully determined (Kays, 1991). Ideally, the general consensus is that watermelons will be preserved for 2-3 weeks if stored at temperature between10℃-15℃. Temperatures below 10℃, can result in chilling injury to the fruit (pitting of the skin, flesh breakdown and black rot) (Mackinley, 2002). Watermelons are high in water content and are subject to desiccation (wilting, shriveling) and to mechanical injury. They are also susceptible to attack by bacteria and fungi, with pathological breakdown being the result. The aim of this research is to develop a microcontroller based storage chamber to improve the quality and still-life period of harvested watermelon fruits; *(Citrullus lanatus)* which belong to the "Cucurbitaceae" family consisting of nearly 100 genera and over 750 species. For freshly harvested watermelon, any method of increasing the relative humidity of the storage environment (or decreasing the Vapour Pressure Deficit (VPD) between the commodity and its environment) will reduce the rate of water loss and metabolic activities. This study involved the construction of an air-tight storage chamber which consists of a refrigerating system and an electronic gas monitoring system for control of oxygen and carbon dioxide concentration. A DHT11 sensor was interfaced with a ATmega328Pmicrocontrollerwhich was programmed in C++ to maintain a stable low temperature and relative humidity (Shoewu, 2013). The reference values used were 13^{o}C for temperature, 3% for Carbon dioxide concentration, 2% for Oxygen concentration and 90% for humidity level.

1.0 Methodology

The storage system was developed so as to monitor and control the various parameter levels suitable for the storage conditions of watermelon fruits. The construction was divided into three sections:

- Chamber structure
- Mechanical section
- Electronic section

2.1 Structure of the Chamber

To fully establish the chamber structure and dimension, the following were considered;

- *Storage size*: The measurement were accounted for by identifying the following:
  - o the volume of the watermelon,
  - o space between adjacent trays,
  - o store length and width,
  - o wall thickness.
- *The chamber arrangement:* The following arrangement were used:
  - o the refrigerating unit
  - o electronic component
  - o storage space

2.1.1 Design Calculations

This chamber dimension considered watermelon (sugar baby variety) as a reference due to its larger size relative to the other varieties.

Mass of fruit to be stored = 20 Kg,

$\frac{20kg}{5kg} = 4$

That gives a total of 4 watermelon fruits.

With an average diameter of 21cm, the watermelons are to be placed on two trays having 2 watermelons on each tray (i.e. 2x1 on each tray).

$Area = 52cm \times 28cm$

Area = 1456cm^2

Storage space height is 56cm

Volume = 81,536 cm^3

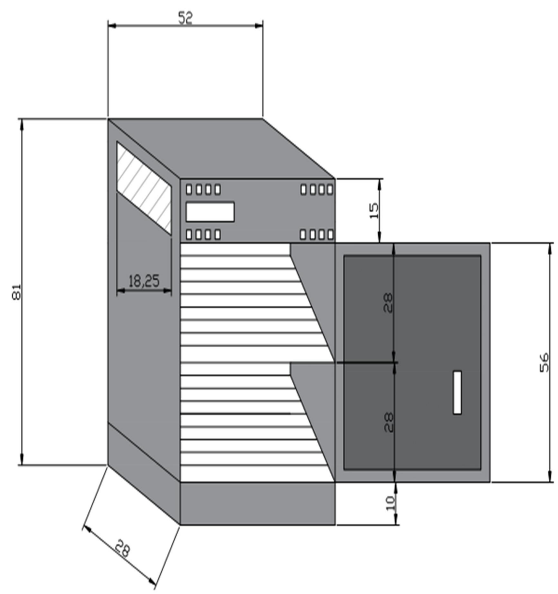

Fig 1: Dimension for the watermelon chamber structure (in centimeters)

2.2 Heat load calculation

The heat load was calculated independently in order to determine the overall capacity in terms of power rating required for the refrigeration system (chamber). The leaks and splashes of heat entering the chamber storage space coming from several sources are;

- *Heat Conduction:* Heat entering the storage chamber through the insulated walls, top and bottom floor.
- *Field Heat:* Heat given off by the watermelon fruits as it cools to the storage temperature
- *Heat of Respiration:* Heat generated by the fruit as a natural by-product of its respiration
- *Service Load (infiltration heat):* Heat from lights, equipment, people, and warm, moist air entering through cracks or through the door when opened.

