Development of Thermoelectric Peltier Plate Cooling for the Cooling Process Poultry Fillet

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Abstract. The aim of this research is to design and test the Thermoelectric Peltier Plate Cooling (TPPC) cooling equipment, that has been developed with its auxiliary apparatus. Peltier is an electronic device capable of generating cold and hot temperatures on its sides when an electric current is applied. The method used in the study starts from the design stage, equipment construction, functional testing, and performance testing. The construction of the cooling equipment consists of a Peltier component equipped with a load cell and a linear actuator to bond the plate sides with the material. The results of the study showed that the TPPC was able to function well and produce relevant temperatures for the cooling process. The lowest final temperatures were achieved at a pressure of 10 N/m^2, 5 N/m^2, and no pressing in the centre of the material reaching -3.8, 7.59, and 8.68 °C, in between the centre and the surface was 0.62, 3.05, and 5.29 °C, and in the surface was -2.99, -1.94, and -1.11 °C, respectively. This shows that the developed technology, Thermoelectric Peltier Plate Cooling, is capable of being applied for the cooling process.

Keywords: Applied, Design, Functional Test, Peltier, Plate Cooling.

1 Introduction

In 2020, there was a surplus of broiler chicken meat of 270,894 tons, or an average surplus of 54,179 tons/month. An effective innovation is needed in an effort to preserve animal products. Good processing technology is expected to be able to maintain quality and increase product shelf life. Fellows, (2000) argue that if the temperature is monitored at the product's center temperature in the cooling process, there is a rapid decrease in temperature to the freezing point when ice crystals begin to form.

An effective method of preserving meat products is storage at low temperatures and has been widely used in industry [2]. In the cooling process, people use ice from water [3], dry ice [4], [5], [6], [7], mechanics using refrigerants [8], and high-pressure treatment [9]. The advantages of the cooling method are inhibiting the growth of pathogenic microorganisms, holding back the rate of enzymatic and physiological damage so that the

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product can be stored for a relatively long period of time. Therefore, cooling and freezing have excellent potential for further development and innovation [10]. However, various technologies developed in previous research in an effort to lower temperatures require large amounts of energy, time and resources.

Low-cost technology will be beneficial for small industries and micro entrepreneurs in the processing of meat and fish products. The application of Peltier as a cooling element for refrigerators has been developed by Afshari, (2021) and tested its efficiency level from air to water and from air to air through a heat-exchanger unit. Thermoelectric Peltier Plate cooling is a tool developed by utilizing a Peltier module that could transfer heat on two sides (hot side and cold side). The ability of Peltier in the cooling process is highly dependent on the ability to reduce the hot temperature that occurs on the hot side [12].

Guras & Mahdal, (2021) use of Peltier modules for liquid cooling, Ivanov et al., (2021) was to design, realize and study a prototype of a small scale mobile thermoelectric cooling system for negative temperatures based on Peltier modules. The advantages of Peltier can be utilized in the cooling process of products, one of which is chicken fillets. Therefore, it is necessary to develop cooling equipment that is able to utilize the advantages of Peltier in producing heat transfer (cold temperature) in chicken fillet samples.

2 Method

2.1 Material

The main material that was used in this study is peltier module cooler and chicken fillet as sample test. Chicken fillet sample is chicken breast meat with compact meat character, bright color, and fresh. The sample material is put into a box (packaging box) that has been placed with ice as a cooling medium. The chicken meat sample is cut into blocks with dimensions of 3 x 3 x 2 cm and the sample weight is measured. The Peltier module that will be used in the research can be seen in Figure 1.

Fig. 1. Peltier Module Coller

2.2 Research Procedure

The method used in the study starts from the design stage, equipment construction, functional testing, and performance testing.

Design Stage

In this study, researchers developed a cooling device by combining several peltiers arranged in parallel and dissipating heat energy by adding a water block and a cooling fan. The cold side of the peltier is used as a cooling medium for the heat-conducting plate that is in direct contact with the cooled material. The principle of developing Thermoelectric Peltier Plate Cooling equipment can be seen in Figure 2.

