Microcontroller

by Ig. Jaka Mulyana

Microcontroller application for pH and temperature control system in liquid sugar liquefaction process made from cassava (*Manihot esculenta* Crantz.)

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Abtract. Sugar is a major source of sweetening but the increase of sugar demand is not in line with sugar cane production capacity in Indonesia. Therefore it is necessary to look for alternative other sweeteners as sugar cane substitution. The process of making glucose syrup made from cassava, sweet potato corn, sago is relatively simple and can be done on a small or medium scale industry. But in fact in Indonesia, glucose syrup producers are almost all big industries. This is due to the lack of development of appropriate technology for the manufacture of liquid sugar. Based on preliminary experiments, there is a significant influence of the combination of α-amylase enzyme factor and liquefaction time factor on reducing sugar content. This is by controlling the processing time, temperature (70 to 80) °C by stirring constantly and pH level 5.5. These three parameters are controlled and are being implemented with the design of an industrial liquid sugar processing apparatus. This system is designed with stainless steel material, and arduino microcontroller. Consumption of system power when the standby condition is 4.5 W. When the system is working at 311 W by activating the stirrer motor, gas valve and lighter.
Keywords: Appropriate technology, arduino, enzyme, glucose.

1. Introduction

Sugar as one of the nine basic human needs is a major source of sweetening and is widely used throughout the community. Sugar demand in Indonesia always increases along with the increase of population and industry growth in Indonesia. Ironically, the increase of sugar demand is not in line with sugar cane production capacity in Indonesia. so that import becomes one choice. In 2012, the need for white crystal sugar is 5.13 × 10^6 t, of which 2.60 × 10^6 t is household and the remaining 2.53 × 10^6 t is the industry need. While the amount of production is only 2.5 × 10^6 t. Dependence on imports will continue to be consistent with population growth, and increased public revenues and industry growth. According to the Indonesian Refined Sugar Association (AGRI), in 2015 the domestic production is only around 2.47 × 10^6 t and national sugar needs of 6 × 10^6 t or equivalent to 6.38 × 10^6 t of raw sugar. As a result, there is a deficit of around 3.53 × 10^6 t which must be covered by imports [1].

Therefore it is necessary to look for alternative other sweeteners as sugar cane substitution. Sugar made from starch like cassava, sweet potato corn, sago can be an alternative [2]. The process of making glucose syrup is relatively simple and can be done on a small or medium scale industry. But in fact in Indonesia, glucose syrup producers are almost all big industries. This is due to the lack of development of appropriate technology for the manufacture of liquid sugar is simple and cheap. In this research will be done the design of equipment production process of liquid sugar made from raw cassava that can be developed by small industry. The device is designed with stainless steel material, and uses arduino uno microcontroller as its controlling center, the working of this tool is the pH meter probe and the Resistance Temperature Detector (RTD) produces a measured resistance value and is accepted by the signal conditioning circuit. If the arduino uno detects and yes changes the measured voltage value and does not match the acid-base and temperature limits then the arduino will run the acid-base pump and the heating regulator.

2. Materials and methods

2.1. Material research

Liquid sugar is known to the public by the name glucose syrup or fructose syrup. Glucose syrup is a condensed solution including monosaccharide groups obtained from starch by means of a complete hydrolysis by using an acid or enzyme catalyst, further purified and thickened. Diagram process flow the making of liquid sugar can be seen in figure 1.

