

ANALYSIS OF THE EFFECT OF INITIAL WATER TEMPERATURE ON CLOVE OIL DISTILLATION TIME (CASE STUDY ON CLOVE OIL INDUSTRIAL BOILER IN HILA VILLAGE)

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ABSTRACT

The oil contained in clove leaves can be taken through the distillation process. The distillation process is carried out to separate the clove oil from the water contained in the leaves. The kettle operated is 2.5 meters high and 2 meters in diameter. The inner side of the kettle is divided into 2 rooms, at the bottom with a height of 1 meter filled with water and at the top with a height of 1.5 meters filled with clove leaves. The loading capacity of clove leaves is 1 ton and the water required is 2.5 m³. With the length of time the clove oil refining process lasts for 8 hours. Without changing the equipment specifications, efforts can be made to shorten the production time, by increasing the enhancer temperature above 26 °C.

Data sourced from the distillation equipment specifications are needed to analyze the amount of energy required during the distillation process, as well as the determination of the distillation time. The analysis was carried out with 3 stages of variation of the initial water enhancer temperature of 26 °C, 50 °C and 75 °C.

The temperature of the replacement water entered into the kettle is 26 °C, resulting in a distillation time of clove oil for 8 hours. When the replacement water temperature was increased by 50 °C, the distillation time was 7.89 hours. The more the enhancing water temperature is increased by 75 °C, the distillation time decreases to 7.786 hours. Thus, the distillation process time of clove oil can be shortened by increasing the initial temperature degree of the replacement water.

Keywords: Initial water temperature, time, distillation, Clove Oil

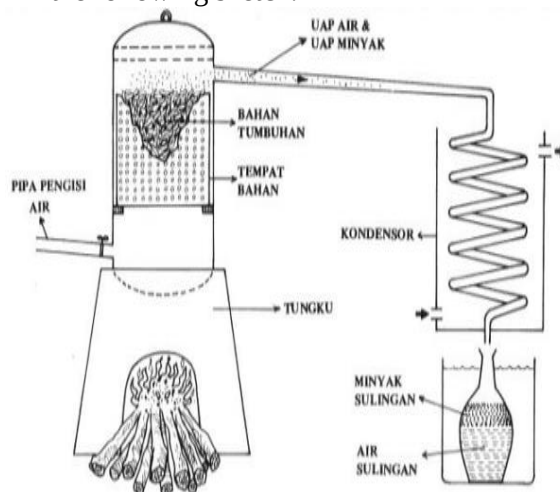
INTRODUCTION

The oil contained in clove leaves can be taken through the distillation process. The distillation process is carried out to separate the clove oil from the water contained in the leaves. The clove oil distillation industry that is the focus of this research is located in Hila village, Leihitu District, Central Maluku Regency. It operates a kettle measuring 2.5 meters high and 2 meters in diameter. The inner side of the kettle is divided into 2 rooms, at the bottom with a height of 1 meter filled with water and at the top with a height of 1.5 meters filled with clove leaves. The loading capacity of clove leaves is 1 ton and the water required is 2.5 m³. Where the clove oil refining process lasts for 8 hours from 09.00 to 17.00 The length of the refining process time requires alternatives to shorten production time without reducing production capacity.

Without changing the specifications of the existing equipment, it is possible to shorten the clove oil distillation process time from 8 hours. By preheating the enhancement water that is to be input into the kettle. High-temperature enhancement water takes a shorter time to reach boiling point than low-temperature water. With the technique of preheating the addition water at a high temperature, it is expected to shorten the distillation process time.

THEORETICAL FRAMEWORK

Clove oil is produced through the clove leaf distillation process. The equipment used for the distillation process consists of: Kettle, furnace, condenser piping system, separator and clove oil container. The working principle is that water, clove leaves and twigs are put into the kettle. The kettle is heated until the water boils, the steam formed will evaporate the oil contained in the leaves and twigs of cloves. Furthermore, the clove vapor is condensed in the condenser so that it turns into a drop of clove oil which is collected in a container. During the distillation process the amount of water in the kettle will decrease, so it is necessary to replace the reduced amount of water. The essential oil distillation system is shown in the following sketch:



Essential oil distillation system (source: Jaka Sulaksana, 2015)

Some previous researchers have conducted research on essential oils, as follows:

1. Kaharudian, 2017, provides information that the results of preliminary research show that the best level in the material density variable is 350 g/l, while the best level in the length of distillation is 8 hours. The results of the main research showed that the optimal condition of clove oil yield was 4.18% obtained from a material density of 345.18 g/l and a distillation time of 8.58 hours.
2. Fajar L.H. and Aphari I.M. (2013), provided information that the results of research on the extraction of eucalyptus leaves using ethanol solvents with maceration extraction method.
3. The optimal yield condition of about 3.77% for patchouli leaf distillation was obtained at a distillation temperature of 135 oC with a time of 6 hours. (Harunsyah, 2012).
4. The distillation time of clove leaves is about 5-7 hours at a pressure of 0.5 bar, producing clove oil with a density that meets SNI standards, which is 1.030-1.032 g / ml (Nuryoto et. Al 2011).

