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Design and Build Mini Alcohol Distillation Equipment from Nira Aren

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ABSTRACT

Palm sap is a sweet liquid obtained from the sugar palm plant (Arenga pinnata MEER) by cutting the flower stalk. Generally, palm sap is widely used for the manufacture of brown sugar, fresh drink of palm sap (saguer), vinegar and alcoholic beverages. The model planned for the manufacture of this distillation is water distillation, where the accommodated palm juice is placed in a container that is in direct contact with heating water, then the juice vapor is passed through a pipe which is then condensed through a condenser and the results are accommodated through an alcohol container. over H2O (water) and alcohol, because the difference in boiling temperature where the boiling temperature of water is higher so that at a temperature of 87 C which is the boiling temperature of the alcohol will evaporate first while the water has not undergone the evaporation process. So the pump efficiency is 91.6%. From the results of the calculation of the design of palm juice distalization, the following conclusions can be drawn: Construction of Distalation Capacity: 5 liters Heating media: Stove for kerosene materials Distallation model: Distillation with water, equipped with a condenser Skeleton Material: Iron profile plate 40 Base material: 12 mm plywood board Condenser water tank Size: 300 mm × 300 mm × 300 mm Material: 0.7 mm zinc plate University of North Sumatra.

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1. INTRODUCTION

Palm sap is a sweet liquid obtained from the sugar palm plant (Arenga pinnata MEER) by cutting the flower stalk (Hazwi, 2009). Generally, palm sap is widely used for the manufacture of brown sugar, fresh drink of palm sap (saguer). (Siregar, 2009), vinegar and alcoholic beverages (Riyani, 2018). There are 3 million palm trees that are spread throughout North Sumatra (Munir, 2015). According to data from 1994/1995 from the Regional Office of the Ministry of Industry and Trade of North Sumatra (Sunderlin & Resosudarmo, 1997), there were 854 business units of alcoholic beverage industry with 20-40% (Susianawati, 2006), known as the rat stamp whose raw material is palm sap. From this amount, about 4 million liters of alcohol are obtained per year which are only used for alcoholic beverages (Pribadi, 2017). As for the business of making alcohol with high purity, no effort has been made, even though the need for high alcohol content for the pharmaceutical, cosmetic, and chemical industries is quite large and tends to increase. (Hambali et al., 2007). Alcohol, another name is ethanol (C2H5OH) which is a very important raw material for the pharmaceutical industry as a mixture of drugs (Aziz et al., 2018), for cosmetics as an antiseptic, as a chemical solvent in the laboratory and industry, in hospitals as a disinfectant and burning spirit for household purposes (Putro, 2012).

Separation of alcohol from fermented palm sap is generally carried out by traditional distillation (Gugule et al., 2019), but the main problem in this distillation is that it is not effective in separating compounds having a boiling point difference below 80°C. (Kristanti, 2019). In addition, the method that is done many times to get the results to be very pure is time consuming and not economical (Piryadi, 2013). The main problem faced by small entrepreneurs is the distillation system (distillation) of palm sap into alcoholic beverages which is still very simple, namely by using distillation equipment which is generally made of bamboo which is 25 meters long and the cooking place is made of used drums (Rumagit & Tulung, 2017). Through touch and refinement of processing distillation technology, the quality of alcohol can be increased to high purity industrial alcohol so that its products can be marketed at a higher price than the alcohol produced by traditional distilleries (Teti Indrawati, n.d.). The apparatus for fractional distillation is very different from traditional distillation (Mulyono et al., 2016). The fractionating distillery has a fraction column inserted between the heating tanks via the distillation neck or connected via a pipe, wherein the pipe is inserted from the side of the fractionating column tube vertically. In fermented palm sap, there are various components, but there are two major components that must be separated, namely water and alcohol in addition to fusel oil as the cause of odor and taste. The two components have different boiling points at atmospheric pressure, namely 100°C for water and 87°C for alcohol (Julianto & Rubiyanto, 2011). Fusel oil contains high alcohols such as pentanol in addition to ketones, aldehydes, esters and water (Faida, 2019). In general, fractionation distillation is used to separate mixtures between 2 kinds of volatile liquids (Irawan, 2010), suppose a mixture of 2 liquids A and B, where B is more volatile than A (boiling point B) Based on the results of the study above (Syar, 2021), industrial alcohol can be made from the basic ingredients of palm sap that has been fermented by microorganisms.

