Study of PID control implementation in the process of cheap breaking using Peltier cooling elements

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Abstract. Methods of the processing dairy products other than pasteurization and reducing water content (condensed milk), milk can also be processed into cheese. Namely with the cheese maturation method. Maturation is the final process of the cheese making process. Maturation (ripening) is a process that converts fresh curds (raw cheese) into cheese full of flavour. The research of the method of cheese ripening process is used Proportional Derivative Integral (PID) controller to control the parameters of temperature and humidity in the cooling room. Embedded through ATMEGA 16 devices as controllers, the sensing process is used by temperature sensors, humidity sensors and Peltier devices as coolants for the ripening process. The desired temperature setting is 16-20ºC with a% humidity level. After the room temperature is reached 16-20ºC with% humidity then the cheese material is inserted into the cooler for the ripening process. The working principle of this system is to stabilize temperature and humidity. Test of the results obtained by the value of the parameter controller Kp = 5.53, Ki = 8, Kd = 2, for the 16-200C temperature setting and% humidity. Changes in time from room temperature to set-point temperatures are relatively fast with the overshoot percentage of 11.11% and the rise time of 9 minutes.

1. Introduction

Cheese is a fresh or marinated product produced by the separation of liquid (whey) from the coagulant after milk clumping [1]. Cheese is made through the process of coagulation / formation, cutting, heating curd, whey removal, pressing and ripening [2].

Maturation is the final process of the cheese making process. Cheese ripening is done by storing cheese for some time and at a certain temperature. The longer the ripening, the stronger the taste of cheese is formed. In ripening cheese, temperature and humidity affect the speed of proteolytic activity and acid production. High temperatures will speed up the process, but it is not profitable. At high temperatures, acid production is faster, resulting in a strong sour taste and accelerated evaporation so that more water is lost and decay occurs more quickly. At low temperatures there is a balance of acid production and proteolytic activity and inhibited evaporation of water [9].

During the ripening process, the cheese is kept at a certain temperature until the cheese is ready to be eaten. During this time the cheese ripening is usually the desired cheese product often fails. Due to various factors. Like, the room temperature and humidity that are not in accordance with the bacteria that are already in the cheese. Human intervention and a non-sterile place. This is considered less effective in the cheese ripening process. Quality is very influential on the selling price. Good quality will have a positive impact on cheese businessmen [5].

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2. Literature review

2.1. Process of cheese maturation

The cheese ripening process is the process that converts fresh curds (raw cheese) into cheese full of flavour. This ripening process is caused by fungi / bacteria that form the characteristics of cheese at a certain temperature, humidity and time. [5].

2.1.1. Camembert cheese (soft cheese). Camembert cheese is one type of soft cheese originating from France that is made with the main raw material of fresh milk (Scott, 1981). The process of clotting milk casein in this cheese uses rennet. The bacterial culture used to produce lactic acid comes from the bacterium Penicillium candidum. Figure 1 shows the type of Camembert Cheese.

Figure 1. Camembert cheese [10].

Codex General Standard for Cheese (1999) classifies cheese based on the condition and condition of cheese, including the moisture content of a non-fat material (Moisture on Fat-free Base (MFFB), which will determine the texture, fat content in dry ingredients (Fat in Dry Base / FDB) as a forming component of texture and taste and ripening process as a stage of improvement of maturation Based on this classification, Camembert cheese is a type of soft cheese with moisture content in non-fat dry ingredients (MFFB) averaging above 57% and fat content in dry matter (FDB) averages 48%. This cheese in the ripening process requires a temperature between 16-200 C and% humidity. The characteristic of Camembert cheese includes a soft but formed texture, has outer skin and creamy texture on in. The colour of this cheese will turn yellow when the cheese is cooked, this colour is caused by the bacterium Penicillium candidum. [10].

2.2. Milk processing industry road map

- The milk processing industry includes making milk powder, sweetened condensed milk, sour milk, milk head / milk cream including preservatives such as sterilization and pasteurization.
- The milk processing industry generally uses fresh milk as raw material. In addition to raw milk raw materials, this industry also requires additional ingredients such as sugar, cream, vegetable oil, etc. to be processed into other processed products.

Diversified types of dairy products include: liquid milk (UHT, pasteurization), powdered milk, sweetened condensed milk, cheese, butter, yogurt, and ice cream. Fresh milk and processed products are presented in the form of industrial trees in Figure: 2. [1].