- **Heat Conduction (HC)**

To determine the heat conduction,

$HC = \frac{Area \times Temperature\ Difference}{R-value}$ (1)

$HC = 49.36\ W$ $(www.angelfire.com)$

- **Field Heat (FH)**

$FH = Specific\ Heat \times Difference\ in\ Temp. \times Weight$ (2)

$FH = 29.86\ W$

- **Heat of Respiration (HR)**

$HR = Weight \times HR_t$ (3)

HR_t = the heat of respiration used in the calculation will be average of the values.

The average is: $\frac{0.034+0.1\ 1\ 0}{2}$ = 0.072btu/Ib/hr

$Weight = 44.092lb = 20.00Kg$

$HR = 0.93\ W$

- **Service Load (SL)**

$SL = 0.10 \times (HC + FH + HR)$ (4)

$SL = 8.02\ W$

- **Total Heat Load (THL)**

$THL = HC + FH + HR + SL$ (5)

$THL = 88.17\ W$

Thus, THL = 0.1182hp

Therefore, the compressor power required for the chamber is 0.1hp

2.3 Simulation Analysis

The circuit was designed using Isis Proteus 8.4 SPO professional software. This application was used to simulate the storage chamber's system operations. Only the temperature and humidity circuits could be simulated due to the unavailability of the carbon dioxide sensors and oxygen sensors on the software interface. Figure 2 shows the controller simulated circuit.

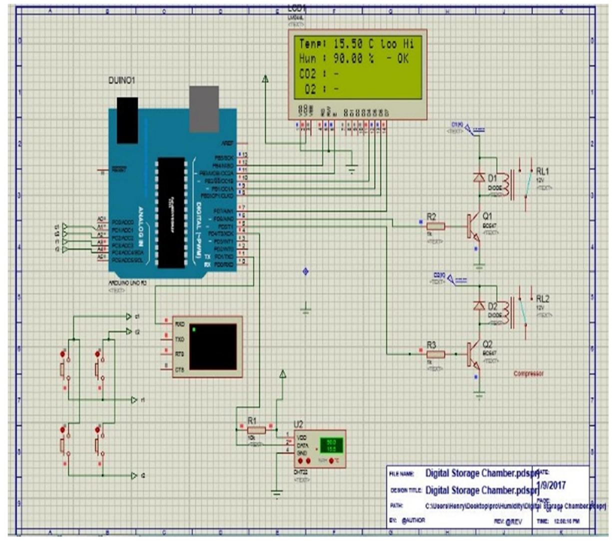

Fig 2: Temperature and humidity controller circuit

The range of temperature designed to preserve the water melon is 10℃-15℃ thus, a reading of 15.5℃ as shown in figure 2 reads "too Hi" because the temperature is not within the range of required temperature. The relay remains closed for the compressor to keep working and pumping away heat from the storage space to the environment.

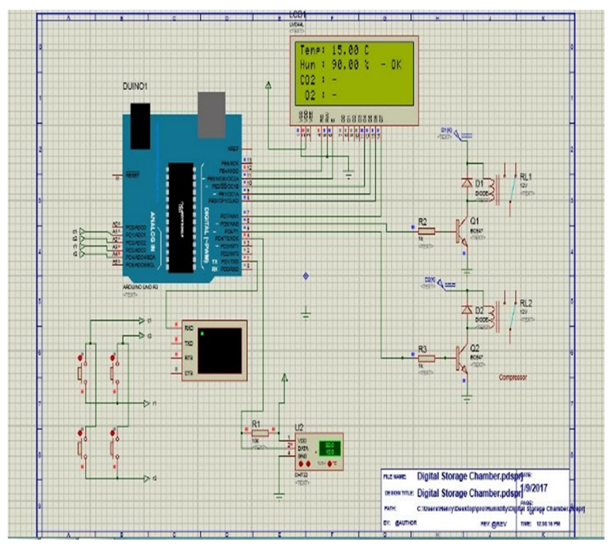

Fig. 3: Controller circuit at closed relay state

Figure 3 shows the circuit measuring a temperature of 15^{o}C and the relay is closed showing that the compressor is in operation and cooling continues.