The objectives of the Design of Alcohol Fractionation Distillation Equipment From Palm Oil are: (1) Improving the traditional distillation technology system with a fractionation distillation system. (2) Motivating small entrepreneurs to optimize the use of these tools. The benefits of designing an alcohol fractionation distillation device from palm sap are: (1) it can add insight into the process of making alcohol fractionation from palm sap and apply the knowledge gained during lectures which is used to design an alcohol fractional distillation device from palm sap (2) to support technology development suitable for small and medium industries. (3) For students who want and are interested, they can develop this alcohol fractionation tool from palm sap. (4) For small and medium industries that need this tool.

2. RESEARCH METHOD

2.1 Capacity Planning for Palm Oil Distillation Equipment

The palm sap heating tank is planned to be able to accommodate 5 liters of palm sap (Winarso et al., 2014). This heating tank is made of 0.7 mm thick zinc plate in the form of a cube.

2.2 Heating Media

The heating medium used is a kerosene stove, this stove has a capacity of 2.5 liters of kerosene (Sumangat et al., n.d.).

2.3 Distallation Model Planning

The model planned in the manufacture of this distillation is refining with water, where the accommodated palm juice is placed in a container that is in direct contact with heating water, then the juice vapor is passed through a pipe which is then condensed through a condenser and the results are accommodated through an alcohol container (Mahfud & Sabara, 2018).

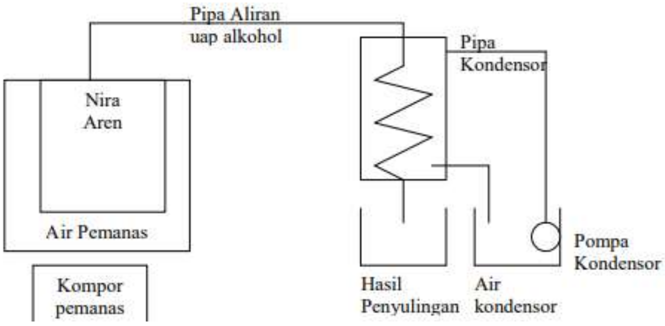

Figure 1. Heating Water System Distallation Model

3. RESULTS AND DISCUSSIONS

3.1. Aren Nira Place (Nira Heater) And Water Heater

3.1.1. Place Nira Aren (Heat Nira)

Nira consists of H2O (water) and alcohol, due to the difference in boiling temperature where the boiling temperature of water is higher so that at a temperature of 87 C which is the boiling temperature of the alcohol, it will evaporate first while the water has not undergone the evaporation process. The amount of heat energy received by the heating water must be able to evaporate the palm sap, then the amount of heat energy to evaporate the palm sap can be calculated as follows:

$$Q = \left[\left(\rho V_{Air} \right) \times Cp_{Air} \times \Delta T \right] + \left[\left(\rho V_{Alkohol} \right) \times Cp_{Alkohol} \times \Delta T + \left(\rho V_{Alkohol} \right) H_{Laten\ Alkohol} \right] \quad (1)$$

Table 1. Alcohol yield in 25 L of palm sap

Volume bahan baku (L)	Suhu Air (°C)	Volume distilat (L)	Kadar Alkohol (%)	Rendemen (%)
25	78-90	2,71	86-90	10,84
25	78-90	6	86-89	24
25	78-90	6,2	82-84	24,8
25	78-91	6,77	82-85	27,08
25	78-91	4,07	84-86	16,28
25	78-91	2,71	87-90	10,84
Rata-rata rendemen				19

Using pinometer and alcoholmeter
Source: Suryanto, E., 1998, Effect of Addition of Active Coconut Shell Charcoal and Calcium Oxide on Increasing Alcohol Purity of Nina Aren, Unpublished, Sam Ratulangi University, Manado. From the table above, in 25 L of palm sap, there is 19% alcohol. This means that in 5 liters of palm sap there are 0.95 liters (0.95 × 10-3 m3) of alcohol (approximate price) and the rest is water (4.05 × 10-3 m3), so:

$$Q = \left[\left(1000 \times 4{,}05 \times 10^{-3} \right) \times 4{,}174 \times 55 \right] + \left[\left(800 \times 0{,}95 \times 10^{-3} \right) \times 2{,}437 \times 55 + \left(800 \times 0{,}95 \times 10^{-3} \right) \times 850 \right] \quad (2)$$