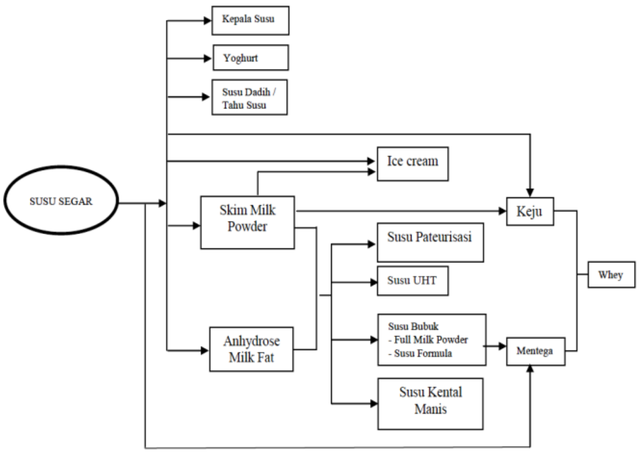

Figure 2. Industrial tree diagrams [6].

2.3. Dairy industry research institute

Conduct dairy research activities, both from raw milk raw materials, production processes, product diversification, and machine / equipment development. Figure: 3 shows the relevance of the milk processing industry.

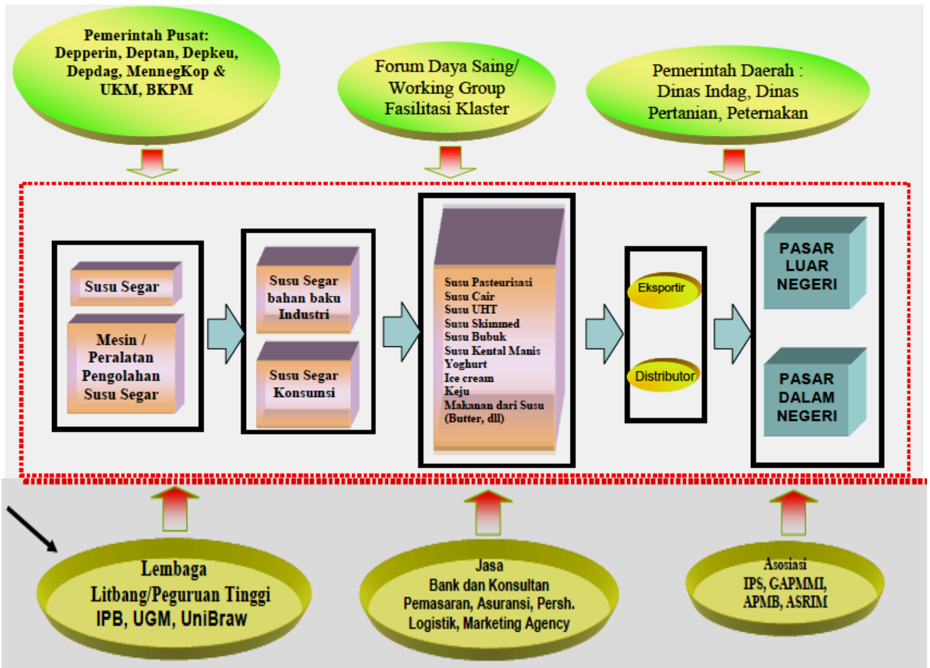

Figure 3. Industry linkage framework milk processing [6].

2.4. Conformity in developing the focus of Polynema research (RIP)

The focus of research in the Food Security area is in synergy with the focus of polynema research as shown in Figure 4.

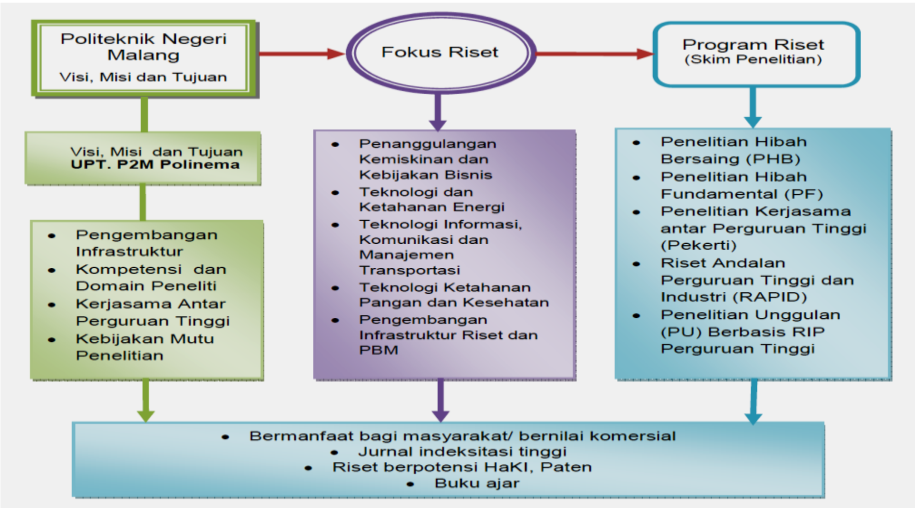

Figure 4. Focus of Polinema research 2016 (RIP).

2.5. Proportional Integral Derivative (PID) method

Proportional integral derivative (PID) is a controller for 1212 that determines the precision of an instrumentation system with the characteristics of feedback on the system. This PID control component consists of three types, namely Proportional, Integrative and Derivative. 111The three types can be used together or individually depending on the response we want to a plant. Proportional control has 111 advantages for minimizing errors, and integral control actions have the advantage of minimizing errors, and differential control actions have the advantage of reducing the lack of responses or excess responses [8].