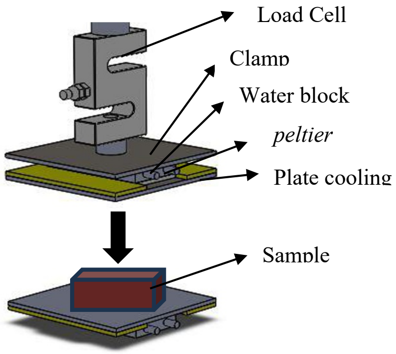


Fig. 2. The principle of developing Thermoelectric Peltier Plate Cooling

Equipment construction

All components are assembled and form a Thermoelectric Peltier Plate Cooling (TPPC) cooling unit. TPPC construction consists of: 1) Linear actuator, a device installed to provide a pressure effect on the conductor plate. The linear actuator is installed on one side of the conductor plate that has been attached to the peltier and heatsink. In addition, the linear actuator functions to advance or retract the plate so that the material will adhere tightly to the cold conductor plate; 2) Load cell, the installation of the load cell functions to determine the value of the mechanical pressure force given so that it can reduce the risk of damage to the material. The setting of the amount of pressure is regulated through a program that has been developed; 3) Cooling chamber, made of 0.8 mm stainless steel conductor plate which functions as a cooling medium. The conductor plate is made in the form of a rectangular box with dimensions of 17 x 16 x 14.5 mm; 4) Cooling plate, made of stainless steel with a thickness of 0.3 cm and dimensions of length x width of 15 x 13.5 cm. The cold source on the cooling plate comes from the Peltier which is attached tightly using bolts and nuts. There are two cooling plates on the top and bottom of the cooling chamber which are equipped with two peltier units on each cooling plate; 5) Peltier unit with water block, Peltier is a cooling source measuring 40 x 40 mm with the ability to produce cold and hot temperatures on the opposite side. The ability to produce low temperatures is highly dependent on the ability to dissipate heat on the opposite side. Each side of the conductor plate is attached with two Peltier's arranged in parallel. To dissipate heat on the hot side, one water block unit measuring 80 x 40 mm is placed which is connected to the cooling radiator ; 6) Hose and pump, function as circulation channels from the water reservoir to the water block to cool the hot side of the Peltier; 7) External radiator and fan, function to cool the water flowing through the hose to the water block and keep the water temperature stable. Each Peltier cooling unit is connected to a radiator; 8) Support pole. The support pole is made of iron connected to the cooling room. The installation of the support pole serves to strengthen the structure of the cooling equipment and place the linear actuator which has a compressive force effect

Functional testing

The design of TPPC equipment was developed through a series of trials to obtain the lowest temperature value on the cooling plate that can be produced by the Peltier cooling component. In the initial design stage, researchers used several system design illustrations, namely the use of heat sinks and fans as heat dissipation media on the hot side of the Peltier. However, after testing, the temperature produced on the cooling plate was around 6-12 ^{o}C. while according to [15] the storage process of poultry meat or animal products should not be more than 4 ^{o}C.

Performance testing

TPPC cooling equipment testing is carried out by testing the pressure and temperature values produced on the cooling plate and the cooled product. The success rate of the TPPC cooling system design is determined by assessing the minimum temperature produced on the cooling plate. Performance test of various test parameters was carried out using 3 compressive force treatments, namely without pressure (P0), 5 N/m^2 compressive force (P5), and 10 N/m^2 compressive force (P10). The performance test of TPPC cooling equipment was carried out on various parameters, namely: 1) Changes in temperature on the cooling plate; 2) Changes in temperature on the material.

2.3 Data Analyze

The data of temperature change on various compressive force treatments were measured and analyzed using descriptive analysis using graphs with the Excel program.

3 Results and Discussion

3.1. Principle of development of Thermoelectric Peltier Plate Cooling (TPPC)

The principle of developing a Thermoelectric Peltier cooler is that the material is clamped using two cooling plates on both sides of the material. The ability of the Peltier to produce cold temperatures is highly dependent on the release of heat on the opposite side. The cooling plate is attached to the cold side of the Peltier which has been supplied with electric current. On the hot side, a water block is attached to which cold water is supplied with a cooling radiator. The principle of developing a Thermoelectric Peltier is that the transfer of cold temperature from the Peltier to the cooling conductor plate then flows to the material occurs by conduction. The linear actuator will provide a pressing force (pushing force) on the cooling component so that the interface between the cooling plate and the material becomes denser. The high density between the material and the cooling conductor plate allows for a faster heat transfer rate. Conduction heat transfer allows the rate of heat transfer to be faster than convection heat transfer with fluids. This is in accordance with Freire et al., (2021) stated that the Peltier generator system consists of a heat source to obtain a temperature gradient between the two sides of the cell. A closed system is used to maintain the temperature on the hot side, while on the cold side there is a heat absorber to remove heat to the environment.

3.2. Construction of TPPC

The construction of the Thermoelectric Peltier cooling equipment that has been developed is known as Thermoelectric Peltier Plate Cooling. The construction design of the TPPC and its apparatus devices can be seen in Figure 3.

