NUTMEG OIL DISTILLATION MODEL HH1 (1 BOILER WITH 2 KETTLE DISTILLERS): TECHNOLOGY AND COST ANALYSIS

HELMI HARIS[1,*], FINA UZWATANIA[2], DENI HENDARTO[1], WILNA IZNILILLAH[1], ARTI HASTUTI[1], RIDWAN RACHMAT[1], MUHAMMAD ZAINAL FANANI[1], MUHAMMAD ABDIKI WICAKSONO[1]

[1]Universitas Djuanda, Jl. Tol Ciawi, No. 1, Bogor, Indonesia
[2]Birmingham University, Edgbaston, Birmingham, United Kingdom
*Corresponding Author : helmi.haris@unida.ac.id

Abstract

This study aimed to analyse the quality and techno-economics of the distillation of nutmeg oil obtained from Nutmeg plant techno-economics parts using a steam distillation distiller. The research method analyses the production of essential oils from nutmeg plant parts using a distillation apparatus model, with 1 boiler and 2 kettle distillers with a capacity of 200 kg for each kettles distiller. The procedure of this research starts from the preparation of raw materials (dried nutmeg leaves, young nutmeg seeds, old nutmeg seeds, and nutmeg mace), drying of raw materials, destruction of dried nutmeg with a crusher, distillation for 6-8 h, oil quality analysis according to the Indonesian National Standard (SNI) nutmeg oil, and oil packaging on the dark-coloured conductor. Furthermore, a techno-economic analysis of the feasibility of this nutmeg oil distillation business was carried out for 20 years. The results showed that the nutmeg oil produced had met the quality of SNI nutmeg oil (*SNI 06-2388-2006*). The total needs funds needed is 10,504,336,633 IDR. consisting of a fixed cost of 15,176,633 IDR. and variable cost of 9,689,160,000 IDR. with a % Profit Estimated at 13%, results show that Break Even Point (BEP) was achieved after producing 4,233.14 kg nutmeg oil. Return on Investment (ROI) of 2.44 times and the return time of the investment issued (Pay Out Time) 0.394427841 or 1/39.44 = 2.54 years. Does it can be concluded that nutmeg oil distillation activities using steam distillation model 1 boiler with 2 kettle distillers is quite profitable and feasible to implement.

Keywords**:** Nutmeg oil, Steam distillation method, Techno-economic.

1. Introduction

Essential oils from nutmeg plants have significant economic value. Therefore, optimal development measures with strict quality control are required, referring to applicable quality standards, such as the Indonesian National Standard (SNI) 06-2388-2006 for nutmeg oil. Competition in the market is influenced by many factors, including the quality of the nutmeg oil produced. Pala Bogor is a type of nutmeg variety Nurpakuan Agribun has oval-shaped leaves, the upper leaves are green, the bottom of the leaves are light green, and the skinned fruit is greenish yellow, round, and oval. The shell of old seeds is shiny brownish-black, and fresh fruits are red [1].

The distillation technique that is widely used is steam distillation due to its effectiveness in terms of the speed, duration, and higher yield of essential oils. The extraction pressure of nutmeg oil through steam distillation must be below atmospheric pressure to maintain the purity of nutmeg oil because pressure above atmospheric can damage the quality of nutmeg oil [2]. The marketing prospects for nutmeg oil are still wide open, therefore a review of its techno-economic aspects is required. Based on our previous study [3, 4], this study aimed to explore the potential of all parts of the nutmeg plant to be produced into nutmeg oil. The uniqueness of this research is that all parts of the nutmeg plant, including fallen leaves, young nutmeg, old nutmeg, and nutmeg, can be used as raw materials for making nutmeg oil.

2. Literature Review

This distillation equipment consists of heating boilers, distillation boilers, condensers, oil separators, nutmeg seed crushers, ovens, digital scales, measuring cups, plastic conductors, and for quality testing of nutmeg essential oils using laboratory equipment. The distillation equipment used is steam distillation model HH1 (1 boiler with 2 kettle distillers) with a capacity of 200 kg/kettle. The advantage of this HH1 model distiller is that this tool can distil several essential commodities at once without worrying about being contaminated with other essential oils [5]. In addition, it is more efficient in the use of firewood and labour [6]. The main components in the distillation process, namely, boiler, kettle, a condenser (cooler), and a separator tool that separate the oil [5]. The research flow conclude nutmeg oil distillation using model 1 boiler distillation with 2 kettle distillers.