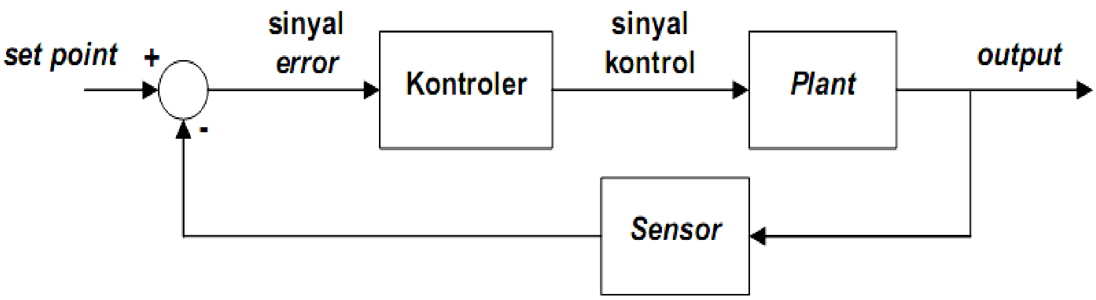

Figure 5. PID control action blocks [8].

2.5.1. PID Ziegler-Nichols I method. In method, the first motor response from the plant is obtained experimentally by inputting the unit step as shown in Figure 6. The type of response is first order with transport delay. The characteristic of the response is time delay (L) and 1 time constant (T) which can be known by 1212 drawing the tangent at the turning point of the curve, as shown in Figure 6. [8]

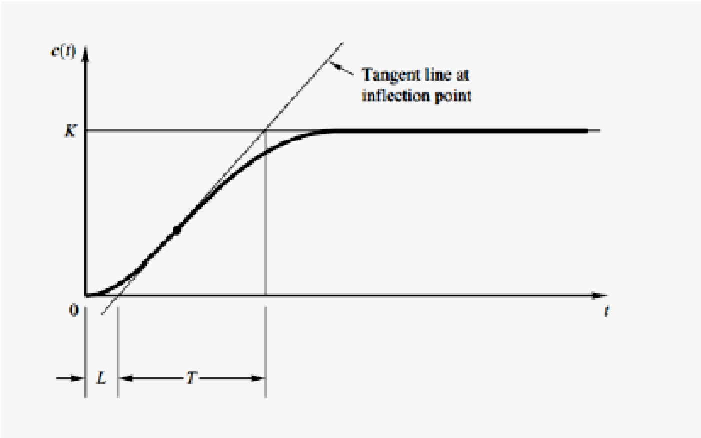

Figure 6. Tangent response curve [8].

The way to determine tangents is to make a straight line and squeeze in the response that has the most linear value and must go through the 1212 time value required by the response 32323 to reach 63.2% of the steady state response value. This response is obtained from a plant which is given an input in the form of a unit step. The following is the Ziegler-Nichols I rule shown in Table 1.

Table 1. Rules of Ziegler-Nichols I [5].

Tipe Kontroler	*Kp*	Ti	*Td*
P	$\frac{T}{L}$	~	0
PI	$0{,}9\frac{T}{L}$	L/0,3	0
PID	$1{,}2\frac{T}{L}$	2L	0,5L

2.6. Peltier cooling system

The Peltier or Thermo-Electric Cooler (TEC) element is an electrical component that can produce cold temperatures on one side and hot temperatures on the other when electrified. The increase or decrease in temperature in the connection depends on the direction of the electric current. Applications that are often used by peltier systems are by utilizing the temperature of the cold parts produced, namely as processor coolers, mini air conditioners, refrigerators in dispensers, beverage coolers, and aquarium temperature regulators. While the temperature of the heat can be removed by attaching the heat sink and fan. The amount of peltier (COP) performance coefficient is the ratio between the heat produced by peltier and the energy supplied. The value of the peltier COP can be determined from the following equation:

$$COP = \frac{N\left(2.\alpha_{xy}.I.T_c - \frac{I^2R}{2} - K.(T_h - T_c)\right)}{N\left(2.\alpha_{xy}.I.(T_h - T_c)\right) + I^2R} \qquad (1)$$

Where R is the electrical resistance relationship (Ω.cm2), I is an electric current (A), k is the thermal coefficient of the couple (W / cm.K), is the Seebeck coefficient (V / K), Th is the hot side temperature, Tc is the temperature on the cold side and N is the number of elements / couple. Figure 7 shows a peltier device.

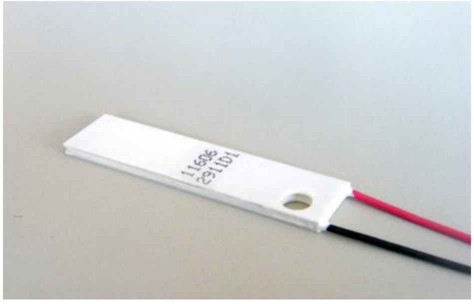

Figure: 7. Peltier device (TEC) [11].