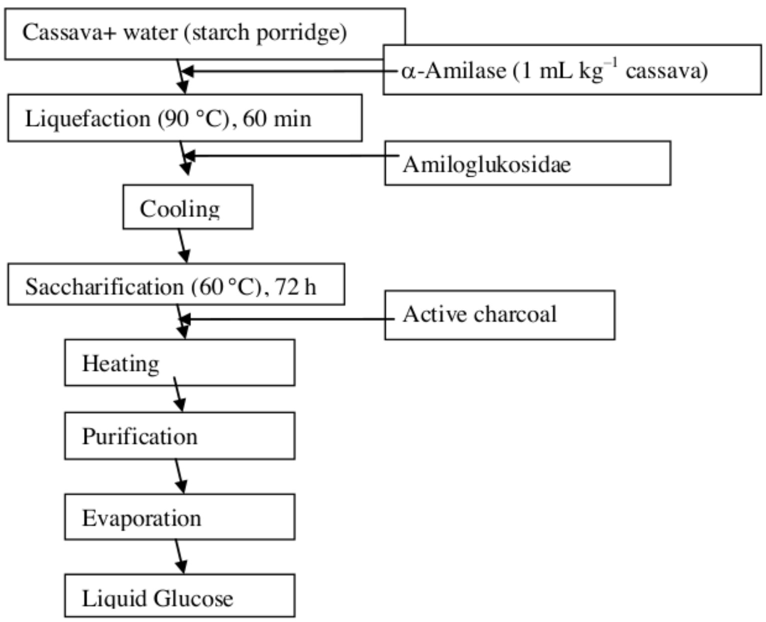

Figure 1. Liquid sugar making process [3].

The process of making liquid sugar is divided into several stages:

(i) Liquefaction stage: Liquefaction process is the process of change of starch from condensed to dilute. The mixture of starch and water (star suspension) heated to boiling will thicken (gelatinization). The ratio of water and flour is 3:1 stirred until well mixed and then included a number of α-amylose enzymes of 1 mL kg^{-1} of starch. A pH setting of pH 6.2 to pH 6.4 was performed with the addition of one table-spoon of lime. Liquefaction process can be stopped if the solution is completely liquid and clear brown.

(ii) The stage of saccharification: The process of saccharification is the process of dextrin to sugar changes. The starch has been broken down into a later descooled cooling from 105 °C to 60 °C with the addition of an enzyme amyloglucosidase of 1 mL kg^{-1} of starch to break down the descrank chain

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into glucose. The saccharification process takes a maximum of 72 h. The saccharification process is completed when the viscosity value 30 Brix to 35 Brix has been achieved.

(iii) Phase of purification: The purification process is done by mixing the glucose liquid with activated charcoal. Activated charcoal has a very strong adhesion or absorption capability that can bind, coagulate and precipitate inorganic or organic components to free the syrup from unwanted impurities. Purification is done by mixing the liquid glucose with activated charcoal with temperature setting 80 °C.

(iv) Filtering stage: Filtering is useful for separating the activated charcoal and components attached to the syrup liquid. This filtration is expected to retain the particles of impurities that have been previously coagulated by the activated char so that the resulting liquid is clear yellow.

(v) Evaporation stage: Evaporation is performed on reactors previously used for liquefaction and saccharification processes. The process is carried out at 70 °C. Evaporation aims to concentrate glucose from (30 to 35) brix to (43 to 80) brix to obtain clear colored yellowish sugar. The type of cassava used cultivated the same is white cassava. Use of the α-amylase enzyme is purchased from the same manufacturer and the residual α-amylase enzyme already used is stored in the refrigerator to avoid damaging the α-amylase enzyme.

2.2 Methods of research

The research methods include the following steps:

(i) Designing of liquid sugar processing and manufacture of liquid processing tool based on milrocontroller which includes mechanical and electronic design both hardware and software. The block diagram of the control system of the system can be shown in figure 2.

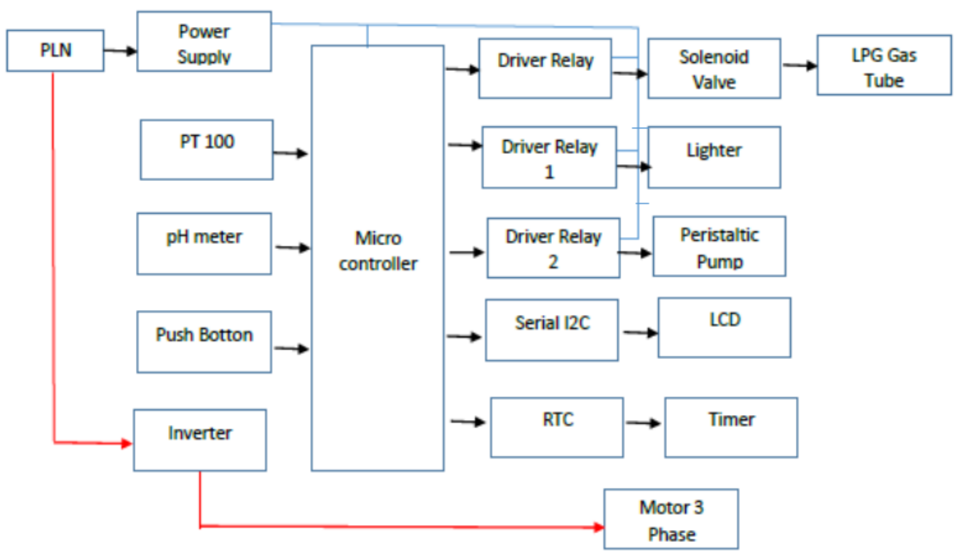

Figure 2. Block diagram.