3.1.2. Water heater

The water heater is made of zinc plate with a thickness of 0.7 mm and the size is adjusted to the size of the heating stove measuring 0.35 m × 0.35 m × 0.35 m. The water heater is in the shape of a cube, its length should be longer than the length of the heating stove. The juice heater is located inside the ir heater. The planned side of the water heater (S) is:

S1 = S +0.028 m
Where : 0.028 m = distance between water heater and juice heater
S1 = 0.185 + 0.028 = 0.213 m

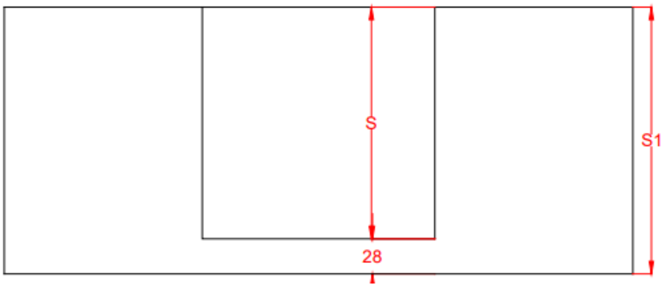

Figure 2. Water Heater Side Size

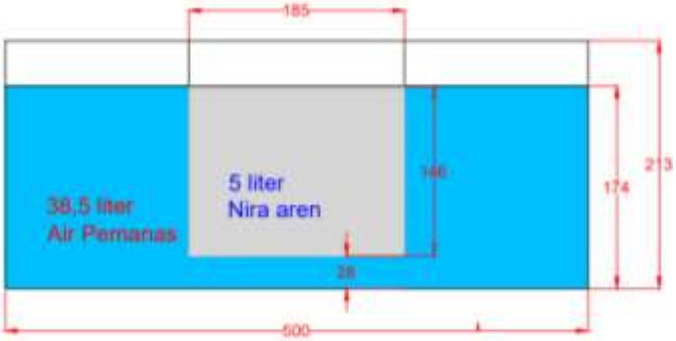

Figure 3. Water Heater Size

3.2. Condenser

In accordance with the working principle of the condenser to convert alcohol vapor into liquid alcohol, it is necessary to have a suitable cooling medium. The cooling medium selected is water circulated through a pump. The energy balance in the condenser is that the energy absorbed in the cooling water must be equal to the energy released by the alcohol vapor. If the hot temperature of palm juice vapor passing through the copper pipe is 87 C and the temperature of the alcohol leaving the condenser is planned to be 32ºC while the cooling water entering the condenser is 29 C, in the condenser system planning tWater Out < tAlcohol Out then the temperature of the water leaving the condenser is 31 C, So the heat released by the alcohol is:

$$Q_{Alkohol} = m_{Alkohol} Cp_{Alkohol} \Delta T_{Alkohol} + m_{Alkohol} H_{Laten} \quad (3)$$

Meanwhile, the volume of cooling water is: VAir 00258.0 ×= 569.34674 = 89.46046 m3

3.3. Condenser Design

The alcohol vapor flow pipe is designed from copper, this pipe is widely sold in the market with a pipe outer diameter of 10 mm with a thickness of 1 mm. Then the area of the heat exchanger is:

$$A = \frac{Q_{Alkohol}}{U \Delta T_m} \quad (4)$$

As for the mass flow rate of alcohol:

$$\dot{m}_{Alkohol} = \frac{m_{Alkohol}}{waktu} = \frac{800 \times 0,95 \times 10^{-3}}{34674,569} = 2,19 \times 10^{-5} \text{ Kg/s} \quad (5)$$

The average flow rate is:

$$u = \frac{m_{Alkohol}}{\rho_{Alkohol} A_{pipa}} \qquad (6)$$

Then the area of the pipe wall (A) is:

$$A = \frac{27{,}568}{133{,}017 \times 2{,}839} = 0{,}073 \text{ m}^2$$

As for the length of the pipe can be calculated as follows:

$$L = \frac{A}{\pi d} = \frac{0{,}073}{\pi(8 \times 10^{-3})} = 2{,}9 \text{ m}$$

