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# Distillation Equipment Design of Nutmeg Oil using Hybrid **System**

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Abstract. The quality of nutmeg oil is determined by the quality of the nutmeg and the technology that are used in the purification process of the nutmeg. For instance, the distillation process will affect the yield and the essential quality of the production of the nutmeg oil are involving the boiler material, cooling system, and boiler design. The existing nutmeg oil distillation system is time consuming because the operators are highly depending on the firewood and the operators who must monitor closely throughout the time during the nutmeg oil refining process. The new distillation process and technique is based on the new type of boiler that is made from Stainless steel 304 with a diameter of 70 cm, length 120 cm, and with the thickness of 3 mm. The Boiler also comes with a new control system to precisely control the pressure and temperature. Meanwhile, the excess pressure of the boiler is controlled by pressure safety valve because the boiler is designed to withstand up to 3 bar maximum pressure capacity. The kettle is made of 304 Stainless steel equipped with a multi-storey basket to polish and to enhance the circulation and vapour pressure inside the boiler. The condenser pipes are made from the aluminium pipe to maximise the condensation process of the raw nutmeg oil. For the new distillation process, the hybrid system is utilised, where the sources of firewood and electricity are used as the source of energy to operate the boiler. It can be seen that hybrid kettle design reaches 2.8 tons with a 30% operating-saving cost. On top of that distillation time can be shortened to 48 hours from the previous 72 hours. It is stated that this hybrid boiler system is much more effective when compared to conventional systems. Laboratory test results stated that the distilled nutmeg oil has fulfilled the Indonesian national standard.

Keywords: distillation, boiler, kettle, nutmeg oil

#### 1. Introduction

The Southern Aceh District is known as one of the producing areas of nutmeg in Indonesia. The production of essential oils from nutmeg is done through refining. There are four methods of distillation commonly used, namely the method of steam distillation, water distillation, steam distillation, and extraction using solvents. Judging by the speed and capacity of the oil production, the method of distillation commonly used to obtain nutmeg oil is the method of steam distillation [1]. The distillation process is done by using steam

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from ripe beans and dried seeds and nutmeg flowers. Steam distillation to extract nutmeg oil is conditioned under atmospheric pressure because Nutmeg has a component of fatty oil. Nutmeg oil is obtained after the fat contained therein are excreted first. High pressure distillation can lead to the possibility of following fatty oils thereby reducing the quality of essential oils [2].

The quality of nutmeg oil is determined by the quality of the basic ingredients and distillation processes used [3]. Drying techniques for raw materials and distillation processes that include boiler material, cooling system and boiler design for distillation affect the yield and quality of essential oils produced [4], [5].

Southern Aceh Regency is one of the regions producing nutmeg in Indonesia. According to the editor of Binoculars Aceh, in 2017, there are three locations of breeding the largest nutmeg plants in South Aceh district, namely in the village of Air Pinang and Air Berudang, sub Tapaktuan and Blang Kuala Village, Meukek regency, with 15,821 hectares of total Breeding nutmeg in Aceh. [6].

Based on data input by the central Statistical Agency of Southern Aceh Regency, Nutmeg production in Southern Aceh Regency in 2017 is 6,510 tons. Table 1 shows the area and self-production of nutmeg in Southern Aceh Regency [7].

Area and Nutmeg Production Pattern of 2017						
Sub District	TBM	TM	TR	Total	Draduation	
	(Ha)	(Ha)	(Ha)	Total	Production	
Trumon	8	4	2	14	3	
Trumon timur	32	12	3	47	5	
Trumon tengah	50	33	10	93	20	
Bakongan	4	5	1	10	3	
Bakongan timur	55	46	10	111	30	
Kota bahagia	30	13	5	48	7	
Kluet selatan	38	14	5	57	4	
Kluet timur	47	39	6	92	21	
Kluet utara	198	98	6	302	75	
Pasie raja	565	400	7	970	310	
Kluet tengah	50	10	10	70	5	
Tapaktuan	718	970	90	1.778	1.010	
Sama dua	625	960	75	1.660	850	
Sawang	754	2.529	374	3.657	830	
Meukek	754	2.529	374	3.657	2.070	
Labuhan haji	800	510	125	1.435	410	
Labuhan haji timur	912	650	125	1.687	525	
Labuhan haji barat	780	440	15	1.235	330	