Some parameters are determined through data analysis of the refining process using the following equations: The heat transfer heat of the boiler from the fuel combustion process can be determined by the following equation (Juelf R.A, 2018):

$Q = U.A.(\Delta T)$ KJ/hour. where,

U = heat transfer coefficient KJ/m²jamoC.

Q = heat transfer energy, KJ/hour.

ΔT = Average temperature difference between two fluids.

A = Area of heat transfer field, m²

METHODS

The type of research used in the research is analysis where the research data is obtained from field observations and used to analyze the time of the clove oil refining process. The data sources of this research are as follows: (a) Literature review, research data obtained through literature that supports the discussion of the problem, (b) Observation, data obtained through a review of the industry. Variable data in the study are as follows:

- The independent variable is the initial temperature of the adding water.
- The dependent variable is distillation time.
- Control variables are kettle, water capacity, amount of fuel, raw material capacity are considered the same value.

DISCUSSION AND RESULTS

Results

Clove oil is included in the class of essential oils, as well as eucalyptus oil, cereals and others. The process of refining clove oil in principle works the same as the process of refining other essential oils. It's just that the clove distillation material besides the leaves also includes twigs. During the distillation process, the water in the kettle will decrease, and every 3 hours water with a temperature of 26 oC is added. Each time cold water is added, the temperature of the water in the kettle drops, and it takes time to heat it up again to reach boiling point. If the temperature of the adding water is increased, it is estimated that the crossing process time can be shortened.

The results of field observations obtained information on the performance data of the eucalyptus oil boiler, as follows:

- Diameter = 2 meters
- Height = 2.5 meters
- Clove room = 1.5 meters
- Water space = 1 meter
- Clove leaf capacity = 1 ton
- Water capacity = 3.14 m³
- Water addition /3 hours = 0,75 m³
- Total water addition / process = 2
- Oil production capacity = 46 kg
- Volume of remaining water after 3 hours of distillation process = 2,39 m³
- Water boiling time 3.14 m³ = 35 minute
- Distillation process time = 8 hours

a. Clove oil distillation plant

The clove oil distillation installation which is the object of this study, as shown in Figure 4.1. below.

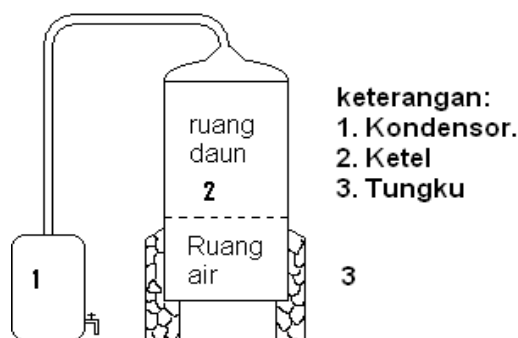


Figure 4.1. Sketch of clove oil distillation installation

- The time to boil 3.14 m³ of water from a temperature of 26 oC to reach 100oC takes 35 minutes.

a.First state analysis

Calculation of energy requirements

a) Heating water as much as 3.14 m³ with a temperature of 26 oC, to a temperature of 100 oC, requires energy of:

$$Q_1 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 3.14 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj/M}^3 \text{ oC}$$

$$T_1 = 100 \text{ oC}$$

$$T_2 = 26 \text{ oC}$$

$$Q_1 = 3,14 \cdot 4,174 (100 - 26) \\ = 969.87 \text{ Kj.}$$

b) The energy content of water as much as 2.39 m³ at a temperature of 100 oC, amounting to;

$$Q_2 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 2.39 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj / m}^3 \text{ oC}$$

$$T_1 = 100 \text{ oC}$$

$$T_2 = 0 \text{ oC}$$

$$Q_2 = 2,39 \cdot 4,174 (100-0) \\ = 997.586 \text{ Kj.}$$

c) The energy content of water as much as 0.75 m³ at a temperature of 26 oC, amounting to;

$$Q_3 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 0.75 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj/M}^3 \text{ oC}$$

$$T_1 = 26 \text{ oC}$$

$$T_2 = 0 \text{ oC}$$

$$Q_3 = 0,75 \cdot 4,174 (26-0) \\ = 81.39 \text{ Kj.}$$

d) Determination of mixed water temperature 2.39 m³ 100 oC plus 0.75 m³ 26oC.