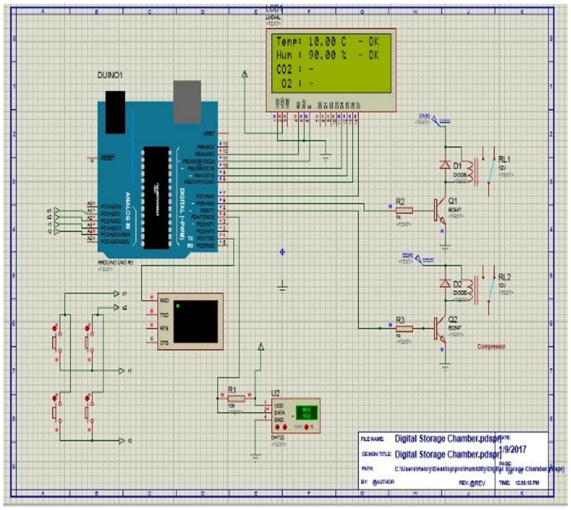

Fig. 4: Controller circuit at open relay state

In figure 4, the temperature is at 10^{o}C which is also within the range of specified temperature for watermelon fruit storage, the relay becomes open at any temperature below this point so that the compressor will be off (or the valves will be opened to let heat into the storage space). The schematic diagram of the design is shown in figure 5.

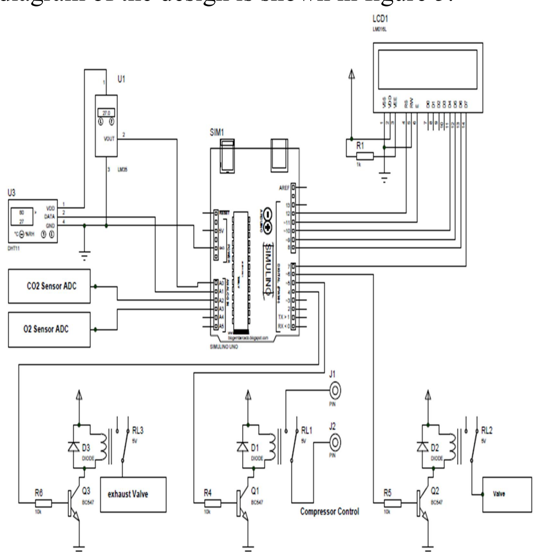

Fig. 5: Schematic Diagram of watermelon Storage Chamber.

2.0 Results and Discussion

After the design of the circuits through simulations procedure, the circuit was implemented on a Vero board and packaged with tests carried out on the controller circuits as shown in figure 6.

Fig. 6: The LCD when the DHT11 sensor was exposed to ambient temperature

Figure 6 shows values of temperature and relative humidity recorded while testing the system at ambient temperature condition. It was observed that as the temperature fell lower (especially when it got to 5^{o}C and below), the rate of changes reduced exponentially. Using the MATLAB Inc. software, graphs were plotted as shown in figures 7 to 10 to show the relationship between time and voltage parameters.

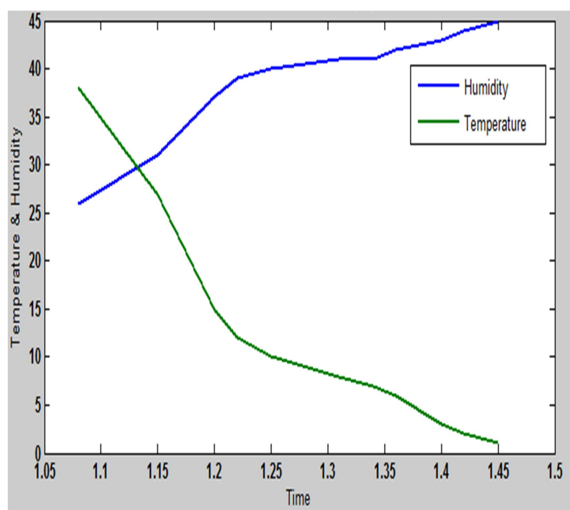

Fig. 7: time (minutes) against temperature (^{o}C) and humidity (%) levels of chamber

In figure 7, the point of intersection between the temperature and humidity line shows that they both have the same value of 31 ^{o}C and 31% respectively after 9 minutes of operation which indicates a condition when the storage space is at ambient condition.