Table 1. Area and self-production of nutmeg in Southern Aceh

Some of the research that will be used as reference in this research namely, the energy efficiency and performance of the prototype wood-fired nutmeg oil refining equipment. From the distillation with this prototype obtained oil with characteristic that is in accordance with SNI 06-2388-2006 about nutmeg oil. The combined response of the weighted value of type 0.904, the bias index 1.478, the solubility of ethanol 90% at a temperature of 20 °C by 1:1, the optical rotation (+) 16.8 °, and the remaining evaporation of 0.7%. Standard nutmeg oil on SNI for 0.880-0.910 type, bias index 1.470-1.497, ethanol solubility 90% at 20 °C 1:3 and so on clear, optical rotation (+) 8 °-(+) 25 ° and residual evaporation 0.7% [8]. To optimize the use of energy is done by designing an electronic-based control system to the dominant parameters of temperature, steam pressure and the weight of nutmeg that will be distilled. Nutmeg oil Refining System

The results of this research have been able to control temperature and pressure automatically. Control done by controlling the fuel valve (used gas) so that the energy use optimization is 14.87% [9].

Due to the increasing demand of world nutmeg oil, it is necessary to effectively enhance the performance of the purification techniques in order to increase the quantity and quality of nutmeg oil. The problems in the distillation process of nutmeg oil can be briefly explained as follows:

- 1. The existing nutmeg oil distillation system is still using firewood and takes a long time during the distillation process.
- 2. The distillation process has not used an electronic-based regulatory system, so it still takes operators who must monitor carefully throughout the time of the nutmeg oil refining process.

The purpose of this research in general is to produce good quality nutmeg oil so that this commodity will have high selling value in local and world market. Furthermore, to keep the continuity of the supply of the nutmeg oil continuously and to increase the quantity of nutmeg oil production. In order to achieve this general goal, there are a few researches that related to this nutmeg oil production process. One of them is research that are related to distillation process with hybrid system. The specific objectives of the study namely:

- 1. Designing a distillation system of nutmeg oil hybrid systems that can use firewood and electricity.
- 2. It can be control electronically and the settings can be reset if needed parameter changes such as temperature and duration of distillation time.
- 3. Reduce the cost for energy needs in the distillation process (distilling) nutmeg oil, the length of distillation time optimised according to the weight/amount of nutmeg to be extracted and the vapour pressure given.
- 4. Increase the productivity and quality of the resulting nutmeg oil.

The main goal of the refining process (distillation) nutmeg oil, is the designing of the distillation system with boiler water tube, boiler with multilevel baskets and utilising the energy sources from the firewood and electricity. Therefore, for energy optimisation consumption the electrical energy is mainly required in order to reduce production costs, other than that, is the system of arrangement on the enhancement of the process is done electronically by a microcontroller that is easy to use and suitable applied to the regulatory (control) systems.

#### 2. Methodology

This research was conducted based on the results of the study of nutmeg distillation process. The results of the study were shown in the Fishbone diagram in Figure 1.



Figure 1. Fishbone diagram

Based on the Fishbone diagram in Figure 1, the study was conducted for 2 years period, in which the first year it started by designing and creating a gas-fuelled distillation system, tool components such as stainless-steel boilers, boiler with stainless steel material baskets, pipes and stainless-steel condenser tub. Meanwhile, in the boiler equip with a temperature and pressure indicator and an exhaust valve for the excess gas pressure. While the boiler is only equipped with temperature indicator only. In the second year, the research was conducted by designing and creating wood and electrical distillation equipment as well as modifying boilers with water tube system and adding water cooling system to cool water in the condenser tub. At the stage of this research has been equipped also with a control system against temperature and pressure during the distillation process. Further from the results obtained then the design of nutmeg oil refinery scales industrial scale with hybrid system.

The main components of the nutmeg oil refiners made in this study are the boiler, kettle, and condenser. From the first and second stage research has been built and tested the performance of this tool to produce the quality of the National Standard of Nutmeg oil.

#### 2.1. Boiler

The boiler is made of stainless steel A304 with a diameter of 40 cm, height 71 cm and with a thickness of 3 mm. The boiler also features a manometer/pressure gauge to control the pressure in the boiler and the thermometer to control the temperature. In addition, there is also a pressure safety valve that will function if there is excessive pressure. The kettle is designed with a pressure capacity of 3 bars. Process to produce steam is by using a water tube system. The water tube is made of 1/2-inch stainless steel pipe with a thickness of 3 mm. The process of making the boiler with the water tube system as shown in Figure 2.