3. Research of methods

3.1. Determining system specifications

- Box dimensions (space), Length: 50 cm, Width: 30 cm, Height: 35 cm
- Mechanical Weight: ± 5Kg
- Chassis material: Acrylic
- Temperature sensor: Lm35, DHT11
  Parameter range used: Temperature: 250C - 150C Humidity ≥ 50
- Processor: ATMEGA 16
- Actuator: Peltier, DC Pump
- Display: 16 x 2 LCD
- Working voltage
- Source: Peltier = 7V, 6A
- DC pump = 3V, 5A
- Power Supply = 12V, 20A

Figure 8 shows the dimensions of the miniature box research system.

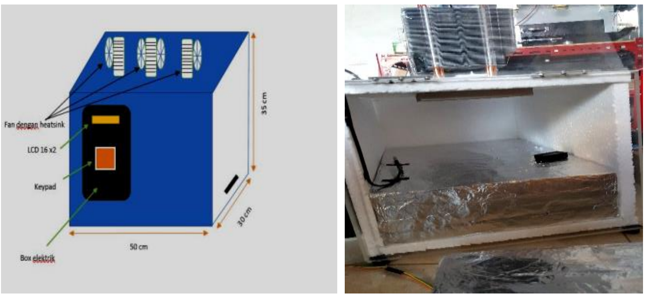

Figure 8. Dimensions of research miniature room.

3.2. Designing a block diagram system

Basically the working principle of the temperature and humidity control system that uses the PID method is to control the temperature and humidity in the box, keep the temperature so that it is always stedystate according to the desired temperature input through the set point. While the control system utilizes the PID method so that it can reduce the steady state error. The keypad is used to enter the set-point value (temperature and humidity) from the values of Kp, Ki and Kd to be achieved which are displayed via LCD. After determining the set-point value of the ATmega16 microcontroller will process the data by comparing the temperature readings by the Lm35 sensor with the set-point that has been determined. The comparison between the actual temperature and the temperature at the set-point

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will produce an error. The error will be minimized with the PID control embedded in the ATmega microcontroller 16. The PID output works to regulate the voltage in the power supply through input errors from the difference between the set-point and the temperature read by the temperature sensor. The PID output is a PWM signal. To set the PWM it is set in the peltier driver via the IRF250N mosfet. Humidity is regulated by using a relay that functions to turn on the dc pump if the humidity does not match the set-point. The reset button is used to reset ATmega16. If all the processes have gone according to set-point, then the cheese will be included for a certain time to get the maximum cheese product. Figure 9 shows a block diagram system.

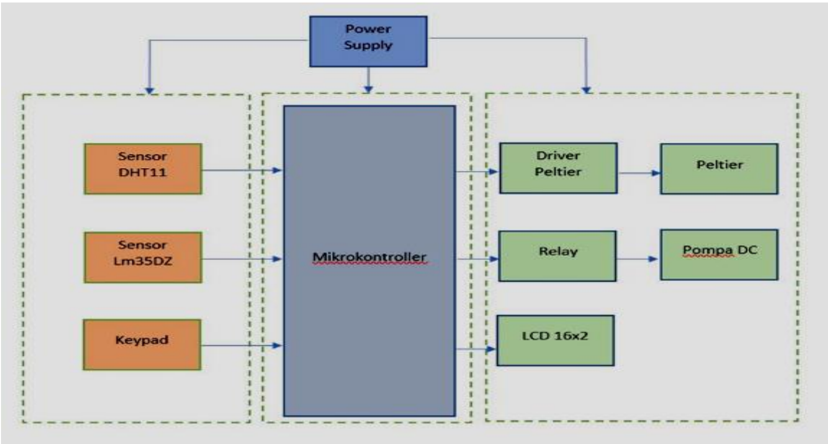

Figure 9. Block system diagram.

The peltier driver (Figure 10) uses the IRF250n MOSFET. On the leg of the optocoupler PC817 is connected with a PWM input microcontroller. The PC817 optocoupler consists of infrared (LED) which is coupled with a phototransistor. Phototransistor will be active when exposed to light. When on PORT A0 and A1 logic 1 there is a voltage passing through the active R1 Led (inside the optocoupler) so that the current will flow from the Collector to the Emitter. The PC817 optocoupler is used in this peltier driver as a component that triggers the IRF250n MOSFET. This Mosfet is an active NPN or MOSFET type when given the logic "1" (high) then at Gate MOSFET the IRF250n is given a pulldown resistor so that the logic contained in the MOSFET is not floating. The 6A05 type diode is installed parallel to the peltier driver. The diode anode is installed in the direction of the peltier negative (-) pole towards the MOSFET drain. And Figure 11 shows the relay driver to activate the moisture sprayer pump [3].