3. Method

Nutmeg oil produced from various nutmeg plants were then analysed for quality following the Indonesian national standard (SNI) nutmeg oil (specific gravity, refractive index, residual evaporation, solubility in ethanol, colour, aroma, and yield), SNI 06-2388-2006 [7]. Techno-economic analysis was analysing the materials and equipment price for nutmeg oil distillation using average price of commercial products online. All data is calculated using simple mathematical analysis in Excel. Several economic evaluations (i.e.; gross profit margin (GPM), internal rate of return (IRR), payback period (PBP), cumulative net present value (CNPV), breakeven point (BEP), break even capacity (BEC), return on investment (ROI) and provability index (PI)) were analysed to inform the production potential of nutmeg oil from nutmeg plant parts. Detailed information for the calculation is explained elsewhere [8, 9].

4. Results and Discussion

4.1. Measurement results of physicochemical properties of nutmeg oil, SNI 06-2388-2006

Physicochemical properties of nutmeg oil from the nutmeg plant, SNI 06-2388-2006 can be found in Table 1.

Table 1. Physicochemical properties of nutmeg oil from the nutmeg plant.

Physicochemical Properties	Parts of Nutmeg Plants (A)				SNI 06-2388-2006
	Nutmeg leaf(A1)	Young nutmeg seed(A2)	Old nutmeg seed(A3)	Nutmeg mace(A4)	
Specific Gravity (g/mL)	0.888± 0.001a	0.890± 0.001a	0.888± 0.001a	0.890± 0.001a	0.880-0.910
Refractive Index	1.477± 0.0015[a]	1.475± 0.0000[b]	1.475± 0.0000[b]	1.477± 0.0005[a]	1.470-1.497
Residual Evaporation (%)	1.320± 0.030[a]	1.333± 0.015[a]	1.300± 0.026[a]	1.360± 0.020[a]	Maks. 2.0%
Solubility in Ethanol	clear	Clear	Clear	clear	1:3 clear, so on clear
Colour	4.801° 0.516[a]	4.833° 0.414[a]	4.856° 0.432[a]	4.815° 0.401[a]	Colourless, pale yellow
Aroma	8.200± 1.155[a]	8.200± 0.943[a]	8.200± 0.933[a]	8.100± 1.109[a]	Nutmeg oil specialties
Yield (%)	1.300± 0.360[c]	5.507± 0.467[b]	10.36± 0.52[ab]	15.167± 1..58[a]	

It can be seen that all measured parameters have met the Indonesian national standard (SNI), includes:

(i) Specific Gravity. The specific gravity of nutmeg leaf oil obtained from the distillation process is higher than that of previous research [10], where the essential oil produced from nutmeg leaves has a specific gravity of 0.8543 g/mL. This aligns with other research [11], where nutmeg leaf essential oil has a specific gravity of 0.8862 g/mL. This can be due to differences in the type of nutmeg crop, regional origin, and the distillation method used [12]. Specific gravity value and fraction weight of components in essential oils are often associated, where the value of the particular gravity of nutmeg essential oil is low, indicating a low weight fraction in essential oil with the value of the specific gravity at distillation hours to 6 the value of 0.902 g / mL [13]. The specific gravity of nutmeg mace from the research that has been done has an average of 0.890g / mL, where the results are relatively lower than the other research [14], the average yield of nutmeg mace specific gravity is 0.937 g/mL.

(ii) Refractive Index. Nutmeg essential oil produced in this study has a refractive index of 1.477. The results are based on the quality standards of nutmeg oil and align with previous research [11], where the refractive index of nutmeg leaf essential oil is 1.4779. The refractive index value produced from the essential oil of young and old nutmeg seeds is the same, which is 1.475. These compounds have longer carbon chains than other molecules and contain many hydroxyl groups [15]. The refractive index value of nutmeg mace essential oil is 1.477, determined through three replications. These findings are consistent with other research [16], where the refractive index value of nutmeg

mace essential oil is 1.481. The higher the refractive index of the essential oil, the better its quality [13, 17].

(iii)   Residual Evaporation. The percentage of residual evaporation in nutmeg essential oil samples fell within the range of 1,300% to 1,360% on average, further confirming the adherence to these quality standards. Volatile compounds should not contain vaporization residues, which consist of non-volatile substances and include fats, solid oils, and other molecular weight components [15]. The high or low percentage of residual evaporation in essential oils may be due to poor quality of raw materials or high distillation temperatures during the distillation process, which causes material polymerization, making it difficult or even impossible to evaporate [18].

(iv)   Solubility in Ethanol. Essential oil of nutmeg plant nutmeg leaves, young nutmeg seeds, old nutmeg seeds, and mace on the solubility in ethanol showed a transparent appearance. When the essential oil dissolves completely in ethanol, more non-polar compounds are present in the oil. Conversely, if an essential oil contains more non-polar compounds, its solubility in ethanol, which is a polar substance, will be affected [19]. These findings are consistent with the opinion who proposed that essential oils containing high levels of polar compounds dissolve quickly in ethanol because they have similar properties [20].

