DESIGN OF A HONEY PASTEURIZATION MACHINE BASED ON TOUCH SCREEN USER INTERFACE TO CONTROL HONEY CONTENT USING THE PUGH METHOD

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Abstract. Pasteurization of honey in Honey Small and Medium Enterprises (SMEs) is generally carried out by conventional methods through a thermal process. This method has risks because heating of more than 75°C causes nutritional degradation of the quality of honey. Non-thermal pasteurization is an alternative to the thermal method, although it does not use temperature to deactivate microbes. Based on several studies, PEF technology is a sustainable food processing, ensuring microbial stability with lower treatment temperatures and minimal side effects. LPPD UNS has developed a hone pasteurization machine but due to the long operating time, this developed engine experienced process instability. Therefore, the design of a pasteurization machine using PEF technology for further development is important. This research aims to redesign the pasteurization machine using PEF technology to provide significant value that UI design and systems are considered through several criteria. The emergence of several alternative development redesigns for pasteurization machines. it is necessary to select alternative designs using Pugh's method. The results of the design, the machine is designed with a stirring speed of 20rpm, 25rpm, and 30rpm and the PEF intensity of 25kV, 30kV, and 35kV. Modification of this design is expected so that process instability can be resolved and proper treatment can be obtained in the honey pasteurization process.

1 Introduction

Before it can be consumed, honey requires processing. Honey processing is carried out in two stages, namely harvesting and pasteurization. Honey pasteurization is carried out to remove pollen, wax, and reduce water content, and microbes (Rosawanti et al., 2022). Pasteurization of honey in Honey Small and Medium Enterprises (SMEs) is generally carried out by conventional methods through a thermal process (Eshete, 2019). This thermal process controls microbial growth and fermentation by reducing the water content. However, this method has risks because heating of more than 75°C causes nutritional degradation of the quality of honey (Eshete, 2019).

Non-thermal pasteurization is an alternative to the thermal method, although it does not use temperature to deactivate microbes (Wang et al., 2016). Non-thermal methods make food ingredients subject to microbiological inactivation without or with little or no direct thermal treatment (Chacha et al., 2021). Common non-thermal technologies in the industry consist of High-Pressure Processing (HPP), Pulsed Light (PL), Cold Plasma (CL), Irradiation, Ozone, Ultrasound (US), and Pulsed Electric Field (PEF). For some of these nonthermal technologies, PEF treatment is a more effective technology (Zhang et al., 2019).

Based on several studies, PEF technology is a sustainable food processing, ensuring microbial stability with lower treatment temperatures and minimal side effects (Roobab et al., 2022; Han et al., 2018; Arshad et al., 2021). Pasteurization through PEF technology is effective in reducing E. Coli bacteria in milk (Sharma et al., 2014; Walter et al., 2016). PEF technology in estimating investment capital for low to medium production capacity is more effective. According to Chacha et al. (2021), HPP, PL, CL, Irradiation, Ozone, and US technologies require large investment capital and are more effective for large production capacity plans. In other words, PEF has the potential to be applied to small-scale pasteurization needs.

The Laboratory of Product Planning and Design (LPPD) of Sebelas Maret University has developed a honey pasteurization machine with PEF technology with a capacity of 80 liters. This machine uses an electric input voltage of 30 kV to generate an electric field. To increase the effectiveness of pasteurization, PEF is combined with a heating system so that a stirrer system

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is needed so that the temperature of the honey becomes homogeneous. The machine is equipped with sensors for temperature monitoring at any time. Boekel et al. (2010), monitoring the temperature in the pasteurization process through PEF is important because apart from the heating system, electrical energy is generated. However, due to the long operating time, this developed engine experienced process instability. In addition, several process parameters such as PEF tension and stirring speed did not vary so the process treatment was difficult to obtain, ultimately risking the honey content as indicated by an increase in hydroxymethylfurfural (HMF) and a decrease in diastase number (DN) (Ariandi & Khaerati, 2017). Therefore, the design of a pasteurization machine using PEF technology for further development is important.

Monitoring of electric field intensity in real time has not been programmed into the UI system so operators cannot monitor and adjust parameter changes to ensure the running of the process. Changes in machine design have consequences for changes in the UI system to increase the ability to monitor and control process parameters during pasteurization (Stone et al., 2005). The redesign of the pasteurization machine uses PEF technology to provide significant value that the UI design and system is considered through several appropriate technology (AT) criteria including technical, economic, ergonomic, efficiency, environmental, trends, and sociocultural (Surata, 2014). With the emergence of several alternative development redesigns for pasteurization machines (Ulrich & Epingger, 2020), it is necessary to select alternative designs using Pugh's method (Burge, 2009). The design alternative was chosen to answer process instability based on engine performance at 30kV voltage at room temperature of 24ºC and 60ºC reactor tube. The analysis and synthesis phases of alternative machine designs with PEF technology are crucial for the success of a safe honey processing process to maintain honey content.

2 Metode and Materials

2.1 Participatory Approach

The results of the participatory approach in the form of stakeholder requirements are then classified according to the assessment criteria. four stakeholders in designing a honey pasteurization machine including lecturers, previous researchers, manufacturers, and honey bee SMEs. The Stakeholder Model in Honey pasteurization machine Design is shown in Figure 1.