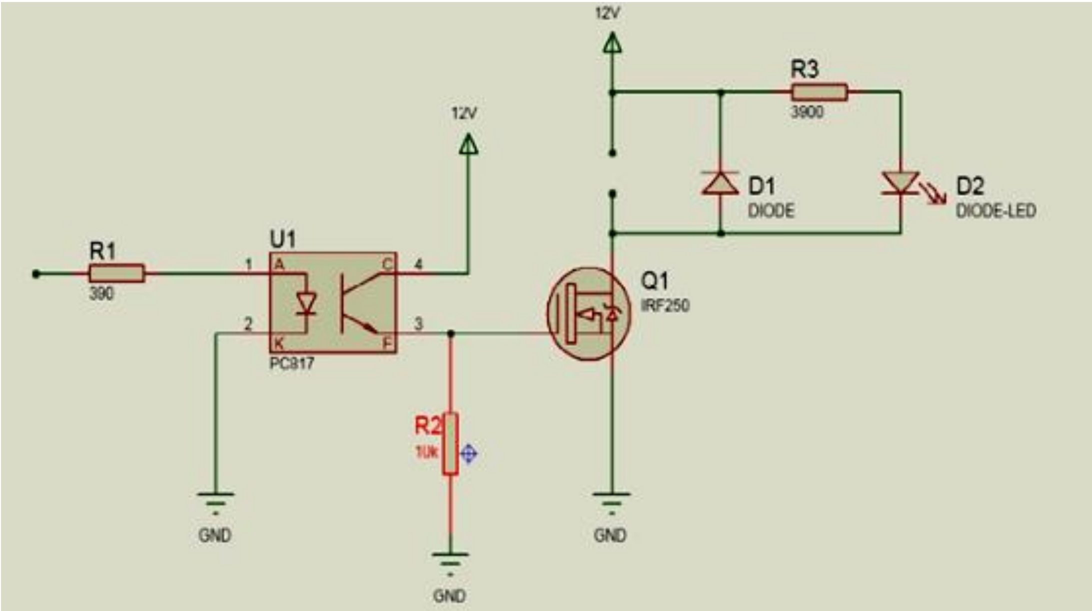

Figure 10. Peltier driver circuit [7].

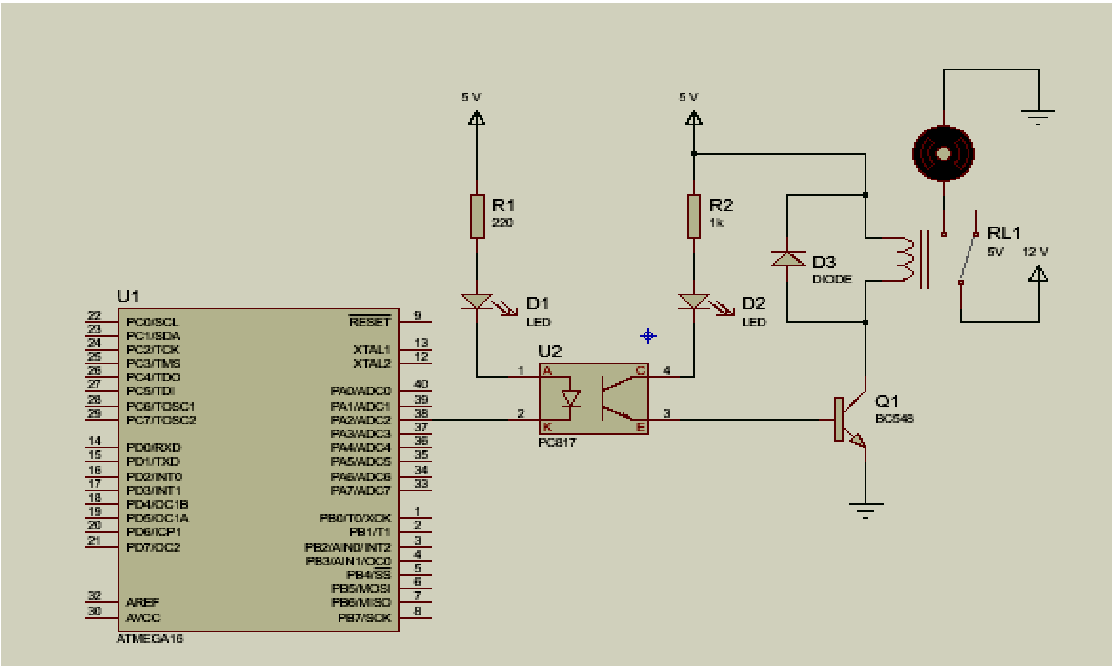

Figure 11. Relay diver circuit [7].

3.3. Designing a research flow chart

Figure 12 is a research flow diagram shown in a flowchart.

