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Design and Construction of Broccoli (Brassica Oleracea, L.) Storage Box Using Thermoelectric Technology

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Abstract

Fresh vegetables determine the selling price of the product, so traders must be careful in storing vegetables to keep them staying fresh. Therefore, we need a vegetable storage device that can maintain the specified temperature, can lower the temperature, and is effective. The solution used is to design a vegetable storage device using thermoelectric technology that can maintain temperature. This research was conducted in May-June 2021 and was carried out at the Laboratory of Agroindustrial Technology and Management, Faculty of Agricultural Technology, University of Jember. The tools used for research are Laptop and Arduino IDE. Materials used in this research are Breadboard, Arduino Uno, Peltier TEC1-12706, DS18B20 Sensor, Jumper Cable, Heatsink, Fan, 1 channel Relay, Power supply, LCD, and Styrofoam Box. The tool that had been tested for performance was then tested by operating the cooler box. Testing the tool aimed to determine the ability of the cooler to reach the desired temperature. Based on the functionality validation test, it was found that X=1 which means the cooler in the broccoli vegetable storage box is declared to be functioning properly. The DS1820B sensor used in this study got a % error value of 1.19% which means the temperature sensor can work well. The cooler box has the fastest ability to reach a temperature of 15oC in 10 minutes 09 seconds with a power of 12 W. The cost required for a cooler for 1 (one) day is cheaper than a showcase, which only costs Rp. 2,336.

Introduction

Broccoli (Brassica oleraceae, L.) is a vegetable that belong in cabbage family (Brassicaceae). Broccoli is one of the sensitive vegetables which is easy to lose its freshness. High temperature can cause broccoli to decompose faster. The particular reason for this circumstance is because the flower bud opens and evolves quickly. Good quality broccoli is determined by the density, color, completeness, and the diameter of it flower (Safaryani et al., 2007). Storing at low temperature can reduce the respiration rate, this means refrigeration could maintain the quality of fresh fruits and vegetables. By storing broccoli in low temperature, the broccoli will remain fresh for a long time and will not decompose easily (Olosunde et l., 2009). The quality of freshness of vegetables determines the product's selling price, therefore merchants should be more careful at storing vegetables to maintain the freshness.

An experimental study shows that the Coefficient of Performance (COP) of thermoelectrics ranges from 0.3-0.5. From this research, it can be done potential performance improvement by improving the thermal contact on the thermoelectric module and heat exchanger (Min & Rowe, 2006). Thermoelectric is a technology that works by transforming electrical energy to heat pump process. Thermoelectric is a refrigerator or a heat pump without using the moving part (Lamba & Kaushik, 2017). The cooling system operates on the direct current (DC) and could be used for heating and cooling by reversing the current direction. This cooling or heating is

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done by transferring the heat from one side of cooling module to another side when the current electricity flows and obeying the law of thermodynamics. Thermo Electric Cooler (TEC) / Peltier is an electricity component that use peltier effect to produce heat (heat flux) on the connection between two different materials. Peltier is useful as an active heat pump in solid state which transferring heat from one side to another opposite surface side. The current electricity that is consumed depends on the direction of current electricity.

Thermoelectric is made from two different semiconductors. One is from type N and others is type P. These two semiconductors are different because in order to work, they have to acquire different electron densities (Aziz et al., 2017). Two semiconductors are placed in a parallel position thermally and both of its ends are connected to the cooling plate, usually these cooling plates are made from copper or aluminum. When both of the ends are connected to the electric source, the electric current will flow through the 2 semiconductors earlier. This will cause temperature difference. This temperature difference will cause Peltier Cooler to exude heat, which will be absorbed around the cooling plate and gets transferred to the other plate (heat sink). The TEC module as a cooling medium has advantages such as easy to carry, compact in shape, non-vibrating, environmentally friendly, and low energy consumption (Riffat & Ma, 2003).