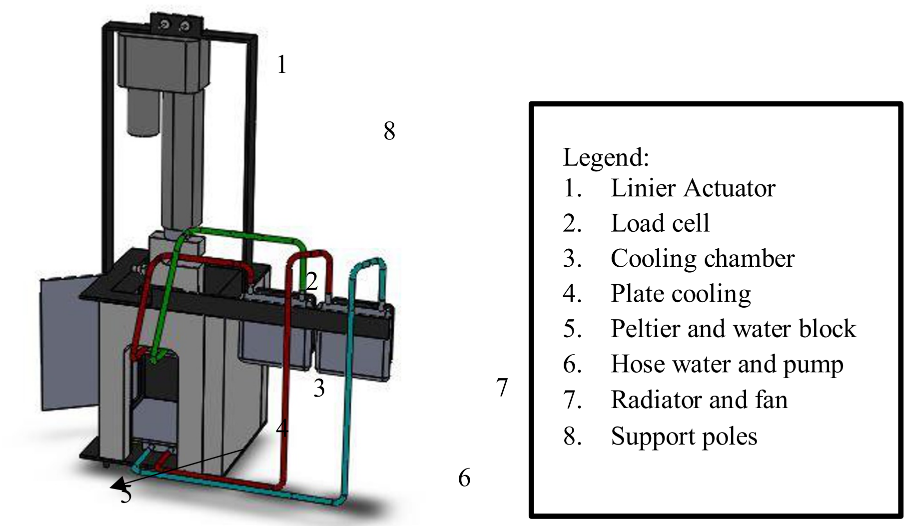


Fig. 3. The construction design of the TPPC and its apparatus

The next stage is assembling the TPPC device according to the design. The assembly aims to unite the components into a complete part of the device. The assembly begins by connecting the Peltier components with the cooling plate, water block, support plate and load cell. This part is the core part that is installed in the cooling chamber. The next stage is the installation of a linear actuator that was connected to electrical power to provide a vertical downward pressure effect through the movement of the plate so that the top of the plate comes into contact with the cooled sample. In addition, to remove the heat generated through the hot side of the peltier, the water block is connected to a radiator that is supplied with cooling water through a hose. Peltier elements require a good cooling system because peltier elements produce two temperatures, namely hot and cold. For the cooling system on the peltier element consists of parts, namely, radiator, water block, cooling water, and pump. By using a water cooling system, it can cool the Peltier element ideally [17]. This allows the heat to be removed more optimally. The constructed Peltier cooling equipment is shown in Figure 4

a) b)

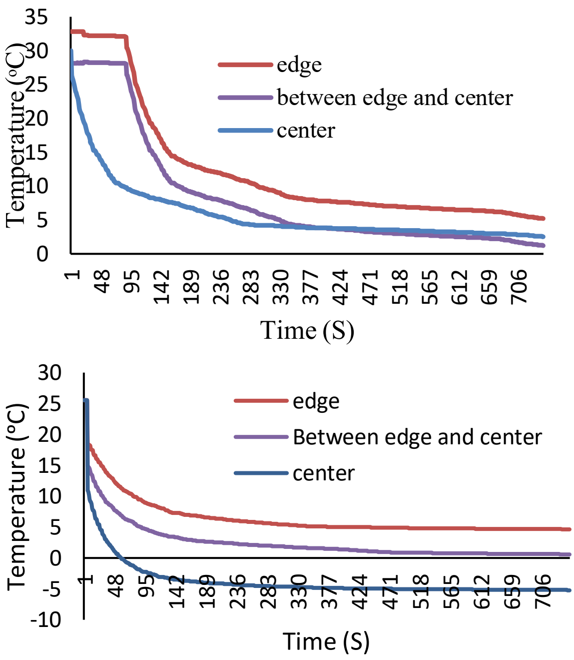
Fig. 4. Thermoelectric Peltier Plate Cooling: a) Front view; b) Side View

3.3. Functional Test Of TPPC

The cooling process series using TPPC cooling equipment is as follows:

a) Animal material in the form of blocks is placed on the lower cooling unit in the cooling room.
b) Make sure all units are properly installed and functioning normally.
c) Connect the electric current through the switch installed on the top of the equipment by pressing the switch button.
d) The linear actuator will move vertically downwards so that there is a meeting plane between the material and the cooling unit.
e) The pressure value and temperature changes in the material and cooling unit will be read via the ADC.

The use of water block components and radiators equipped with fans produces very low plate temperatures. The results of temperature testing show that a series of cooling components using one Peltier element using a water block is able to produce a temperature of 2 ^{o}C. Furthermore, to produce a lower temperature, a trial was conducted to add a Peltier circuit into two units installed in parallel. The test results showed that the temperature of the cooling plate was able to produce a temperature of -5 to -6 ^{o}C at the center of the plate. The temperatureof TPPC on plate cooling can be seen in Figure 5.