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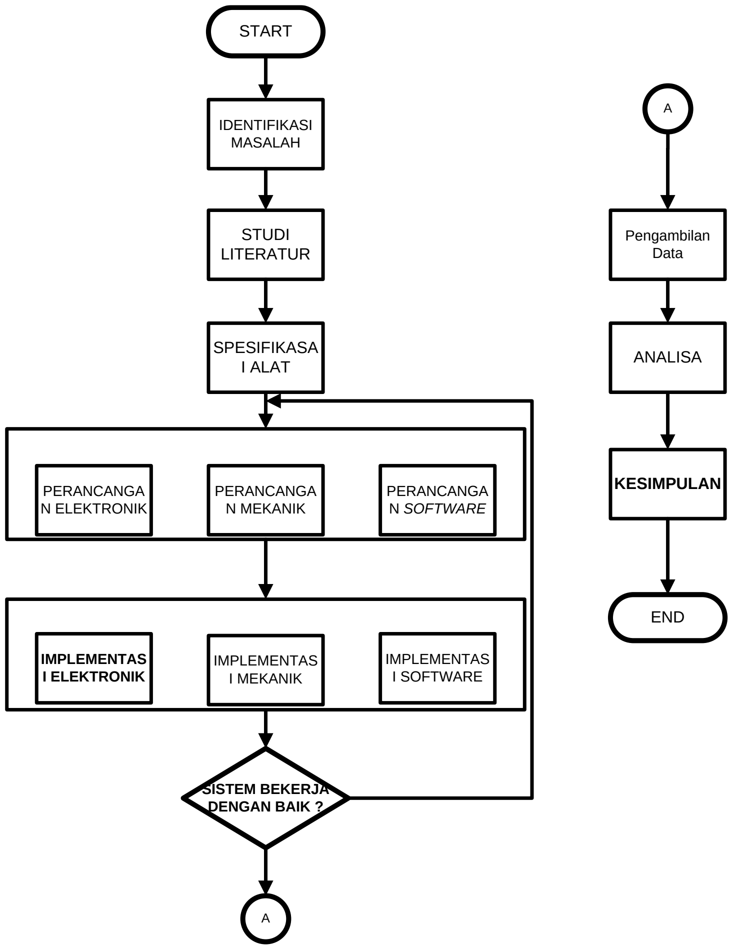

Figure 12. Research flow diagram.

3.4. Software design

Software design for system temperature control on the peltier is explained in the flowchart of Figure 13.

Start the system to turn on all electronic devices. Then the LCD displays information. After that, enter the values of Kp, Ki and Kd and determine the system set-point to be controlled. Then the tool will read the temperature. From the temperature sensor reading there will be an error. This error will be minimized by reducing the set-point with temperature readings. After that the error will be controlled by a PID which will produce output in the form of a voltage that will enter the peltier. Then the system will read humidity, if the system humidity is <50%, the pump will be ON for 1 second. But if the pump> 50% the pump will OFF.