Therefore, we need a device to storage vegetables in order to maintain certain temperature, lowering the temperature, and effective. The solution is to design a vegetable storage device using the technology of thermoelectric which can maintain the require temperature for vegetables. This aims to maintain the quality of vegetable in order to fully satisfy the consumers' wishes

Methods

This research was conducted in May-June 2021 and was carried out at the Laboratory of Agroindustrial Technology and Management, Faculty of Agricultural Technology, University of Jember. The tools used for research are Laptop and Arduino IDE. Meanwhile for some of the materials used in this research are Breadboard, Arduino Uno, Peltier TEC1-12706, DS18B20 Sensor, Jumper Cable, Heatsink, Fan, 1 channel Relay, Power supply, LCD, and Styrofoam Box.

Operational Design and Functional Design

In the operational design, the working principle of the cooler is a Peltier connected to the power supply. The DS18B20 temperature sensor is connected to the Arduino Uno and programmed with the Arduino IDE, then the sensor will detect the temperature parameters. The recorded sensor setup output data will then be read by Arduino Uno. The data that has been read by the Arduino Uno will be processed by reading and sending commands via a relay to the Peltier to turn on if the temperature on the DS18B20 sensor is above the desired temperature. The desired temperature for storing vegetables is 25oC, 20oC, and 15oC. While the functional design of this research is in the form of a cooler which will be designed with the main components in its manufacture, including Arduino Uno, Peltier, DS18B20 Sensor, and Power Supply.

Device Making

In this process, all components such as the DS18B20 sensor are assembled with Arduino Uno and other supporting components. The DS18B20 sensor has 3 pins consisting of VCC, DATA, and GND. Connect the first pin (VVC) to 5V on the Arduino Uno, the second pin (DATA) to pin 4 on the Arduino Uno, and the third pin (GND) to GND on the Arduino Uno. Peltier has two pins, namely pin1 which is connected to VCC 12V on the Power Supply and pin2 which

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is connected to GND on the Power Supply. The fan has two pins, namely pin1 which is connected to the 12V VCC on the Power Supply and pin 2 which is connected to the GND Power Supply. 1 Channel relay has 3 pins consisting of VCC, IN, and GND. Connect the first pin (VCC) to 5V on the Arduino Uno, the second pin (IN) to pin 5 on the Arduino Uno, and the third pin (GND) to GND on the Arduino Uno. The 12 V VCC pin on the 1 Channel Relay is connected to the 12 V VCC on the Power Supply and the GND pin is connected to the GND on the Power Supply. The LCD that has been coupled with I2C is connected to VCC and GND on the Arduino Uno and connected to SDA and SCL on the Arduino Uno. The Power Supply as a tool resource is connected directly to a 220 V power source. After all the materials have been assembled, the Arduino Uno microcontroller is programmed with the Arduino IDE software.

Field Testing and Data Processing

Cooling box testing is carried out after carrying out various stages from assembly to the tool performance test process. The tool has been tested for performance and is working well, then the tool is tested by operating the Cooling Box, namely connecting the power supply to a power source. Testing the tool aims to determine the ability of the cooler to reach the desired temperature

Results and Discussion

Results of Design and Assembly of Thermoelectric Storage Devices

When designing and assembling tools, the first thing to do is to prepare tools in the form of Arduino Uno, DS18B20 sensor, Peltier, and other supporting tools such as jumper cables, USB cables, power supply, breadboard, LCD, and fans. After all the materials have been assembled, the Arduino Uno microcontroller is connected to a laptop to be programmed with the Arduino IDE software. Programming is done to give commands to the relay so that the Peltier can turn on and off automatically. The last step is to activate the tool using a 12 volt, 10 ampere power supply, and ensure the DS18B20 sensor installed in the microcontroller can read the data sent and the Peltier can operate properly.