The power supply from the 220 VAC PLN line is connected to the power supply circuit to supply the agitating motor and generate 5 VDC and 12 VDC voltages to supply the driver, microcontroller and sensor circuit. Valve type used is a DC valve. The source of this power supply is not directly connected to the valve and the water pump but through the driver circuit first. This driver circuit will get an input signal from a microcontroller to set the load or valve closing time.

In making this liquid sugar using a voltage source from the power supply to supply the voltage in the microcontroller circuit, the driver circuit and solenoid valve, microcontroller will process the value readings to the pH and temperature sensors by performing some calculations [4, 5]. The relay is used to drive the solenoid valve to open the gas line of the LPG gas tank for heating.

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Both sensors are inserted in the liquid sugar solution to measure their pH. The pH probe produces an electrical voltage according to the measured pH. And the temperature sensor produces a binary value according to the measured liquid sugar temperature, the result of the sensor reading value being sent to the LCD. The next process of programming to run the driver circuit in accordance with the value obtained to be able to set the desired temperature. The work flow chart of the system automation system liquefaction and saccharification process in liquid sugar making from cassava is shown in figure 3:

(i) Measurement and testing of tools that have been made to know the performance of the tool as a whole. In the manufacture of liquid sugar using two processes of liquefaction and saccharification. Liquefaction the cassava (starch) solution is heated at 95 °C to 105 °C and maintained for 1 h, whereas at pH it is maintained at acidity of pH 6.2 to pH 6.4 to maintain pH with the addition of lime. Liquefaction process can be stopped if the solution is completely liquid and clear brown. After 1 h of warming, it is continued in the process of saccharification, after cooling to 60 °C, enzyme amiloglukosidase added 1 mL kg^{-1} of starch. The pH is adjusted to pH 4 to pH 4.6 by adding HCl solution into the starch solution. The saccharification process takes up to 76 h.

(ii) Conducting several experiments to collect data and analyze it. After doing data analysis, drawing conclusions from the overall experimental results.

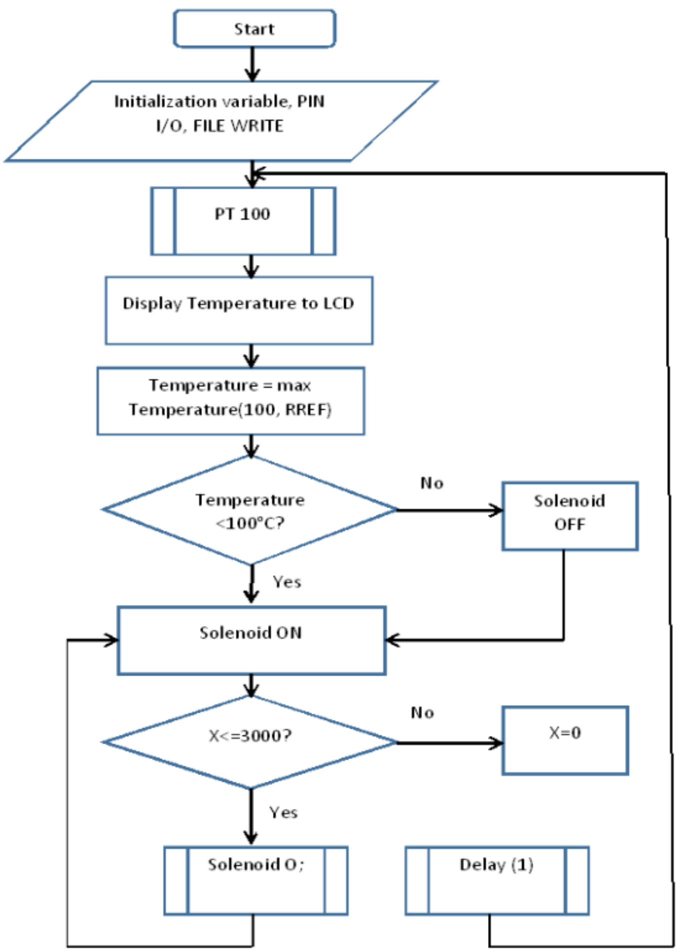

Figure 3. Flow chart diagrams.