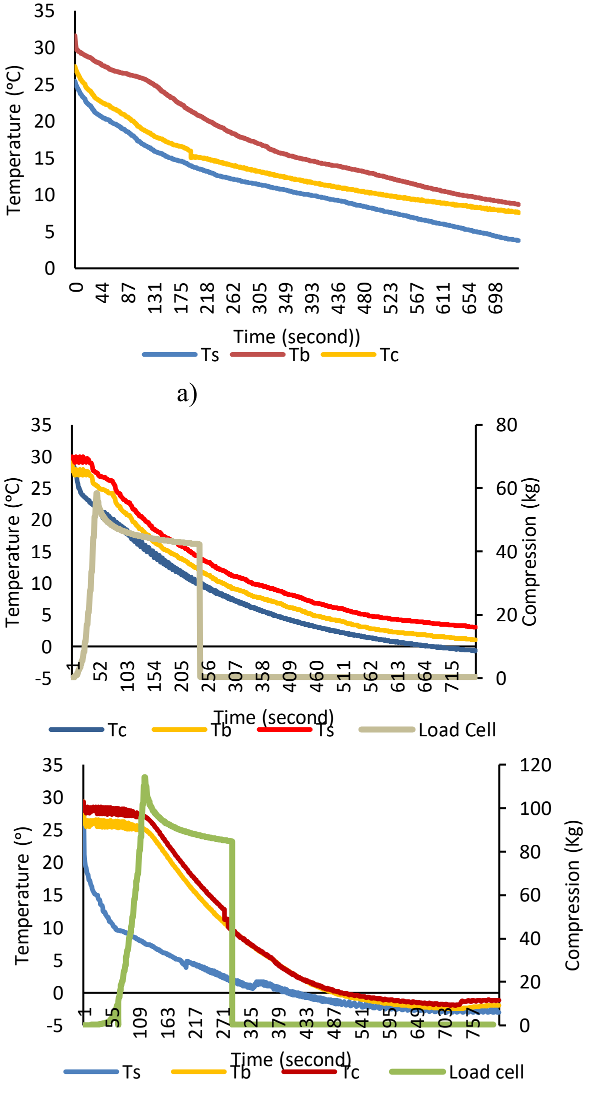


a) b)

Fig. 5. Temperature of TPPC cooling plate with: a) one peltier element; b) two peltier element

3.4. Performance Test Of TPPC

The temperature changes that occur on the cooling plate and materials are key parameters that determine the success rate of cooling equipment design. The faster the rate of temperature change that occurs, the higher the success rate of TPPC equipment design. Gandi and Yusfi, (2016) explained that in designing a cooling system using Peltier in testing using the LM35 sensor, it was shown that the greater the mass of water used to test the cooling capacity, the greater the temperature produced. The Peltier element is able to lower the temperature of 50 g of water to 5.7 °C, while for 500 g of water, the Peltier element is only able to lower the water temperature to 14.2 °C.



b) c)

Fig. 6. Tempertaure decrease in TPPC: a) without compression; b) Compression of 5 N/m^2 (P50); c) Compression of 10 N/m^2 (P100)

Figure 6. shows that the application of a pressing force with a pressing force of 10 N/m^2 can increase the rate of temperature decrease. The lowest final temperature is achieved at a pressing force of 10 N/m^2, 5 N/m^2 and without pressing with temperature values at the center, between the center and the surface, and the surface of the material reaching -2.99, -1.94, and -1.11 °C, -0.62, 3.05, and 5.29 °C, 3.8, 7.59, and 8.68 °C, respectively. This shows that the technology developed in the form of a Thermoelectric Peltier Plate

Cooling can be applied for cooling or precooling processes. Low-temperature processing of meat raw materials is carried out until reaching 71-75 °C in the center of the product. The use of mechanical technology by increasing the surface area or density between the material and the cooling medium is expected to accelerate the cooling rate. The results of the study showed that the provision of pressure by adding force from the linear actuator can increase the cooling rate. The downward vertical force from the linear actuator will increase the pressure on the material. The higher the value of the pressure force given, the greater the cooling rate that occurs in the material. This is in accordance with previous studies that pressure can increase the cooling rate of materials using ice and dry ice media [19].

4 Conclusion

In this study, the cooling equipment that has been developed is known as Thermoelectric Peltier Plate Cooling. Thermoelectric Peltier Plate Cooling was able to function well and produce relevant temperatures for the cooling process. The lowest final temperatures were achieved at a pressure of 10 N/m2, 5 N/m2, and no pressing in the centre of the material reaching -3.8, 7.59, and 8.68 °C, in between the centre and the surface was 0.62, 3.05, and 5.29 °C, and in the surface was -2.99, -1.94, and -1.11 °C, respectively. This shows that the technology developed in the form of a Thermoelectric Peltier Plate Cooling can be applied for cooling or precooling processes.

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