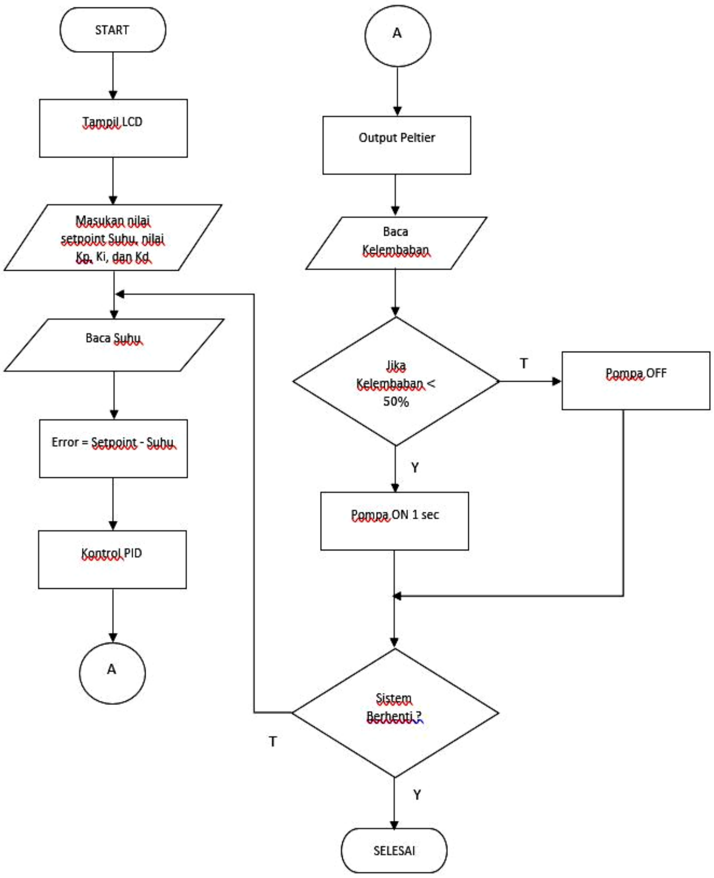

Figure 13. Software system

3.5. *Designing the PID controller*

The control system uses the PID method shown in Figure 14

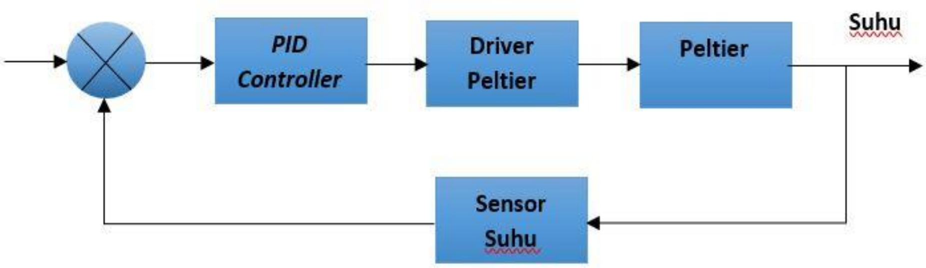

Figure 14. Controller Block Diagram

The PID Controller input is an error which is the difference between the Set Point and the actual temperature measured by the Lm35 sensor. This PID is embedded in the ATmega16 controller. The output of the PID in the form of PWM which is regulated voltage then goes into the peltier driver, the peltier driver is connected to PD0 and PD01 (Port D 0 & 1) at the minimum system) which can then flow the voltage to the peltier. At Port D5 the temperature sensor is connected. The temperature senor which is directly measured by the Lm35 sensor re-enters an error between the set point and the actual temperature measurement performed by the Lm35 sensor. This error is reduced by PID control.

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The PID design is done to determine the values of Kp, Ki and Kd from the controlled plan in this case is the temperature. The design is done by giving input as a step unit on the plan so that the response is obtained. From this response it can be seen that the response curve is an S curve or oscillation. If the response is an S curve, the Ziegler Nichlos I method is used

After getting the response, then the calculation for Ziegler Nichlos 1 is performed using the calculation as shown in Table 2.

Table 2. Tuning PID Ziegler Nichols 1

Tipe Kontrol	Kp	Ti	Td
P	T/L	~	0
PI	0.9 T/L	L/0.3	0
PID	1.2 T/L	2L	0.5L

L is the delay time and T is the time delay constant. The values are then entered in the formula below to get the values of Kp, Ki and Kd:

$$K_p = K_p$$
$$K_p = \frac{K_p}{T_I}$$
$$K_p = K_p \ x \ T_D$$

4. Results and discussion

4.1. System response before control

Testing of Proportional Integral Derivative (PID) control is done to find out how the plant response (peltier) is given control of Kp, Ki and Kd. Based on calculations using the Ziegler Nichols I reaction curve method Kp = 5.53, Ki = 8 and Kd = 2. The response graph from the calculation of the Ziegler Nichols I reaction curve method with SP = 20.18, and 16°C is shown in Figure 15 below.

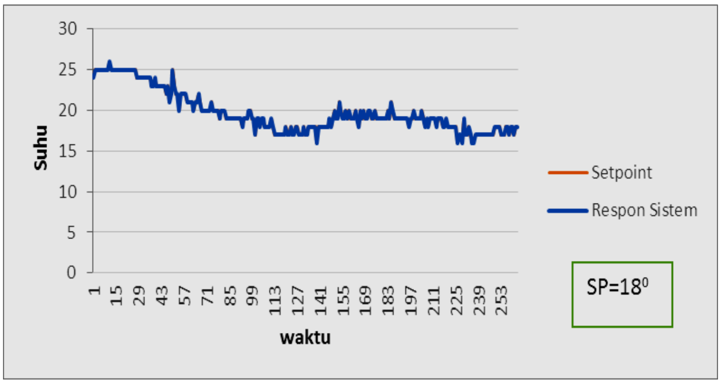

Figure 15. Response Graph of Ziegler Nichols I method calculation results (Kp = 5.53 Ki = 8 Kd = 2) 18°C set point.

From the response graph with the values of Kp = 5.53, Ki = 8 and Kd = 2 shown in Figure 14 can be analysed from the responses generated as follows:

4.1.1. Rise Time (tr). Rise Time is the time needed to reach the set point value at the start of a system response with a value of 10% -90%.

Setpoint 18^{0}C = X 18 =16.20C

=180C - 16.20C = 1.80C
=180C + 1.80C = 19.80C
X = tr = 13.11 sec.