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3. Results and discussion

The results obtained in this study can be explained as follows:

3.1. Construction tank

The process of liquefaction and saccharification process of liquid sugar consists of two parts, namely stirrer and heater and panel box control system. The stirrer and heating apparatus used for the framework is made of iron and tank and stirrer stainless steel stirrer with tank size of 80 L with the diameter of 47 cm and height 47 cm shown in figure 4.

Figure 4. Mixing and heating equipment.

The panel box in the design of liquid sugar processing contains several components such as power supply, microcontroller, LCD, and driver circuit to run solenoid valve, lighter, peristaltic pump and push button start or stop. The panel box has a dimension 30 cm × 40 cm × 10 cm can be shown in figure 5.

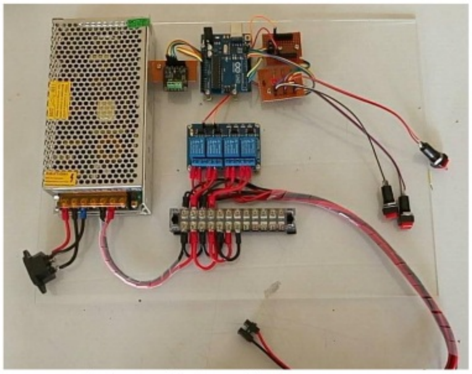

Figure 5. Panel box.

The circuit of electronics as the overall controller of the system is composed of a series of modules PT 100, Series of pH Meter Modules.

3.1.1. The PT100 Module circuit. MAX31865 module is a device of Pt100 to get the desired temperature value. Use amplifiers designed to read low resistance, and have amplifiers that can adjust and compensate for output output. Schematic Pt100 module can be shown in figure 6. Temperature measurement is done by inserting the PT100 sensor into a pan containing water that has been heated and then lowered in temperature to obtain a number of samples from 30 °C to 120 °C. The average percentage error between the measurement thermometer and PT 100 sensor is 0.86 %.

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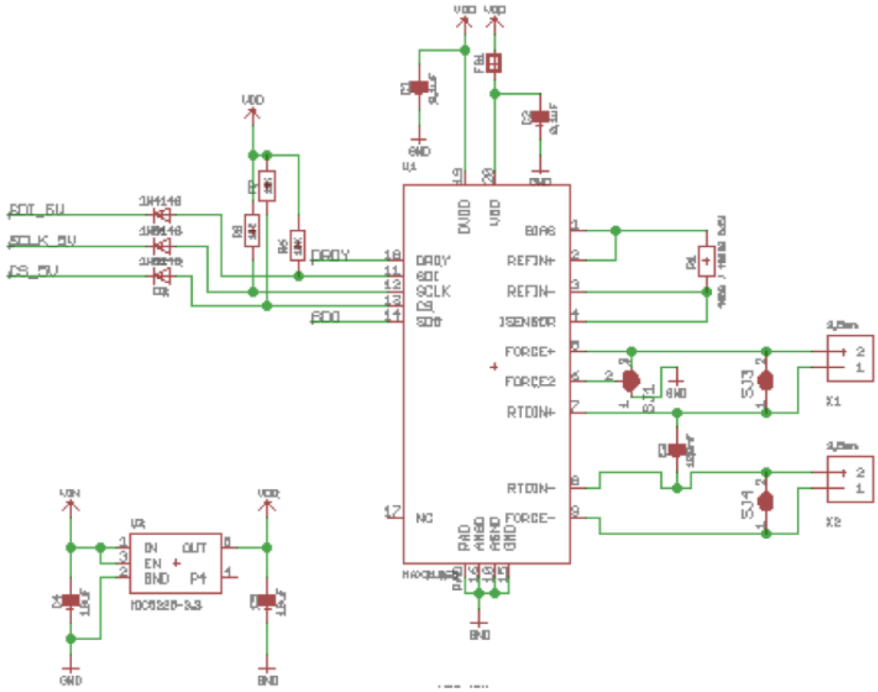

Figure 6. Schematic module Pt100.