The temperature of the mixed water can be determined in the following way:

$$Q_{\text{mixture}} = Q_3 + Q_2$$

$$= 81.39 \text{ Kj} + 997.586 \text{ Kj}$$

$$= 1,078.976 \text{ Kj}$$

Mixed water temperature

$$T_{\text{campuran}} = Q_{\text{campuran.a}} / C_p \cdot V \cdot \text{oC}$$

$$= 1,078,976 / 4,174 \cdot 3,14$$

$$= 82.32 \text{ oC}$$

Heat required to increase the water temperature from 82.32 oC to 100 oC:

$$Q_4 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 3.14 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj/m}^3 \text{ oC}$$

$$T_1 = 100 \text{ oC}$$

$$T_2 = 82.32 \text{ oC}$$

$$Q_4 = 3,14 \cdot 4,714 \cdot (100 - 82,39) \\ = 260.66 \text{ Kj}$$

The addition of water in the kettle during the distillation process is done twice. Thus the heat required to raise the water temperature to 100 oC:

$$Q_5 = 2 \cdot Q_5 \text{ Kj} \\ = 2 \cdot 260.66 \text{ Kj} = 521.32 \text{ Kj}$$

a) Evaporation Process

The capacity of water that undergoes the evaporation process during the distillation process:

- First 3 hours = 0.75 m³

- Second 3 hours = 0.75 m³

Total capacity = 1.5 m³

Heat required:

$$Q_6 = W \cdot L \text{ Kj}$$

Where,

Weight of 1.5 m³ volume of water at 100 oC,

$$W = 1500 \text{ kg}$$

$$L = 75.823 \text{ Kj/kg}$$

$$Q_6 = 1500 \cdot 75.823$$

$$= 113,734.5 \text{ Kj}$$

So the total heat required during the distillation process is as much:

$$Q_{\text{Total}} = Q_1 + Q_5 + Q_6 \text{ Kj}$$

$$= 969.87 + 521.32 + 113.734,5$$

$$= 115,225.69 \text{ Kj}$$

Calculation of distillation process time

1) The amount of heat per hour required to boil 3.14 m³ of water with an initial temperature of 26 oC for 35 minutes, can be determined through the following calculations

$$Q_w = Q_1 / t_1 \text{ (boiling time) Kj / hour}$$

Where,

$$Q_1 = 969.87 \text{ Kj}$$

$$t_1 = 35 \text{ minutes}$$

$$Q_w = 969.87 \cdot 60/35$$

$$= 1662.6 \text{ Kj/hour}$$

2).The time to boil mixed water at an initial temperature of 82.32 oC for 3.14 m³ is:

$$t_2 = Q_4 : Q_w$$

$$= 260.66 \text{ Kj} : 1662.6$$

$$= 0.16 \text{ hours}$$

During the distillation process, 2 times the addition of water is carried out, so the time required becomes:

$$t_2 = 2 \cdot 0.16 \text{ minutes} = 0.32 \text{ hours}$$

3) Evaporation process time

The evaporation process time, water vapor production for the distillation process can be determined as follows:

$$T_{\text{evaporation}} = T_{\text{distillation}} - (t_1 + t_2)$$

$$= 8 - (0.32 + 0.58)$$

$$= 7.1 \text{ hours}$$

a. Second State Analysis

Calculation of energy requirements

a) Heating 3.14 m³ of water with a temperature of 50 oC, to a temperature of 100 oC, requires energy of:

$$Q_1 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 3.14 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj/M}^3 \text{ oC}$$

$$T1 = 100 \text{ oC}$$

$$T2 = 50 \text{ oC}$$

$$Q1 = 3,14 \cdot 4,174 (100 - 50) \\ = 655.318 \text{ Kj.}$$

- b) The energy content of water as much as 0.75 m³ at a temperature of 50 oC, amounting to;

$$Q3 = V \cdot Cp \cdot (T1 - T2) \text{ kcal}$$

Where,

$$V = 0.75 \text{ m}^3$$

$$Cp = 4.174 \text{ Kj/M}^3 \text{ oC}$$

$$T1 = 50 \text{ oC}$$

$$T2 = 0 \text{ oC}$$

$$Q3 = 0,75 \cdot 4,174 (50-0) \\ = 156.65 \text{ Kj.}$$

- c) Determination of mixed water temperature 2.39 m³ 100 oC plus 0.75 m³ 50oC.