Results of Thermoelectric Storage Device Design and Program

The program used to execute the desired command was (#) “preprocessor” which was used to enter text from the library file or could be used to define a macro variable “#include "DallasTemperature.h"” for the DS18B20 sensor, then connected the data to the sensor DS18B20 as follows:

```
#define ONE_WIRE_BUS 4
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensorSuhu(danoneWire);
int piltier = 5;
float suhuSekarang;
```

The "int" or integer function as data storage was executed by entering the connected pin in the microcontroller, "float" is used as a floting point math or used to hold fractional numbers.

setup() is a one-time program. The setup() function was useful for initializing pin mode or initiating serial communication. In this study using "serial.begin" served to determine the speed of sending and receiving data through the serial port "Serial.begin(9600)".

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After setting up the program in setup(), then a loop() function was created. This function would repeat the existing program continuously, so that the program would change and respond according to the input. To turn the cooler back on or want to control the refrigerator automatically on or off, do the following:

```
if (suhuSekarang >= 16){
 digitalWrite(piltier, LOW);
 }
 else if (suhuSekarang <= 15){
 digitalWrite(piltier, HIGH);
 }
```

The "if" function would run the code in curly braces, i.e. if the temperature reached 16oC the peltier would turn on, while the "else if" statement had the meaning "if the temperature condition has reached 15oC then the peltier will die and if it doesn't meet the requirements then the peltier will live " In this program, the circuit that occured in the relay was a closed circuit so that the program was written in reverse with its purpose.

Device Performance Test Results

The performance test of vegetable storage equipment was carried out based on the functionality of the tool that has been designed to obtain and record temperature data, and turn on the peltier. The performance test of this tool was carried out before storing broccoli vegetables. Validation of functionality was carried out in research as a vegetable storage device designer. The results of the validation functionality test are shown in Table 1. below.

Table 1. Functionality Test Results

Statement	Yes	No
The Arduino Uno function in the form of sensor readings can be displayed on the Arduino IDE serial monitor	1	0
DS18B20 temperature sensor function can read temperature data well	1	0
Peltier function can produce cold	1	0
The fan function is in the form of gusts of wind to spread cold and dissipate heat on the Thermoelectric Cooler	1	0
The I2c LCD function in the form of sensor readings can be displayed on the LCD screen	1	0

Source: Processed Data (2021)

Calculation of validation functionality using the formula Iso (2001) as follows:

$$X = 1 - \frac{A}{B} = 1 - \frac{0}{6} = 1 - 0 = 1$$

Based on the test results above, it can be concluded that X = 1, the results of the design of the tool have met the functionality aspect according to ISO/ICE 9126. Therefore, the designed tool can be said feasible to be implemented as a storage tool for broccoli.

Test Results Comparison of DS18B20 Sensors with Standard Measuring Instruments

The performance test on the DS18B20 sensor was carried out by comparing the sensor measurement results with the Room Thermometer measuring instrument to determine the error rate of temperature readings on the DS18B20 sensor. The sample required for comparative testing included a minimum of 30 data (Hamdi & Baharudin, 2014). The test was carried out

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in a room and the sensor reads 30 data with an interval of 5 (five) minutes. Based on the comparison between the DS18B20 sensor and the temperature parameters of the room thermometer sensor, the results showed that the minimum temperature error value that occured was 0°C while the maximum reading error that occured was 1.13°C. The DS1820B sensor used in the monitoring tool in this study worked well, as evidenced by testing the sensor with standard measuring instruments, the average error value was 0.34°C while the %error value was 1.19%.

Cooling Box Test Results

Tools that had been tested for performance and could work well were then tested for tools. The test of the tool was to determine the circulation conditions of the cold spread in the cooler and to determine the ability of the cooler to reach a temperature of 15oC. The circulation conditions for the distribution of cold in the cooler can be seen in Figure 1. Below