3.1.2. Network module pH meter [6]. The output of the pH sensor is a voltage value in which the value of this voltage must be measured with an amplifier circuit in the form of OP-Amp whose task is to amplify the voltage so that the voltage can enter the ADC work area. Figure 7 is an image of the pH sensor Logo module.

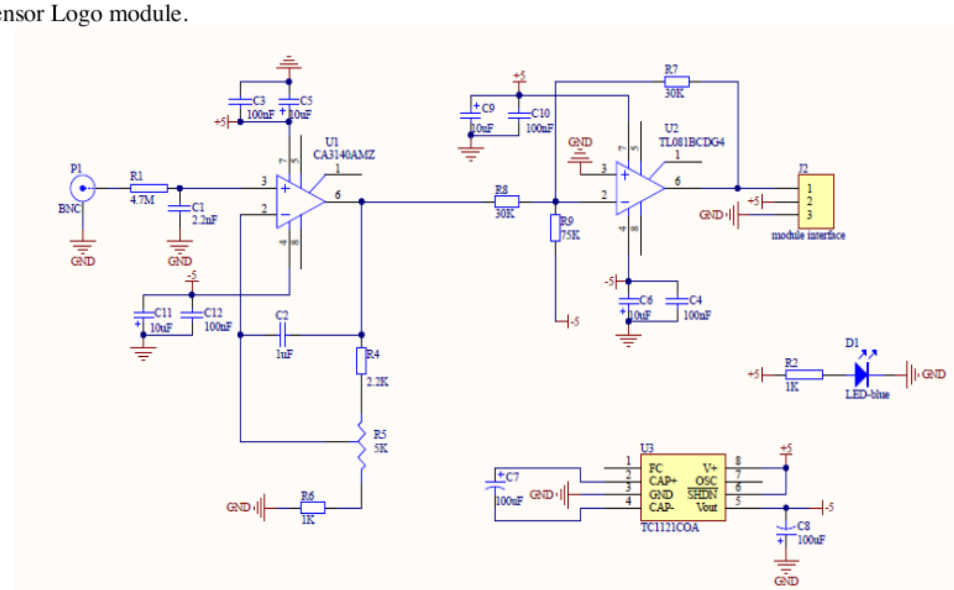

Figure 7. Schematic module logo pH sensor.

Reinforcement of RPS (Signal Conditioning Circuit) is three times that the output voltage does not exceed the input of the maximum ADC voltage allowed. The trick is to set the potentiometer R5 so that the gain does not exceed the specified ADC limit. In conducting the preparation of liquid heating sugar required at certain desired temperatures and pH, Arduino Uno microcontroller first initialises the port. PT100 and Probe pH meter will read the temperature and pH values and value read will be displayed on the LCD. If the start or stop button is pressed (0) then the Solenoid Valve will live to open the LPG gas tap, then the lighter will live for 3 s to spark fire, and the agitator to stir the processed liquid sugar. When the tool does the heating and stirring process, the PT100 Sensor will keep reading the temperature change. If the temperature value has reached the limit then the Solenoid Valve will close the LPG gas tap. In the process of measuring this system the experiment is carried out with a comparative buffer solution and a fixed temperature which is the room temperature around 24 °C to 26 °C to be able to determine the level of accuracy of the tool designed. The average percentage error between the measurement of pH meter ATC and pH meter analog is 1.09 %.

3.2. System testing based on ATmega328 AVR series microcontroller [7]

System testing aims to find out the automation works well and to know the length of time the process occurs. Measurements are made by mixing starch flour with water at a rate of 5 Kg in volume 15 L. The power consumption is 4.5 W when the system standby, and needs 311 W by activating the stirrer motor, gas valve and lighter. The collection of temperature and pH, power and currents data is carried out every 5 min or there is a change in the material being tested. From the data obtained, the testing time is 134 min. The results and measurements system based on microcontroller performance can be shown in Table 1.

Table 1. Data of temperature dan pH based on microcontroller performance.