(v)   Colour. Research studies reveal that the essential oils obtained from various parts of the nutmeg plant, such as leaves, young seeds, old seeds, and mace, mostly have a colourless appearance. Nutmeg oil is considered good quality if it has a colourless or pale yellow appearance. The reason the essential oil changes colour to brownish yellow could be due to the presence of β-caryophyllene, which is a type of terpene hydrocarbon found in essential oils [21]. Exposure of these compounds to air and light can cause oxidation, affecting the colour of essential oils.

(vi)   Aroma. Various researchers have also shown that nutmeg leaf essential oil, nutmeg seed oil, and nutmeg mace oil all have a strong characteristic of nutmeg aroma [22]. The characteristic aroma of nutmeg essential oil is the result of a combination of various chemical components, including monoterpene hydrocarbons, myristicin, monoterpenoid alcohols monoterpenoid, and other components such as eugenol and methyl eugenol [23]. The main contents of nutmeg essential oil are β-pinene 18.74%, myristicin 14.26%, α-terpinene 13.71% [24].

(vii) Yield. A material's yield is the percentage of the number of parts used divided by the total weight of a material [25]. Nutmeg oil yield can be calculated by comparing the weight of nutmeg oil with the weight of the nutmeg plant used [26]. This study revealed that the yield of nutmeg leaf essential oil was 1.3%, which is consistent with the previous research statement [27] that the yield of essential oil from nutmeg leaves usually does not exceed 1.7%. Smaller nutmeg particles yield a higher yield, a yield of 39.61% obtained from seeds with a mesh size of 60 [28].

4.2. Techno-economic calculations

The Techno-economic calculations was shown in Table 2. The amount of funds needed is 10,504,336,633 IDR. which consists of a Fixed Cost of 815,176,633 IDR.

and Variable Cost of 9,689,160,000 IDR. with an estimated % profit of 2.27% with a percentage gain of 13.0%, the results of the business analysis showed that the BEP was achieved after producing 4233.14 kg of nutmeg oil. IRR of 2.44 times and ROI 0.394427841 or 1/0,394 = 2,54 year.

Table 2. Results of techno-economic calculations.

Component	Parameter	Cost (IDR)
Fixed Cost	Capital related cost	751,131,249.75
	Depreciation	64,045,383.75
	Total fixed cost	815,176,633.50
Variable Cost	Raw material	8,769,000,000.00
	Operating labour (OL)	48,000,000.00
	Labor related cost	32,160,000.00
	Sales related cost	840,000,000.00
	Total variable cost	9,689,160,000.00
% Profit Estimated	Sales	12,000,000,000.00
	Manufacturing cost	10,440,291,249.75
	Investment	686,478,712.50
	Profit	0.13
	Profit to sales	2.27
BEP	Unit	12000
	Fixed cost	815,176,633.50
	Variable cost	9,689,160,000.00
	Sales	12,000,000,000.00
	BEP	4,233.144485
	Percent profit on sales	0.129975729
	Return on investment	2.435317987
	Pay out time	0.394427841

CNPV is a value that predicts the condition of a production project in the form of a production function in years [29]. Curve CNPV/TIC can be seen in Fig. 1. The profit until the second year is still negative, and only in the third year (2.54 years) began to have positive gains. With a profit percentage of 13.0%, the trend continues to increase until the 20th year.
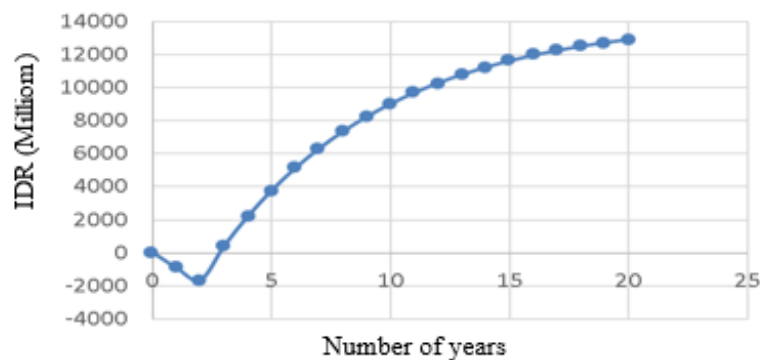

Fig. 1. Yield curve CNPV/TIC.

5. Conclusion

Nutmeg oil produced from nutmeg plant parts using distillation method 1 boiler with 2 distiller boilers has produced nutmeg oil that meets SNI 06-2388-2006. The total funding needed is 10,504,336,633 IDR. consisting of a fixed cost of 815,176,633 IDR. and variable cost of 9,689,160,000 IDR. with an estimated % profit of 13.0%. The results of the business analysis showed that the BEP was achieved after producing 4233.14 kg of nutmeg oil. IRR of 2.44 times and ROI 0.394427841 or 1/0,394 = 2,54 year. So it can be concluded that nutmeg oil Distillation activities using steam distillation model 1 boiler with 2 distiller boilers is quite profitable and feasible to implement.

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