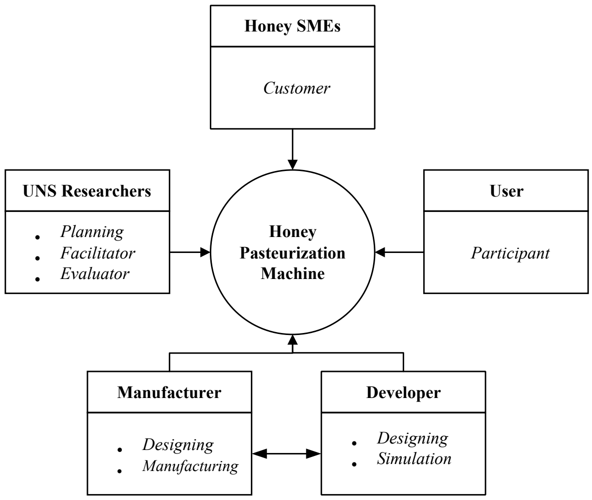


Fig. 1. Stakeholder Model

UNS researchers have the role of planning (planner), facilitator, and evaluator. As planners, UNS researchers are the creators of the timeline and concept regarding the final project of honey pasteurization machine design. As a facilitator, UNS researchers are the determinants and supporting tools for honey pasteurization machine design. as evaluators, UNS researchers are assessors of the suitability of the final project planning regarding honey pasteurization machine design. Manufacturers play the role of designing and manufacturing honey pasteurization machines. Manufacturers are directed by UNS researchers after planning or if repairs are needed on the honey pasteurization machine. The user acts as a participant. As a participant, the user is a user of the honey pasteurization machine he designed for testing the honey pasteurization process. Users provide input in the form of evaluations to developers for further development of honey pasteurization machines. Honey SMEs play a supporting role. As a support, MSME honey is a provider of input in the form of the specifications needed for the design of a honey pasteurization machine. The developer has the role of designing and simulating. As a design maker, the developer designs a honey pasteurization machine based on criteria, the needs of honey SMEs, and user evaluations. As a machine tester, the developer is a tester for the pasteurization process in honey pasteurization machines. the developer works closely with the manufacturer in carrying out the design.

as a customer, honey bee SMEs were interviewed with structured questions which would be summarized into a voice of the customer (VoC). users are also interviewed to get an evaluation of the machine that will be converted into VoC. The results of interviews with users and honey bee SMEs obtained an evaluation for the development of honey pasteurization machines and user voices for honey pasteurization machines which are summarized as VoC is described in Table 1.

Table 1. Engines Specification.

No	Statement
1	Machine evaluation, PEF voltage, and stirring speed were made variable

2	Machine evaluation and real-time PEF voltage monitoring do not yet exist
3	Machine evaluation is a long process resulting in process instability
4	Machine evaluation, the machine is difficult to shift or move
5	I want when the operator uses the machine, the operator is safe from the high voltage and temperature of the machine
6	I want a Stable engine frame
7	I want the machine to use minimal electrical energy
8	I want the material used specifically for processing honey
9	I want an attractive user interface display
10	I want no pollution caused by the machining process
11	I want the machine capacity to be adjusted to the harvest capacity
12	I want low machine maintenance costs

2.2 Finalization of Target Specifications

This stage aims to finalize the specifications and targets based on the design, technical, and material requirements of the PEF technology honey pasteurization machine. Identification of needs is a combination of information on stakeholder needs from a participatory approach through interviews and observations. Identification of technical needs aims to provide technical boundaries of stakeholder needs. identification of material needs aims to determine the appropriate material composition to be applied to honey pasteurization machines to meet the needs of stakeholders

2.3 Finalization of Target Specifications

This stage is the concept formation stage up to the selection of the honey pasteurization machine concept. The concept formation stage is divided into morphological charts (MC) and tree diagrams (TD). The selection of the conceptual design went through several stages including determining the criteria, determining the datum, weighing the criteria, and assessing the conceptual design with Pugh matrix scoring.

2.4 Finalization of Target Specifications

This stage includes visualization of design details, bill of materials, setting detailed specifications, and making prototypes. visualization of design details is the final stage of design by creating a 3D design from the selected concept design. The 3D design made consists of 3D design and component relationship flowcharts. A Bill of Materials is a list of materials, components, and tools needed to design a pasteurization machine. determination of detailed specifications containing detailed specifications for honey pasteurization machines with PEF technology based on a predetermined bill of material. Prototyping includes making machine structures, building UI, and building the main system.

3 Result and Discussion

3.1 Costomer Needs

The results of identifying VoC from a participatory approach to 5 stakeholders, followed by categorizing customer needs against AT criteria (Surata, 2014). Organizing customer needs according to the characteristics of the machine to be made. The criteria and customer needs for the honey pasteurization machine design are described in Table 2.

Table 2. Costumize Needs With Criteria.

Criteria	Honey Pasteurization Machine Customer Needs
Technical	The machine is designed with strong construction
	The machine is designed using a system to accommodate all regulatory needs with various parameters
	The machine is designed based on food processing standards
Economical	The machine is designed taking into account the production capacity and economic conditions of Honey SMEs
	The machine is designed to pay attention to maintenance costs
Ergonomic	The machine is designed with attention to the safety of the operator against high temperatures and engine voltage
	The machine is designed with a user interface
	The machine is designed with ergonomics in mind
Efficiency	The machine is designed with attention to the use of electrical energy
environment	The machine is designed with due regard to product and environmental pollution
Trend	The machine is designed based on the development of nonthermal pasteurization technology
	The machine is designed with the implementation of Industry 4.0
Socioculture	The machine is designed without losing the product's characteristics

3.2 Target Spesifications

Target specifications are made after grouping the design requirements according to the criteria. Target specification refers to the fulfillment of the provisions in the criteria, methods, processes, and engineering to meet the standards and needs of users. The Target specification for the honey pasteurization machine design is described in Table 4.3.

Table 3. Target Spesification.