Timer	Temperature (°C)	pH	Stove	Watt (W)	Current (A)	Information
-	-	-	-	285	3.01	Mixed starch
-	32	7.05	ON	266	2.97	Heating
-	54	7.19	ON	261	2.94	Heating
-	84	7.11	ON	304	3.12	Gelatinization
1	100	6.99	OFF	292	3.04	Enzym on
3	96	6.89	OFF	277	3.00	The material melts
5	96	6.85	ON	277	2.99	Light brown liquid
7	98	6.78	ON	275	2.98	Dark brown liquid
10	101	6.77	OFF	260	2.93	Dark brown liquid
15	98	6.70	ON	269	2.95	
-	-	-	-	-	-	Time break
15	79	6.98	ON	280	2.99	
20	83	6.93	ON	272	2.94	
25	89	6.85	ON	266	2.94	
30	93	6.85	ON	252	2.89	
35	96	6.83	ON	261	2.94	
40	92	6.83	ON	263	2.94	Small fire
45	90	6.81	ON	267	2.94	Small fire
50	92	6.78	ON	262	2.93	Small fire
55	95	6.77	ON	258	2.90	Small fire
59	97	6.76	ON	260	2.94	Small fire
-	-	-	-	4.5	-	Process done

3.3. Data retrieval and data analysis

In the process of making liquid sugar by using enzymatic methods, there are two processes that use the enzyme that is the process of liquefaction and saccharification process [3, 8–10]. Liquefaction process uses α-amylase enzyme while saccharification process using glucoamylase enzyme. The volume of cassava solution used is 1 L. The solution is heated by hot plate while continuous stirring using stirring rod. This stirring aims to keep the solution homogeneous. The heating temperature of the solution is about (70 to 80) ºC up formed gel on the solution of cassava starch. This process is called gelatinization process. The gelatinization process takes about 20 min.

The gel-formed solution then measured its pH using a universal pH paper. The pH of the solution is adjusted to a pH of 5.5 using vinegar. After reaching pH 5.5, the gel-ready solution is ready to enter the next process that is the liquefaction process. The gel-formed solution is then added α-amylase enzyme according to the predetermined level while remaining heated by hot plate with continuous stirring until ± 100 °C. In this process, the temperature of the solution is kept constant until the process is complete. Factors influential in the process of liquefaction which made free variable is the amount of enzyme α-amylase and time of the process of liquefaction. The level of the independent variables can be shown in table 2. The number of α-amylase enzymes in ml units and the liquefaction process time in minutes.

Table 2. Free variable level full factorial design method.

Independent variabel			
Number of enzymes α-amylase (X1), mL	0.8	1.2	1.6
Processing time (X2), min	30	45	60

The combination of the factors and the level of the liquidity process and the result of the measurement of the reduction sugar content from the resulting liquidity process can be shown in table 3. The result of the experiments of the liquefaction process is then measured by reducing the reducing sugar by using the spectrophotometer in the laboratory. The experiment was done by replicating two times.

Table 3. Factor and experiment level combinations, measurement results and mean calculations.

Number of enzymes α-amylase (mL)	Processing time (X2), min	Replication 1	Replication 2	Mean
0.8	30	33.3233	43.499	38.4112
0.8	45	52.68	63.166	57.923
0.8	60	74.3467	80.87	77.6084
1.2	30	167.467	158.568	163.017
1.2	45	102.433	107.925	105.179
1.2	60	78.1067	61.626	69.8664
1.6	30	28.4733	31.553	30.0132
1.6	45	50.3833	53.2112	51.7973
1.6	60	307.8	301.75	304.775

In combination of 1.6 mL of α-amylase enzyme and 60 min of liquefaction process, the average value of reducing sugar content was 304.775 g L^{-1}. From table 2, there is a significant effect of the combination between the enzyme α-amylase factor and the time factor of the liquefaction process on the reduction sugar content.

4. Conclusion

Based on preliminary experiments, there is a significant influence of the combination of α-amylase enzyme factor factor and liquefaction time factor on reducing sugar content. This is by regulating and maintaining the processing time, temperature (70 to 80) °C by stirring constantly and maintained pH level 5.5. These three parameters are regulated and are being implemented with the design of an industrial liquid sugar processing apparatus. From the liquefaction process carried out by the tool it takes around 134 min with a capacity of 20 L. Consumption of system power when the standby condition is 4.5 W. When the system is working at 311 W by activating the stirrer motor, gas valve and lighter.

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