So the length of the alcohol vapor flow pipe required is 2.9 meters
As for the height of the condenser, it is planned to take of the overall height of the water heater, namely 0.5 × 0.563 m = 0.2815 m. And for the condenser diameter can be calculated as follows:

$$V_{Air} \geq V_{Air\ kondensor} + V_{Air\ bak\ penampung} \qquad (7)$$

Where VAir reservoir = 0.3 m × 0.3 m × 0.3 m (planned) 89.46046 m3 VAir condenser + (0.3 × 0.3 × 0.3)
VAir condenser 89.43346 m3
If seen, the volume of water in the condenser is not in accordance with the plan (not in accordance with the construction), so the volume is reduced to 0.000286 (planned price), then the volume of condenser water is 0.025545 m3. If seen, the volume of water in the condenser is not in accordance with the plan (not in accordance with the construction), so the volume is reduced to 0.000286 (planning price), then the volume of water in the condenser is 0.025545 m3. So the diameter of the condenser is 0.34 m. Because the steam flow pipe is too long, it will be made into a spiral shape, the number of n spirals can be calculated as follows:
L = nπd spiral curvature
Where D spiral curvature< DCondenser = 0.30 m
2.9 = n 0.942
n = 3 spiral shapes
To determine the distance between the spirals (s) can be calculated as follows:
tcondenser = nDpipa +((n-1)s)
0.2815 = 3(0.01) + ((3-1)s)
0.2815 = 0.03 + 2s
0.2515 = 2s
s = 0.126 m
So the distance between the spirals is 12.6 cm

3.4. Pump

3.4.1. Pump Flow Capacity

From the calculation of the cooling water discharge is 0.00258 m3/s, but in the market there is no aquarium type pump with a small water flow. Then obtained a pump with the following specifications:
Pump Type: Aquarium Power Heat
Voltage : 220-240 V, 50 Hz, 15 Watt
Capacity : 800 L/hour (0.22 kg/s)
Suction Pipe : 5/8 Inch
So the cooling water flow capacity is calculated from the pump capacity. The pump capacity here is the volume of fluid per unit time released by the pump.
Q = V.A

Where Q = Pump capacity (m3/s)
V = flow velocity (m/s)
A = cross-sectional area of the pipe (m2)
The pump capacity listed is 800 Liters / hour, then the flow rate in the pipe is

$$V = \frac{Q \times 10^{-3}}{3600 \times A}$$

$$V = \frac{800 \times 10^{-3}}{3600 \times \pi/_4\, 0.015875^2} = 1{,}12 \text{ m/s}$$

3.4.2. Total Pump Head

The total pump head that must be available to deliver a certain amount of water, as planned, can be determined from the conditions of the installation to which the pump will be supplied.

$$\mathrm{H} = \mathrm{ha} + \mathrm{hl} + \frac{\mathrm{V}^2}{2g}$$

Where : H = Total pump head (m)
ha = Total static head (m), this head is the height difference between the water level on the suction side and the exhaust side, in this case the static head is the distance from the water surface to the pump axis, then ha = 240 mm hl = Various pipe head losses due to friction, valves , turns, pipe joints (m)
The following will discuss the losses that occur in the installation, namely:

3.4.2.1. Head Losses Due to Friction in the Pipe

In this installation, the PCV pipe type is used, to calculate it, the formula is used;

$$\mathrm{hf} = \lambda \frac{1}{\mathrm{D}} \cdot \frac{V^2}{2g}$$

(8)
Where: Hf = friction loss in the pipe
= Friction Loss Coefficient
g = acceleration due to gravity (9.81 m/s2)
l = total pipe length (m)
D = pipe inner diameter (m)
V= average velocity in the pipe (m/s)
To find the coefficient of friction on the pipe, the parameters needed are:

$$1)\ \frac{\text{Nilai Kekerasan}}{\text{Diameter Pipa}} = \frac{\Sigma}{D} \qquad (9)$$