No	Customer Needs	Target Specification
1	The machine is designed with strong construction	The main frame of the machine uses light, high-density materials

2	The machine is designed using a system to accommodate all regulatory needs with various parameters	The machine has a system with input parameters including timer, temperature, stirrer speed, automatic control, and PEF intensity
3	The machine is designed based on food processing standards	The machine is designed with materials according to SNI 8664: 2018
4	The machine is designed taking into account the production capacity and economic conditions of Honey SMEs	The machine is custom-made according to the needs and production capacity of UKM Madu
5	The machine is designed to pay attention to maintenance costs	Maintenance costs are reduced by using quality materials and computer programs.
6	The machine is designed with attention to the safety of the operator against high temperatures and engine voltage	Machine design pays attention to user safety and the possibility of work accidents by carrying out various prevention methods.
7	The machine is designed with a user interface	The engine is built with an easy-to-use and easy-to-see UI.
8	The machine is designed with ergonomics in mind	The location of UI controls is adjusted to the anthropometric dimensions of eye height with the 50th percentile based on Indonesian anthropometry
		The machine is facilitated by additional frames for machine mobility
9	The machine is designed with attention to the use of electrical energy	The use of a high calibration control system ensures energy efficiency.
10	The machine is designed with due regard to product and environmental pollution	During design, the machine is tested to ensure that there is no polluting effect on the environment and the product.
11	The machine is designed based on the development of nonthermal pasteurization technology	The machine is designed with PEF technology which makes it possible for Honey SMEs.
12	The machine is designed with the implementation of Industry 4.0	The operator has complete control over machine parameters and machine conditions in real time
		The machine is designed with automatic control
13	The machine is designed without losing the product's characteristics	Ensuring pasteurized products have added value and do not eliminate product characteristics.

3.3 Material Requirements

Identification of material requirements is used to determine the technical specifications of the machine. This process aims to determine the material used according to cost and energy constraints. Material requirements are described as follows.

- In the honey pasteurization machine construction, it is divided into two areas. The process area includes a double-layered treatment chamber (TC). The toolbox area contains the dynamo, UI, PLC, and PEF. This design uses construction with high-density materials for the frame and low-density materials for the toolbox.
- The machine is designed to accommodate the setting and monitoring of input parameters, such as timer, temperature, stirring speed, and PEF intensity.
- The honey pasteurization machine is made with foodgrade materials to make it safe, hygienic, and durable. Materials used in food processing machines must comply with regulations and standards.
- Machine specifications must match requirements to ensure optimal design and construction, hygienic design, regulatory compliance, customization, and efficient production.
- The use of quality machine components with computer programs has a significant impact on machine life by increasing durability, increasing performance, and lowering maintenance costs.
- The machine is designed with the use of a malfunction warning system, overheating, and PEF flow separator insulator to the frame to avoid work accidents and machine damage.
- UI is used to facilitate use and supervision when the machine is doing the pasteurization process.
- The location of UI is measured based on the anthropometric dimensions of the eye height of adults with the 50th percentile.
- The machine is made with an additional frame in the form of wheels to facilitate the mobility of the machine.
- Use of components as needed with consideration of energy use.
- Conduct machine testing to ensure there are no side effects on honey products and the environment.
- PEF technology is used for spore degradation in honey without heat.
- UI is used for machine usage and monitoring in realtime.
- The machine is designed with an automatic control system for pasteurization.
- Comparison of pasteurized honey with existing products through content tests

3.4 Conceptual Design

The design concept should be logically feasible and functionally simple. Determining the design function is the first step in forming a conceptual design by defining the function through quantitative data. The honey pasteurization machine is divided into 5 main functions:

1. *Machine supports:* The supports will support the load from the reactor tube, electric motor, gearbox, and toolbox. The machine support has several alternatives, namely aluminum square hollow 30x30mm, carbon steel square hollow 30x30mm, and aluminum extrusion.
2. *Stirrer:* The stirrer is made of a 2.1cm diameter pipe, equipped with 2 propellers at the end of the stirrer, and is driven using an electric dynamo and speed reducer. The mixer drive has two alternatives namely shaft mounted gearbox and worm gearbox.
3. *Control Unit*: CU is the controller, regulator, and sensor reader on the machine. In honey pasteurization machines two CU alternatives can be used including PLC and Arduino with the addition of an inverter.
4. *User Interface:* The UI is the liaison between the operator and the machine CU. The honey pasteurization machine UI has two alternatives including the human machine interface (HMI) and Analog.
5. *Engine Temperature Control:* Maintenance of engine systems by controlling engine temperature with coolant. Alternative temperature control modulation of the engine system has 2 alternatives including heat sinks, cooling fans, and a combination of both.

In generating the conceptual design, morphological charts, and tree diagrams are used. A tree diagram is a method used to describe possible combinations of components for the honey pasteurization machine concept. Combinations in the form of alternative concepts will be selected to proceed to the morphological chart stage. The tree diagram of a honey pasteurization machine can be explained in Figure 2.

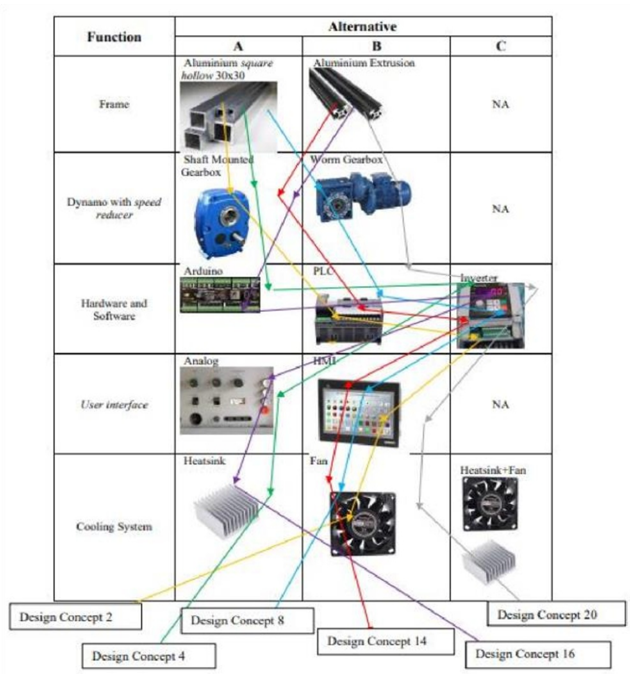
The tree diagram produces 24 alternative design concepts, so it is necessary to eliminate alternatives to narrow down the choices. The alternative tree diagram concept is eliminated as explained below:

- The combination of PLC with heatsink and fan cooling is eliminated. These combinations are eliminated to minimize outgoing costs.
- The combination of Arduino with cooling fan and Arduino with cooling heatsink and the fan is eliminated. This combination was eliminated because the Arduino is limited in the number of devices it controls making it difficult to use fans.
- The combination of worm gearbox, Arduino, and 3 cooling alternatives is eliminated. Worm gearbox tends to heat up faster because of its design and operation, so it requires an effective cooling system. The heatsink is less effective at removing heat from the worm gearbox.