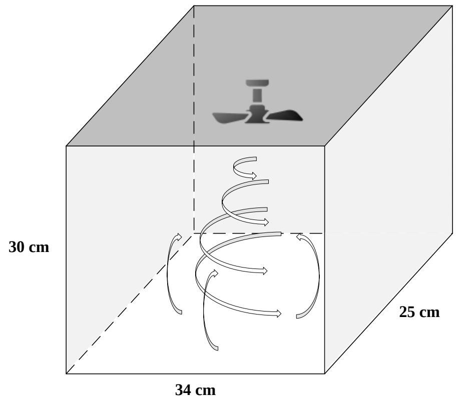

Figure 1. Condition of Air Circulation in Cooling Box

Based on the picture above, the cold temperature in the box was fueled by a fan that was mounted on the inside on the top wall of the box. The movement of the wind on the fan was rotating downwards and bouncing back up. If the cooler was turned on empty, the cold temperature would spread more freely to all parts of the box. Meanwhile, if there was something in the box, then the spread of cold would be slightly hampered. Therefore, the cooler box was tested to determine the ability of the cooler which had a power of 72 W to reach a temperature of 15oC. This was done with the condition of the box without load, 25%, 50%, 75%, and 100% of the box volume. The cooler box would be turned on at the same time as starting to activate the stopwatch. The results of the ability of the cooler box with different loads could be seen in Table 2. as follows:

Table 2. Cooling Box Capability Results

Number	Load (%)	Time	Power (W)
1.	0	10 minutes 09 Seconds	12
2.	25	49 minutes 55 Seconds	60
3.	50	01 hour 02 minutes 33 Seconds	74,4
4.	75	01 hour 13 minutes 05 Seconds	87,6
5.	100	02 hour 06 minutes 07 Seconds	151,2

Source: Processed Data (2021)

Based on the data above, it can be seen that the cooler has the ability to reach a temperature of 15oC the fastest is the one without a load, which is within 10 minutes 09 seconds and requires 12 W of power. Meanwhile, with a load of 100%, the maximum capacity of the cooler takes

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02 hours 06 minutes 07 seconds and power of 151.2 W. The research of Riyanto & Yoewono (2010), they developed a cooling device in the form of a beverage cooler with a power consumption of 23 W to reach a cooling temperature of 15oC in less than 30. The study of Mainil et al. (2015), showed that the temperature of the cooler reaches 15oC within 16 minutes at no-load conditions. This is because the number of loads affects the length of the cold temperature spread in the box, so the more loads in the cooler the longer it takes to reach 15oC and it requires more power.

Apparatus Power Output Comparison

The power calculation is carried out to determine the amount of power used to use the cooler and determine the cost per day. Electrical power is the amount of electric power required per unit time in Watt. The power consumption of the cooler box will be compared with the use of the showcase, which can be seen in Table 3. as follows.

Table 3. Comparison of Cooler Box with Showcase

Cooler Type	Size (cm)	Purchase Price	Power (W)	Power For 1 (One) Day (kWh)	Expenses
Cooler Box	34 x 25 x 30	IDR 400.000	72	1,728	IDR 2.336
Showcase	44,5 x 51 x 50	IDR 1.750.000	93	2,232	IDR 3.017

Source: Processed Data (2021)

Based on the data above, it shows that the cooler box costs less than using a showcase. The cost required to use the cooler for 1 (one) day is IDR 2,336, while the showcase costs IDR 3,017. This is because the cooler requires less 72W power than the showcase. The cooler uses a TEC1-12706 peltier with a working current of only 6 amperes and 12 volts (Aziz et al., 2017). Designed cooler box saves more power and cost when compared to showcase

Conclusion

The design of the broccoli storage box using thermoelectric technology can work automatically according to the desired temperature, namely at temperatures of 25oC, 20oC, and 15oC. The way this cooler works is when it reaches the desired temperature, the cooler will automatically turn off, while if it exceeds the desired temperature, the cooler will automatically turn on again. Based on the functionality validation test, it was found that X=1 which means that the cooler in the broccoli storage box is declared to be functioning properly. The DS1820B sensor used in this study could work well, this is evidenced by the average error value obtained was 0.34°C while the %error value was 1.19%. The cooler box has the fastest ability to reach a temperature of 15oC with no load in 10 minutes 09 seconds and requires 12 W of power. The cost required for 1 (one) day to use the broccoli storage cooler is cheaper than the showcase, which only requires a fee of Rp. 2,336.

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