The temperature of the mixed water can be determined in the following way:

$$Q_{\text{mixture}} = Q3 + Q2$$

$$= 156.65\text{Kj} + 997.586 \text{ Kj}$$

$$= 1,154.11 \text{ Kj}$$

Mixed water temperature

$$T_{\text{mixture}} = Q_{\text{mixture}} / (Cp \cdot V \cdot \text{oC})$$

$$= 1.154,11 / (4,174 \cdot 3,14)$$

$$= 88.06 \text{ oC}$$

Heat required to increase the water temperature from 88.06 oC to 100 oC:

$$Q4 = V \cdot Cp \cdot (T1 - T2) \text{ kcal}$$

Where,

$$V = 3.14 \text{ m}^3$$

$$Cp = 4.174 \text{ Kj/m}^3\text{oC}$$

$$T1 = 100 \text{ oC}$$

$$T2 = 88.06 \text{ oC}$$

$$Q4 = 3,14 \cdot 4,714 \cdot (100 - 88.06) \\ = 176.74 \text{ Kj}$$

The addition of water in the kettle during the distillation process is done twice. Thus the heat required to raise the water temperature to 100 oC:

$$Q5 = 2 \cdot Q4 \text{ Kj}$$

$$= 2 \cdot 176.74 \text{ Kj} = 353.47 \text{ Kj}$$

So the total heat required during the distillation process is as much:

$$Q_{\text{Total}} = Q1 + Q5 + Q6 \text{ Kj}$$

$$= 969,87 + 353,47 + 113.734,5$$

$$= 115,057.54 \text{ Kj}$$

Calculation of distillation process time

- 1) The time to boil mixed water at an initial temperature of 88.06 oC for 3.14 m³ is:

$$t2 = Q4 : Q_{\text{air}}$$

$$= 176.74 \text{ Kj} : 1662.6$$

$$= 0.106 \text{ hours}$$

During the distillation process, 2 times the addition of water is carried out, so the time required becomes:

$$t2 = 2 \cdot 0.106 \text{ minutes} = 0.21 \text{ hours}$$

- 2) Distillation process time

The distillation process time is determined as follows:

$$T_{\text{distillation}} = T_{\text{evaporation}} + (t1 + t2)$$

$$T_{\text{distillation}} = 7.1 \text{ hours} + 0.58 \text{ hours} + 0.21 \text{ hours}$$

= 7.89 hours.

a. Third State Analysis

Calculation of energy requirements

a) Heating 3.14 m³ of water with a temperature of 75 oC, to a temperature of 100 oC, requires energy of:

$$Q_1 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 3.14 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj/M}^3 \text{ oC}$$

$$T_1 = 100 \text{ oC}$$

$$T_2 = 75 \text{ oC}$$

$$Q_1 = 3,14 \cdot 4,174 (100 - 75) \\ = 327.659 \text{ Kj.}$$

b) The energy content of water as much as 0.75 m³ at a temperature of 75 oC, amounting to;

$$Q_3 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 0.75 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj/M}^3 \text{ oC}$$

$$T_1 = 75 \text{ oC}$$

$$T_2 = 0 \text{ oC}$$

$$Q_3 = 0,75 \cdot 4,174 (75 - 0) \\ = 234.78 \text{ Kj.}$$

c) Determination of mixed water temperature 2.39 m³ 100 oC plus 0.75 m³ 75oC.

The temperature of the mixed water can be determined in the following way:

$$Q_{\text{mixture}} = Q_3 + Q_2$$

$$= 234.78 \text{ Kj} + 997.586 \text{ Kj}$$

$$= 1,232.37 \text{ Kj}$$

Mixed water temperature

$$T_{\text{campuran}} = Q_{\text{campuran.a}} / C_p \cdot V \cdot \text{oC}$$

$$= 1.232,37 / (4,174 \cdot 3,14)$$

$$= 94.03 \text{ oC}$$

Heat required to increase the water temperature from 94.03 oC to 100 oC:

$$Q_4 = V \cdot C_p \cdot (T_1 - T_2) \text{ kcal}$$

Where,

$$V = 3.14 \text{ m}^3$$

$$C_p = 4.174 \text{ Kj/m}^3 \text{oC}$$

$$T_1 = 100 \text{ oC}$$

$$T_2 = 94.03 \text{ oC}$$

$$Q_4 = 3,14 \cdot 4,714 \cdot (100 - 94,03) \\ = 88.37 \text{ Kj}$$

The addition of water in the kettle during the distillation process is done twice. Thus the heat required to raise the water temperature to 100 oC:

$$Q_5 = 2 \cdot Q_5 \text{ Kj}$$

$$= 2 \cdot 88.37 \text{ Kj} = 176.74 \text{ Kj}$$

So the total heat required during the distillation process is as much:

$$Q_{\text{Total}} = Q_1 + Q_5 + Q_6 \text{ Kj}$$

$$= 969,87 + 176,74 + 113.734,5$$

$$= 114,881.11 \text{ Kj}$$

Calculation of distillation process time

1) The time to boil mixed water at an initial temperature of 88.06 oC for 3.14 m³ is:

$$t_2 = Q_4 : Q_w$$

$$= 88.37 \text{ Kj} : 1662.6 = 0.053 \text{ hours}$$

During the distillation process, 2 times the addition of water is carried out, so the time required becomes:

$$t_2 = 2 \cdot 0.053 \text{ minutes} = 0.106 \text{ hours}$$

2) Distillation process time

The distillation process time, determined as follows:

$$T_{\text{distillation}} = T_{\text{evaporation}} + (t_1 + t_2)$$

$$T_{\text{distillation}} = 7.1 \text{ hours} + 0.58 \text{ hours} + 0.106 \text{ hours} \\ = 7.786 \text{ hours.}$$

Discussion

From the implementation of testing and analysis, the following results were obtained

Table 1. Data on temperature rise and water heat

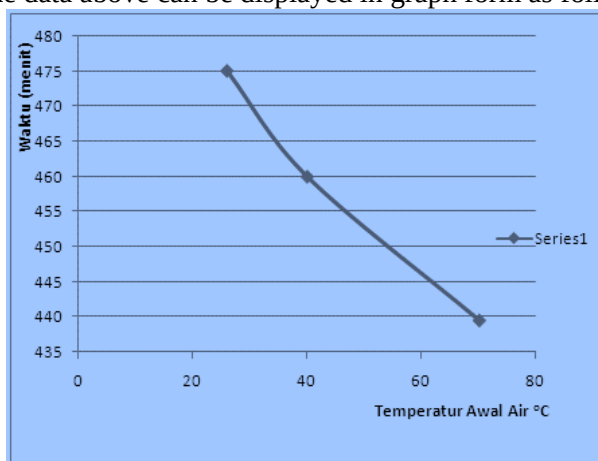
T °C	Q ₁ (Kj)	Q ₅ (Kj)	Q ₆ (Kj)	Q _{Total} (Kj)
26	969,87	521,32	113.734,5	115.225,69
50	969,87	353,47	113.734,5	115.057,54
75	969,87	176,74	113.734,5	114.881,11

Table 1 gives an explanation that the increase in water temperature will affect the amount of energy needed to boil 3.14 m³ of water, the higher the temperature the energy requirements decrease.

Table 2 Data on the relationship between distillation time and initial water temperature

Condition	Water Starting Temperature (°C)	Time (hours)
1	26	8
2	50	7,89
3	75	7,786

The data above can be displayed in graph form as follows:



Graph of the relationship between initial water temperature and water boiling time.

Figure 1 explains that heating the enhancement water in the kettle will reduce the distillation process time. The higher the water in the kettle will reduce the distillation time. In this case, the only time that can be reduced is the boiling time of the water in the kettle. The evaporation time of 7.1 hours cannot be reduced. Because this time is needed, for oil production until the clove oil contained in the leaves runs out, this can be seen by the absence of clove oil produced.

CONCLUSION

From the test results and discussion of the problem, some suggestions and conclusions can be drawn as follows:

1. Conclusion

- a. Replacement water that is put into the kettle, if the temperature is 26 oC, then the time required for the clove oil distillation process is 8 hours.
- b. Replacement water that is put into the kettle, if the temperature is 50 oC, then the time required for the clove oil distillation process is 7.89 hours.
- c. Replacement water put into the kettle, if the temperature is 75 oC, then the time required for the clove oil distillation process is 7.786 hours.
- d. The time of clove oil distillation process can be shortened by increasing the initial temperature degree of the replacement water.

2. Suggestions

- a. The exhaust gas from the furnace can be utilized to heat the replacement water.
- b. The height of the water surface in the boiler needs to be controlled so that the boiler avoids cracks and explosion hazards, due to the high temperature difference between the water and steam space in the boiler whose outside is exposed to fire.

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