The results of tree diagram elimination resulted in 6 alternative design concepts. Then the 6 alternatives are continued to the morphological chart stage. The morphological chart is a method used to obtain product functionality by exploring alternative means and combinations. Morphological chart of honey pasteurization machine as described in Table 4.

The morphological chart shows the combination of honey pasteurization machine design concepts from the tree diagram, six design concepts are obtained and divided by color, namely yellow for design concept 2, green for design concept 4, blue for design concept 8, red for design concept 14, purple for design concept 16, gray color for design concept 20.

Table 4. Morphological Chart.



3.5 Concept Assessment and Selection

The first step is the weighting of the criteria obtained from distributing questionnaires to stakeholders. The four criteria with the highest percentage weight respectively are technical (19%), efficiency (16%), socio-cultural (15%), and ergonomics and health (14%). The four highest criteria meet the main criteria for AT (Sibanda et al., 2016). The other three criteria supporting the main criteria include environment, trend, and economy.

Table 5. Weight of Criteria.

Criteria	Evaluator					Weight
	1	2	3	4	5	
Technical	4	3	4	4	3	19%
Economical	2	1	2	2	2	9%
Ergonomic	3	3	3	2	3	14%
Efficiency	3	3	3	4	3	16%

Environment	3	2	2	2	3	12%
Trend	3	2	3	3	2	13%
Socio-Cultural	3	3	2	3	4	15%
					Total	100%

Assessment of the design concept begins with carrying out a screening process by comparing the design of the milk pasteurization machine high press burner technology as a baseline for alternative design concepts. The filtering process uses three symbols, namely better than the baseline (+), the same as the baseline, it is indicated by a zero symbol (0), and worse than the baseline (-). The total weight of each criterion is added up for each design concept and given a ranking. Alternative design concepts that will enter the concept selection stage are three design concepts that have a higher ranking level.

Alternative design concepts for honey pasteurization machines 8, 14, and 20 enter the next stage, namely the design concept selection stage. The weight of each criterion in the selection of design concepts has been determined by calculations which can be shown in Table 6. Assessment of the design concept is carried out visually using a scale of 1 to 5 with a description of each value (Ulrich & Eppinger, 2015) as follows:

1. Very poor compared to the baseline at 0%
2. Poor compared to baseline at 10%
3. Same as a baseline at 20%
4. Better than baseline by 30%
5. Very good compared to baseline by 40%

The evaluation matrix for the honey pasteurization machine design concept for alternative concepts 8, 14, and 20 can be explained in Table 7.

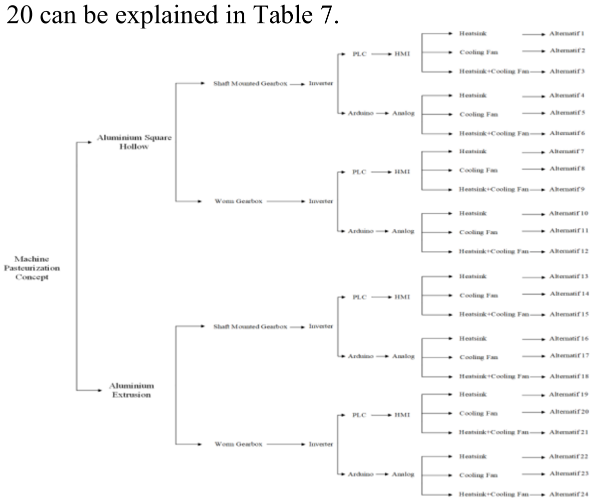


Fig. 2. Tree Diagram

Table 6. Pugh Scoring.

Criteria	**Customer Needs**	***Baseline***	**Design Concept Alternative**					
			2	4	8	14	16	20
Technical	Strong Construction	0	0	0	0	+	+	+
	Parameter Accommodations	0	+	-	+	0	-	+
	Food Processing Standards	0	0	0	0	0	0	0
Economic	Production capacity	0	+	+	+	+	+	+
	Maintenance Cost	0	-	-	0	+	0	+
Ergonomic	Operator Security	0	+	+	+	0	0	0
	UI ease	0	+	0	+	+	0	+
	Location UI and Ease of Mobility	0	+	+	+	+	+	+
Efficient	Energy Use	0	-	-	+	0	-	+
Environment	Pollution and Contamination	0	0	0	0	0	0	0
Trend	PEF technology	0	+	+	+	+	+	+
	Automation	0	+	0	+	+	0	+
Sociocultural	Product Quality Maintained	0	0	0	0	0	0	0
	Total(0)		4	6	5	6	7	4
	Total(+)		7	4	8	7	4	9
	Total(-)		2	3	0	0	2	0
	Final Score		5	1	8	7	2	9
	Rank		4	6	2	3	5	1

Table 7. Pugh Scoring.