4.1.2. Present Overshoot (PO). The Present Overshoot is a value that stat``es the comparison of the maximum response price that exceeds the steady state value at the initial system response.

$$PO = \frac{Max\ Peak - Setpoint}{Setpoint}\ x\ 100\%$$

So that,

$$PO = \frac{16-18}{18}\ x\ 100\%$$

$$PO = 11.11\%$$

4.1.3. Time Peak (tp). Time Peak is the time when the highest peak at the beginning of the strating, ie at 16°C.

4.1.4. Time Settling (ts). Time Settling is the time used during the steady state, which is at 40 minutes.

Table 3. Characteristics of the Response with a value of Kp = 5.53, Ki = 8 and kd = 2

Curve Response Performance	Results
tr (rise time)	13,11 minute
ts (settling time)	40 minute
tp (peak time)	23.1 minute
Po (percent overshoot)	11.11%

Based on the graphical response image of the values of Kp, Ki and Kd, the calculation of the Ziegler Nichols I method shows that the PID controller system, the temperature is well maintained and matches the desired set point. in testing with set point 18ºC there is still overshoot but there is still a dose of tolerance and the overshoot temperature can go back down to the set point.

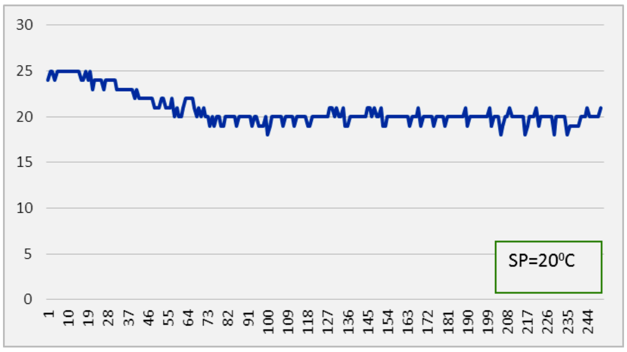

Figure 16. Response Graph of Ziegler Nichols I method calculation results (Kp = 5.53 Ki = 8 Kd = 2) 20°C set point.

Table 4. Characteristics of the Response with values Kp = 5.53, Ki = 8 and kd = 2 Set Points temperature 20°C

Curve Response Performance	Results
tr (rise time)	7 minute
ts (settling time)	11.33 minute
tp (peak time)	16.6 minute
Po (percent overshoot)	11.11%

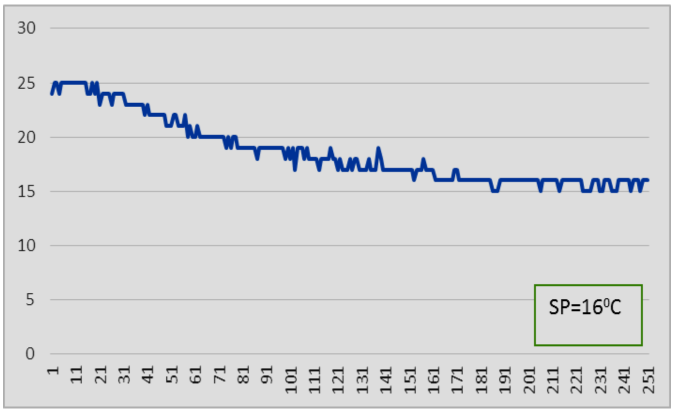

Figure 17. Response Graph of Ziegler Nichols I method calculation results (Kp = 5.53 Ki = 8 Kd = 2) set point 16°C.

Table 5. Characteristics of the response with values Kp = 5.53, Ki = 8 and kd = 2 Set points temperature 16°C.

Curve Response Performance	Results
tr (rise time)	17,16 minute
ts (settling time)	27.5 minute
tp (peak time)	31.3 minute
Po (percent overshoot)	6.25%

Table 6. Data on test results for test material samples.

No	Plant Temperature (ºC)	Reference Temperature (ºC)	Time (sec)	Test Material Sample Results
1	20	19,50	640	

Table 6. Cont.

No	Plant Temperature (ºC)	Reference Temperature (ºC)	Time (sec)	Test Material Sample Results
2	19	19	910	
3	18	18	1170	
4	17	17,23	1457	
5	16	16,40	1710	

The results of testing material sample in Table 6 shows that the cheese with the best ripening is at a temperature of 18ºC. This can be seen from the characteristics of the cheese that matches the soft cheese. At temperatures above 18ºC the cheese undergoes changes to the skin of the whitish cheese. While at temperatures below 18ºC the cheese changes in the form of hardened cheese.

5. Conclusion

The results of the study from the research data are:

- The cheese ripening process is the best temperature for the soft cheese type at 18ºC in 1170 seconds (sec) with a level of soft yellowish skin texture.
- To achieve a set point value of 18 ºC a stable control parameter was obtained at: (Kp = 5.53, Ki = 8, Kd = 2)
- The maximum temperature that can be reached by the system is 15ºC with a time of 44.5 minutes (1170 sec).

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- Implementation using the PID control in the cheese ripening process using the Ziegler-Nicohls method the resulting temperature response is able to stabilize the desired temperature by obtaining parameter values Kp = 5.53, Ki = 8 and Kd = 2.

Suggestion

The cooling process using peltier elements still has disadvantages, where the current used is too large so the power used is also large. This causes energy inefficiency.

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