According to Jack. B. Evett and Cheng Liu (1987), the hardness value for PVC pipe is 0.00015(m), then

$$\frac{\Sigma}{D} = \frac{0{,}00015}{0{,}015875} = 0{,}00945$$

2) Reynolds number is the number contained in the Moody diagram, from this Moody diagram the coefficient of friction is determined

$$\mathrm{Re} = \frac{\mathrm{vD}}{\mathrm{V}} \qquad (10)$$

Where: Re = Reynolds number
V = Kinematic viscosity of the liquid (m2
/s), assuming water temperature
approximately ±30ºC, then according to jack. B. Evett and Cheng
Liu (1987), the value of v = 0.8(m2
/s)×10-6
D = Inner diameter of pipe = 5/8 Inch = 0.015875 [m]
v = Average flow velocity in the pipe [m/s] = 1.12 m/s

$$\mathrm{Re} = \frac{1{,}12 \times 0{,}015875}{0{,}8 \times 10^{-6}} = 22225$$

With a value of Re > 4000, this flow is called turbulent flow. To find the coefficient of friction can be seen on the Moody diagram with Re = 22225 and

$$\frac{\varepsilon}{d} = 0{,}00945 \text{ didapat } \lambda = 0{,}046\text{, jadi}$$

$$\mathrm{hf} = 0{,}046 \frac{1{,}33}{0{,}015875} . \frac{1{,}12^2}{2g} = 0{,}29 \text{ m}$$

b. Loss of head due to elbow

$$\mathrm{hf} = f . \frac{V^2}{2g} \tag{11}$$

where : hf = loss due to bends (m) f = coefficient of friction for bends (elbow). According to Jack. B. Evett and chng liu (1987), coefficient of friction for bends = 0.75

$$\mathrm{hf} = 0{,}75 . \frac{1{,}22^2}{2g} = 0{,}057 \text{ m}$$

Because in the installation there are 5 turns then hf becomes
0.057 × 5 = 0.285 m, so:
Total head (H) = 0.29 + 0.285 = 0.575 m
Pump efficiency calculation
Pump efficiency is the useful power divided by the power that enters the pump, the pump efficiency can be calculated by the following formula:

$$\eta = \frac{P_{in} - P_{out}}{P_{in}} = 1 - \frac{\gamma Q H}{P_{in}} \tag{12}$$

Where : H = Total pump head (m)
= Density of water 9.81 (kN/m3)
Q = pump capacity (m3/s)

$$\eta = 1 - \frac{9{,}81 \times 800 \times 10^{-3} \times 0{,}575}{3600 \times 0{,}015} = 0{,}916$$

So the pump efficiency is 91.6%.

4. CONCLUSION

From the results of the calculation of the design of palm sap distalization, the following conclusions can be drawn: (1) Construction. Distal capacity: 5 liters. Heating media: Kerosene burner. Distallation model: Distillation with water, equipped with a condenser. Skeleton Material: Iron profile plate 40. Base material: 12 mm plywood board. (2) Place of palm sap. Size: 185 mm × 185 mm × 185 mm. Material: 0.7 mm zinc plate. Capacity : 5 liters.(3) Water bath. Size: 500 mm × 500 mm × 213 mm. Material: 0.7 mm zinc plate. Capacity : 43.5 liters University of North Sumatra (4) Condenser. Size : 340 mm × 281.5 mm. Material: 0.7 mm zinc plate (5) Condenser pipe. Size :

5/8'"× 1330 mm. Elbows: 5 pieces. (6) Copper pipe. Size : 10 mm × 2900 mm. Material: Copper. Model : Spiral shape 300 mm (7) Pump Type : Aquarium Power Heat. Flow capacity: 800 L/hour. Voltage: 220-240 V, 50 Hz, 15 watts. Suction pipe: 5/8 Inch. Pump Efficiency : 91.6%. (8) Condenser water bath. Size: 300 mm × 300 mm × 300 mm. Material: 0.7 mm zinc plate, University of North Sumatra.

Suggestions in this study are: (1) In the construction of the sap heater, it must be higher than the water heater, so that if there is a leak the steam is not mixed. (2) In the condenser the outflow of water should be made even lower than the inflow of water. (3) The water heater should have a drain so that it is easier to clean it. (4) The sap heater should be able to be assembled and disassembled.

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