Criteria	Customer Needs	Weight	Alternative					
			8		14		20	
			Rating	Value	Rating	Value	Rating	Value
Technical	Strong Construction	5%	1	0,05	1	0,05	3	0,14
	Parameter Accommodations	6%	3	0,17	3	0,17	3	0,17
	Food Processing Standards	8%	3	0,25	3	0,25	3	0,25
Economic	Production capacity	3%	3,8	0,11	3,8	0,11	3,8	0,11
	Maintenance Cost	6%	2	0,13	3,4	0,21	4,4	0,28
Ergonomic	Operator Security	4%	3	0,13	3,4	0,15	4,4	0,20
	UI ease	7%	3,4	0,22	3,4	0,22	4	0,26
	Location UI and Ease of Mobility	3%	3	0,10	3	0,10	3	0,10
Efficient	Energy Use	16%	3,4	0,56	3,2	0,53	4,2	0,69
Environment	Pollution and Contamination	12%	3	0,37	3	0,37	3,4	0,42
Trend	PEF technology	5%	4	0,19	4	0,19	4	0,19
	Automation	9%	4,2	0,36	4,2	0,36	4,4	0,38
Socio-culture	Product Quality Maintained	15%	3,8	0,59	4	0,62	3,8	0,59
		Total	40,6	3,23	42,4	3,34	48,4	3,78
		Rank	3		2		1	

The results of the assessment of the honey pasteurization machine design concept, design concept alternative 44 has the highest value compared to design concept alternatives 20 and 32 so the alternative chosen and developed next is design concept alternative 20.

3.6 *Design Detail Visualization*

Detailed design visualization in the form of 3D prototype visualization from selected design alternatives as preparation for prototyping and determining product specifications. Figure 3 is an alternative 3D pasteurization machine design based on design alternative 20 through the Inventor 2024.

Alternative design 20, honey pasteurization machine has the following components:

- Frame: Aluminium Extrusion
- UI: HMI
- CU: PLC with Inverter
- Cooling System: Fan
- Motor: Worm Gearbox

The PEF technology honey pasteurization machine scheme is described in Figure 4. The use of a pasteurization machine begins with inputting pasteurization parameters to the HMI which is forwarded to the PLC. At the PLC, the input of the stirring speed parameter is forwarded to the inverter, the target temperature input to the PID (Proportional Integral Derivative) to control the temperature, and the PEF input to the relay to turn on the high voltage pulse generator. The mixer is driven using a dynamo and worm gearbox with PLC control and inverter assistance. The inverter is commanded by PLC based on the frequency (Hz) to drive the AC motor and worm gearbox.

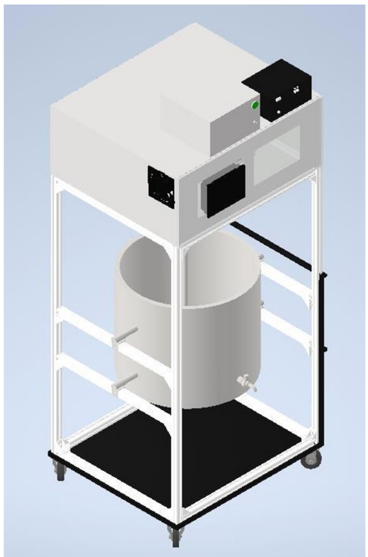


Fig. 3. Schematic Diagram Machine

The pasteurization process begins with a heating process using heat transfer fluid (HTF) technology with the help of a stirrer until the temperature of the honey reaches 60°C. The main sensor on the tube is a PT-100 temperature sensor located on the outer layer of the oil storage area. The PLC regulates the heater lifetime and scales the temperature increase as it approaches the target temperature. Temperature control is carried out with the working principle of PID. Schematic heater settings are described in Figure 6.

Figure 5 shows the relationship between the percentage of heater use and the increase in honey temperature. When the temperature of the honey is 30°C, the percentage of heating used is higher because it uses more energy to heat the honey. On the other hand, when the water temperature is closer to 60°C, the percentage of heating usage is less because it uses less energy.

Once the target temperature is reached, the PEF turns on. An explanation of the PEF generation process from a highvoltage pulse generator can be explained in Figure 4.13. The PEF generation process begins with decreasing the 220V AC voltage to 15.6V with a frequency of 50 Hz. AC voltage 15.6V frequency 50Hz rectified with rectifier diodes to DC 20V. The 20V DC voltage is then regulated by the step-down converter to regulate the incoming 0-15V power to the flyback driver. Then the DC voltage is converted to AC by the flyback driver. The voltage is multiplied by the flyback transformer to 25- 35kV with a frequency of 58kHz with a sinusoidal waveform.