Figure 2. Boiler Water Tube Manufacture

## 2.2. Kettle

The distilled kettle used in the study is also made of Stainless steel A304 with a diameter of 72 cm and a height of 100 cm and a thickness of 3 mm plate. In addition, Baldem with a diameter of 50 cm is used as a cover for a distilled kettle. The installation process is shown in Figure 3.



Figure 3. Kettle with Beldam's

# 2.3. Condenser

The condenser is made of stainless-steel pipe with a size of 1/2 inches A304 in Figure 3. The condenser pipes are made in spiral form with a height of 80 cm. The condenser making process is shown in Figure 4. After all the process of design and manufacture, nutmeg distillation equipment is done by the water tube method in Figure 4. Overall, the nutmeg oil refining system in this study was shown in Figure 5 and Figure 6.



Figure 4. Manufacture of condenser



Figure 5. The process of assembling and installing distillation tools.



- 1. Steam Boiler
- 2. Distillation Kettle
- 3. Steam Conductor Pipe
- 4. Condenser Tank
- 5. Cooling Tower

Figure 6. Prototype nutmeg oil distillation

# 3. Results and Discussion

#### 3.1. Number of low-yield

Nutmeg oil refining capacity of 40 kg is distilled for 12 hours which spends 12.5 kg of wood and obtained a different amount of yield between phase 1 without water tube and stage 2 is with water tube as shown in Figure 7. The best results are shown by the system that use boiler water tube so that the steam flowing to the boiler is always constant.



Figure 7. First stage nutmeg oil distillation

# 3.2. The results of the nutmeg oil characteristic

Testing characteristics of nutmeg oil is done in the laboratory of Palm Research Centre with the results as in Table 2. Table 2. Test results

		10010 20 1000100		
Parameter	Unit	Test results (1)	Test results (2)	Method
Remaining Evaporation	%	3,48	1,52	SNI 06.2388.2006
Specific gravity	g/cm <sup>3</sup>	0,8847	0,8295	ASTM D 4052
Colour	-	Pale yellow	Clear	SNI 06.2388.2006

From the results of the testing showed that the quality of nutmeg oil is increased in the use of the second stage distillation system where the boiler uses water tube system, kettle with a basket of materials to improve the vapor circulation evenly, the condenser are using the aluminium pipes and the water cooling systems in a condenser container.

#### 3.3. Industrial capacity designing

Based on the research results for 2 (two) years, then the design of industrial capacity distillation equipment that will be applied to the Nutmeg Society Handicraft Industry Centre in the Meukek Village in Southern Aceh District. The production capacity for this distillery is 2.8 tons for distillation.

#### 3.3.1. Boiler

Boilers that serve as steam producers using wood and electricity fuels as heat sources. This boiler has 40 pipe water tube that serves to accelerate the process of steam formation especially if the source of heat from wood, while if using electricity has been available 4 (four) rod heater that each heater is capacity 400 Watt. In addition, this boiler has a control system for temperature and pressure settings that the data acquisition can be directly record by the computer. All parts of this boiler are made of A304 stainless steel with a 3 mm thick plate and isolated by fire brick for a more maximum warming process as shown in Figure 8.

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Figure 8. Design of boiler

### 3.3.2. Kettle

The kettle is designed to have a multi-level basket that serves to maximize steam circulation in the boiler as shown in Figure 9. In addition, the use of baskets can also facilitate the filling and demolition of nutmeg raw materials. The kettle cover is Bold Dum shaped tied by clamp. In this cover, paired pressure and temperature indicators can be read by the computer. The schematic diagram is shown in Figure 10.



Figure 9. Design of kettle



Figure 10. Design of kettle with control system

### 3.3.3. Condenser

Condenser pipes that are found above the water coolant surface using stainless steel A304. While the whole condenser pipe is immersed in cooling water using aluminium material because this material is relatively faster cooler if it is in water, so the process of phase change of steam to liquid is relatively more constant

## 4. Conclusion

The conclusions gained from this study are as follows:

- 1. Have done research to design build nutmeg kettle prototype with hybrid system. The result of this prototype will be used as reference in designing nutmeg boiler industry capacity.
- 2. The time required for the heating process to produce steam and achieve a pressure of 3 bar between 15-20 minutes, much more effective when compared to conventional systems.
- 3. Laboratory test results stated that nutmeg oil, which was distilled using a water-tube boiler, meets Indonesian national standard.

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