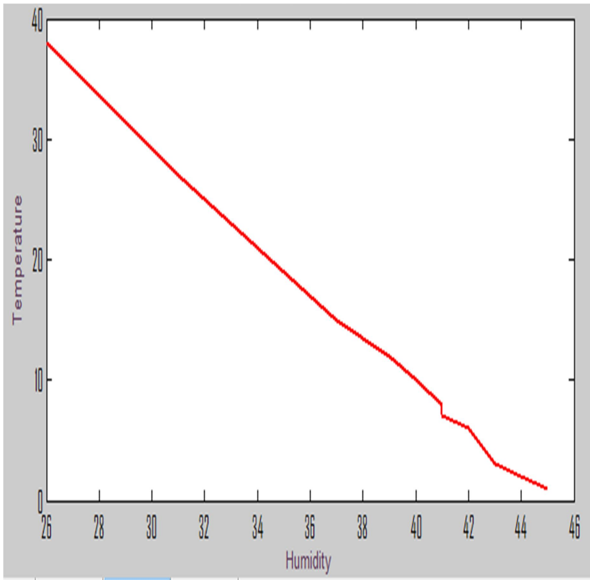

Fig. 8: humidity (%) level of chamber against temperature (^{o}C)

The relationship between the humidity and temperature is inversely proportional as shown in figure 8 with a negative gradient value. This means that the temperature of the chamber storage space falls as the humidity rises and vice versa.

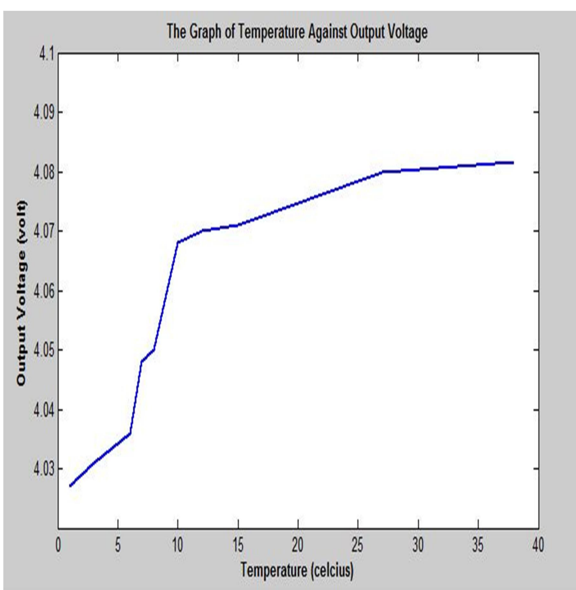

Fig. 9: temperature (^{o}C) level of chamber against microcontroller output voltage (V)

In figure 9, it was observed that the temperature increased as the microcontroller output voltage increases

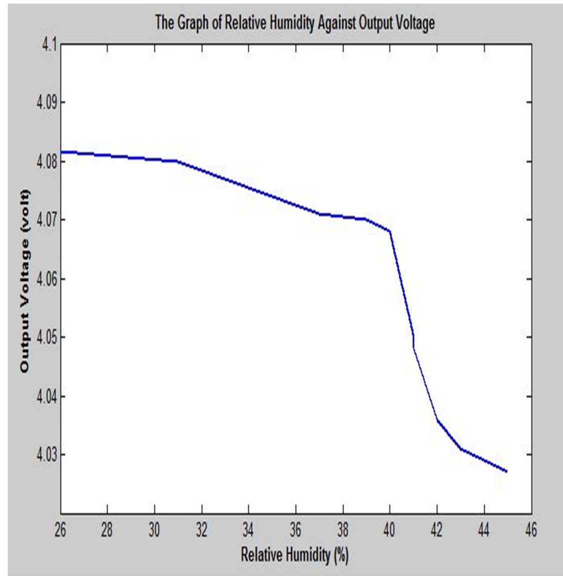

Fig. 10: relative humidity (%) level of chamber against microcontroller output voltage (V)

Figure 10 shows that the microcontroller output voltage decreases with increasing relative humidity. From the study, we were able to identify and optimize major parameters affecting the still-life and quality of watermelon fruits which are temperature of 10-15^{o}C, humidity of 90-95%, oxygen level at 2% and carbon dioxide level at 3%.

3.0 Conclusion

The design and construction of a microcontroller-based automatic storage chamber for watermelon fruits was successfully achieved. An ATmega328P microcontroller based system was used to control the process. The design incorporated the use of a refrigerating system to control the rate of transpiration and respiration. The control of temperature and humidity was achieved through the use of DHT11 (temperature and humidity) sensor, which feeds the microcontroller with chamber atmospheric data. A temperature range of 10-15°C was achieved. Simulation analysis was carried out on the humidity and temperature controlling circuit and it was observed that the device maintained temperature range and humidity level at 10-15°C and 90% respectively. The storage chamber is capable of increasing the shelf life of watermelon fruits.

5.0 References

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