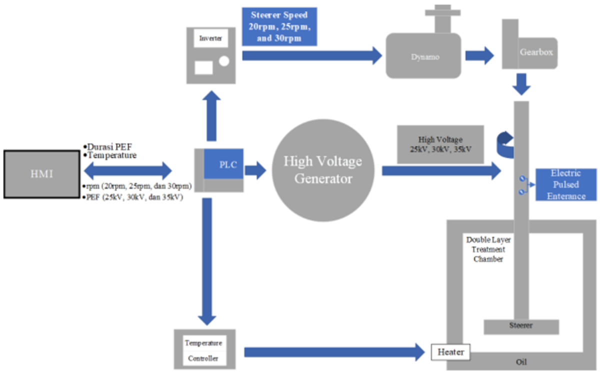


Fig. 4. Schematic Diagram Machine

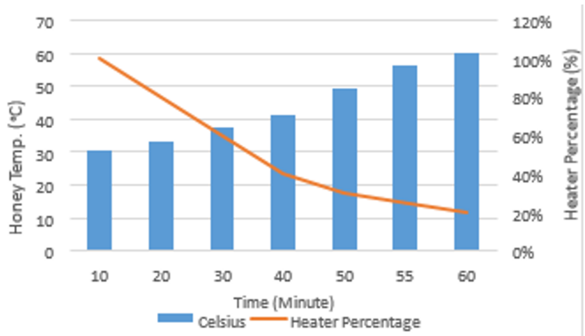


Fig. 5. Changes in Temperature Againts Honey Pasteurization Time

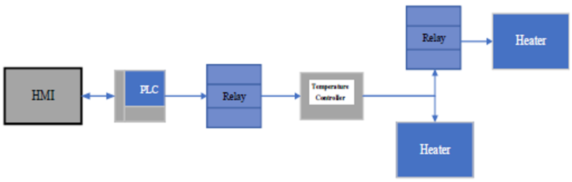


Fig. 6. Heating Diagram

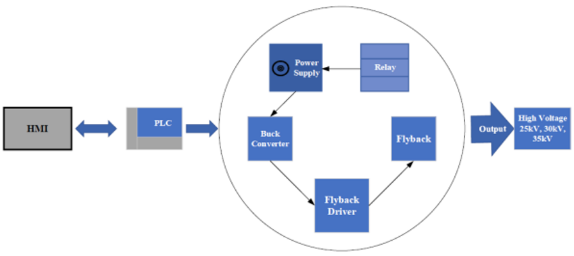


Fig. 7. *PEF* Generation

3.7 BOM

Machine components are separated into 3 categories to facilitate observation. The first category is the material group, the second category is the hardware group, and the third category is the PEF group. The BOM of the PEF technology honey pasteurization machine can be explained in Figure 4.13

The first group of materials consists of frames, tool boxes, and tubes. The frame is constructed with a total of 28 meters of extrusion aluminum. The toolbox is made of 2 sheets of 850mm × 770mm stainless steel and 2 sheets of 300mm × 1000mm stainless steel. The tube consists of 2 parts, namely the reactor tube made of 8 pieces of 500mm × 500mm stainless steel sheet and a steering wheel made of 1-meter long stainless steel pipe and 100mm × 300mm stainless steel sheet.

The second group is hardware, consisting of motors, heaters, CU and UI, and PEF. The parts included as a motor are a 1/2 Hp dynamo, a 1:40 scale worm gearbox, and an inverter. The heater consists of 2 600-watt heaters. CU and UI consist of PLC, HMI, Temperature Controller Unit, PT-100 sensor, and 3 SSRs.The last group is PEF which consists of 1 20A stepdown transformer, 2 fans, 1 capacitor, 1 rectifier diode, 1 stepdown converter, 2 flyback drivers, and 2 flyback transformers.

3.8 Design Detail Spesification

Design detail specification used for build parameters and features that are on the machine

1. Worm Gearbox NMVR 40 Spesification: In moving the stirrer, a 1340rpm 3phase 4pole AC dynamo and a 1:40 speed reducer gearbox are used. Based on these specifications, the stirrer can be adjusted in the PLC system with the help of an inverter, stirring honey at a speed of 20-30rpm.
2. User Interface: The use of Omron's HMI in the UI helps to make it easier for users to know machine status in real-time, set input parameters, and minimize operator errors.
3. Control Unit: The use of the VF100 PLC with the help of a Mitsubishi inverter, allows the machine to be programmed automatically.
4. Temperature Control: The use of the PID Controller as a temperature control allows the machine to be programmed automatically based on the target temperature specified on the PLC setting input. After the target temperature is reached, the process can go to the next process without additional or automatic commands.
5. Capacity and Weight: 80L for reactor cube capacity. The weight of all components is 155kg
6. Material: The materials used in the honey pasteurization machine are aluminum extrusion for the frame and stainless steel for the toolbox and reactor tube.
7. Voltage: 220V
8. Heater: 600W electric heater with 1.1-1.5kW data depending on heater usage.
9. Steerer
10. Honey pasteurization machine auxiliary frame
11. 80L capacity
12. 25kV-35kV PEF voltage

3.9 Prototyping

Making a honey pasteurization machine prototype was carried out after the design stage of the design results was carried out. The purpose of making a prototype is to find out the physical form of the design concept, and the manufacturing process, and to test the performance of the concept that has been developed.

A. Machine Frame

In the engine frame, there are two parts including the frame and the toolbox described as follows

1) Frame

The frame is the support and placement of honey pasteurization machine components. The frame is made using extrusion aluminum throughout and is assembled using angle bracket connectors. Connection of aluminum extrusions using connectors is carried out with M8 T-Slot nuts into the slots on the surface of the aluminum extrusions. Total frame dimensions are 120 cm × 63 cm × 72 cm with a 30 cm high toolbox at the top.

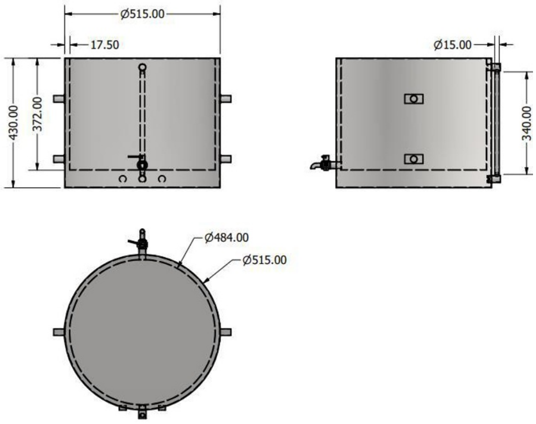


Fig. 8. Reactor Tube

Figure 8 is the dimensions of the reactor tube with a double-layered design. The dimensions of the inner layer are 48 cm and 37 cm high, and the outer layer dimensions are 51.5 cm and 43 cm high. The volume of oil needed to fill the gaps between the layers is 22 liters. The maximum volume of honey that can be accommodated is 60L with a total mass of 95.2 kg. Figure 4.16 is a drawing of a honey pasteurization machine with dimensions of 72 cm wide, 63 cm wide, and 120 cm high. The results of making the honey pasteurization machine frame can be explained in Figure 9.

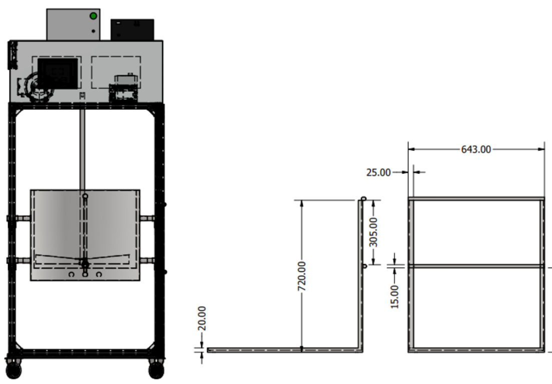


Fig. 9. Machine Frame

2) Toolbox

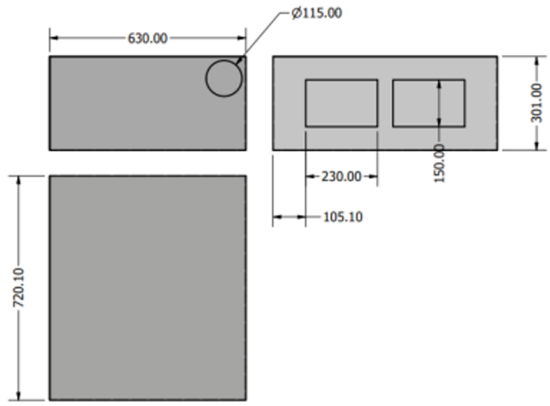


Fig. 10. Toolbox

B. User Interface

Making the UI on the HMI for CU input on a honey pasteurization machine is explained as follows:

1) Control Unit

PLC is a choice of CU design concept 6 with tough characteristics and can run complex programs. PLCs can increase the usability of HMIs by maximizing a simple UI. The PLC used in the honey pasteurization machine is Omron with technical drawings which can be explained in Figure 11.

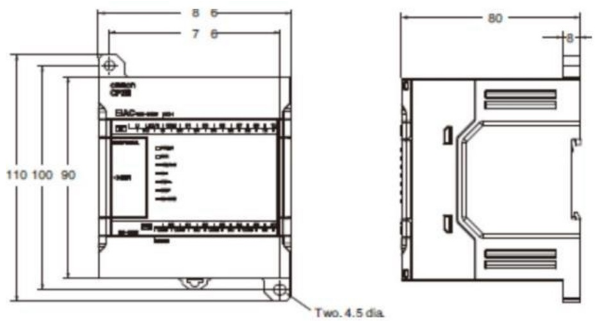


Fig. 11. Drawing Omron PLC from Manual Book PLC Omron

Figure 12 is a decision tree diagram (DTD) of the PLC and HMI program concepts using the ladder diagram programming language. DTD in the context of PLC and HMI programs is used to model the logic of a machine system for parameter control purposes. DTD's initial statement was “Pasteurization Process”. There are 4 decision questions in honey pasteurization, namely whether there is bacterial or spore contamination, the use of controls, limited power, and the condition of the product being processed.

The resistance of the processed product to temperature becomes critical in the bacterial elimination process. if the product is resistant to high temperatures, the process can be continued using a high-temperature sterilization process that is still supported by the system. Conversely, if the object is not resistant to high temperatures, the process is continued with pasteurization to the maximum temperature for product resistance and continued with PEF activation.

Temperature and timer-based process control is used to run the machine automatically after the UI setting time. Honey pasteurization machines can only be used for liquid and semi-liquid ingredients. The reactor tube is stirred during the pasteurization process to save processing time and distribute the temperature. PEF mixing and propagation processes cannot be carried out on solid objects.

2) User Inteface

Programming with the HMI module allows two-way functionality through external signal input and interactive response to the user. HMI is used to provide a minimalist, structured, and attractive appearance. HMI technical drawings can be explained in Figure 13.

The HMI displays 3 usage pages to make it easier to use and adapt to needs. Figure 14a. page used to enter pasteurization process input. Figure 14b. main page when the pasteurization process takes place automatically. Figure 14c. the manual page for certain needs with manual settings.

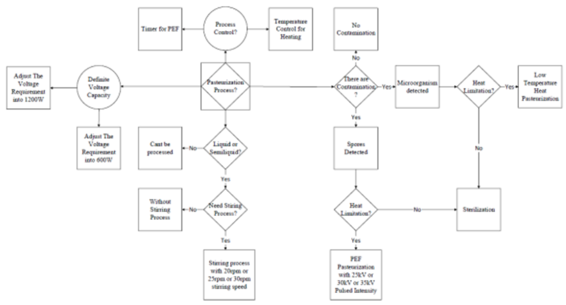


Fig. 12. Decision Tree Diagram Program

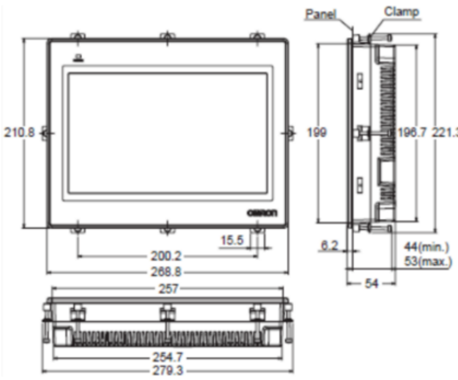
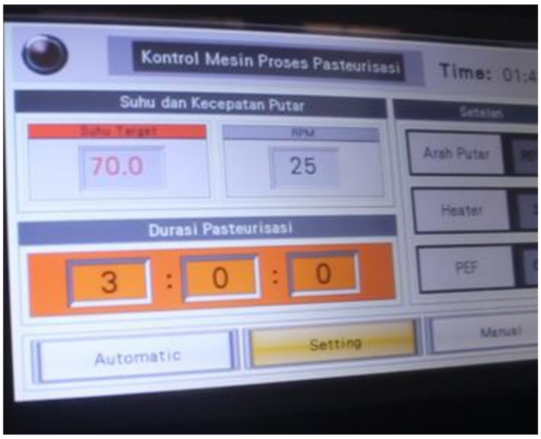


Fig. 13. Drawing HMI from Manual Book HMI Open



A

B

C

Fig. 14. Drawing HMI From Manual Book HMI Open

3) Final Result

The final result of the process of making a honey pasteurization machine is described in Figure 15

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Fig. 15. Final Result Pasteurization Machine

3.10 Honey Test Result of Pasteurization Machine Process

The pasteurization process is carried out using 10L of raw poppy honey. This test was carried out to answer process instability based on engine performance at 30kV PEF voltage at room temperature of 24ºC and 60ºC reactor tube. The pasteurization process is described as follows:

1. Put raw opium honey into the reactor tube.
2. Input parameter input
   a. Target Temperature: 24ºC and 60ºC
   b. Stirrer Speed: 0rpm
   c. Use of Heater: 2 pieces

    d. PEF Voltage: 30kV
    e. PEF Duration: 2 hours
3. Start the process by pressing the button on the "Automatic" page of the machine UI.
4. Wait for the engine alarm to sound and the engine to a complete stop
5. Open the faucet on the tube and move the honey to the place that has been prepared.

Fig. 16. Color of Raw Honey and Pasteurized Honey

In pasteurization at room temperature, honey does not go through the heating process. Honey is pasteurized using a non-thermal method using a PEF voltage of 30kV. According to Jadhav et al (2021), Non-thermal pasteurization minimizes the physical changes in food products. Pasteurization using the non-thermal method causes a slight change in color as shown in Figure 16B. In pasteurization with a target temperature of 60ºC, honey goes through a thermal or heating process from 30ºC to 60ºC. After the target temperature is reached, then the honey is processed non-thermal using a PEF voltage of 30kV. Pasteurization with a combined method of thermal and non-thermal honey color as shown in Figure 16C.

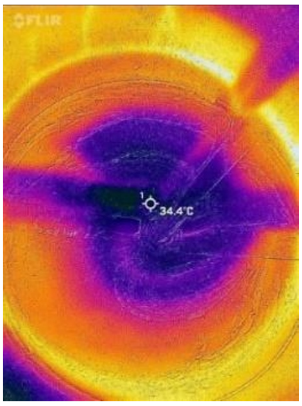

Fig. 17. Heatwave After 50 Minutes Heating Process Without Steerer

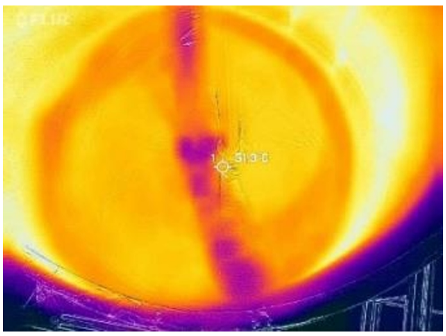

Fig. 18. Heat Wave After 50-Minute Heating process With Steerer

Heating without stirring causes the temperature to be uneven, thereby slowing down the pasteurization process. Heating without stirring takes 75 minutes to reach 60ºC. Stirring system plays an important role in ensuring temperature distribution in the pasteurization process (Sunmonu et al., 2022). The temperature of honey after 50 minutes of heating without stirring is described in Figure 17. The orange color is honey that has been exposed to heat, while the purple color indicates honey that has not been exposed to heat. The stirring process in the pasteurization of honey is crucial in distributing the temperature and speeding up the pasteurization time. Figure 18 is the temperature of pasteurized honey with a stirring process.

3.11 Laboratorium Test Pasteurized Honey

Pasteurized honey was tested at UPT Laboratory UNS. The purpose of testing honey in the laboratory is to find out the difference in the content of raw honey and pasteurized honey. Table 8 is the laboratory test results for raw honey and pasteurized honey.

Table 8. Honey Test.

No	Test Type	Quality Req. According SNI 8664:2018	Test Result		
			Raw Honey	PEF	PEF and HTF
				Honey24ºC, 30kV, 120minute	Honey 60ºC, 30kV, 120minute
1	Organoleptic				
	- Smell Test	Honey Typical	Honey Typical	Honey Typical	Honey Typical
	- Taste Test	Honey Typical	Honey Typical	Honey Typical	Honey Typical
2	Mold and Yeast Test	Max.1x10^2	1x10^2kol/g	<1x10^1kol/g	1x10^1kol/g
3	Moisture test	Max. 22%	18%	18%	17,4%
4	HMF Test	Max. 40mg/kg	20,10mg/kg	20,51mg/kg	20,81mg/kg
5	Diastase Test	Min. 3DN	15DN	12DN	10DN

Table 8 shows that non-thermal and thermal-non-thermal pasteurized honey has a distinctive taste and smell of honey. Non-thermal and thermal-non-thermal pasteurized honey has decreased mold and yeast. Non-thermal pasteurized honey did not decrease in water content, while thermal-non-thermal pasteurized honey experienced a 0.6% decrease in water content. Non-thermal pasteurized honey experienced an increase in HMF of 0.41 mg/kg while thermal-non-thermal pasteurized honey experienced an increase in HMF of 0.71 mg/kg. The diastase enzyme of non-thermal pasteurized honey decreased by 3DN and thermal-non-thermal pasteurized honey decreased by 5DN.

4 Conclusion

The honey pasteurization machine is classified as a food industry machine with a reactor tube with a capacity of 80 liters and a weight of 140 kg. The input voltage is 220V and the power is 1.1-1.5 kW depending on the use of the heater. The machine is designed automatically and according to SNI 8752: 2019 standards. The UI sets the honey temperature, processing time, stirrer speed, and PEF intensity. The stirrer speed has 3 variations including 20rpm, 25rpm, and 30rpm. PEF intensity can be set from 25kV, 30kV, and 35kV.

In an automatic program, it is necessary to set parameters on the setting page including target temperature, PEF duration, stirrer speed, and PEF intensity. The process starts with heating and stirring until the target temperature is reached, then PEF turns on according to a predetermined duration.

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