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Value Added in Agarwood Oleoresin Extraction: Benefits of Microwave and Ultrasonic Maceration

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ABSTRACT

Background: Agarwood farmers are currently unable to extract agarwood oil because they do not get any benefit from the processing process due to the high cost and the yield obtained is still low; it is necessary to identify the right processing method so that they can obtain high agarwood oil and the cost is not too expensive. The added value of agarwood oil can be obtained by processing agarwood into oleoresin through agarwood oil extraction.

Methods: This study consists of several aspects of identifying the added value of agarwood oil. The first aims to extract agarwood oil using several techniques, namely microwave-assisted extraction (MAE) and ultrasonic-assisted extraction (UAE). Then calculate the Life Cycle Costing (LCC) and the added value of agarwood oil using the Hayami method.

Result: The calculation of life cycle costing shows that microwave-assisted maceration is the most effective and cheapest extraction method, with a cost of IDR 1,063 and has an extract yield of 4 grams during the 24-hour extraction process. An extract yield of 2 grams was obtained for 24 hours for IDR 2,127 for the extraction process using the ultrasonic-assisted maceration method. The results of the calculation of added value from the comparison of agarwood oil extraction methods show that the agarwood oil processing method with the microwave-assisted maceration method obtains higher added value compared to the ultrasonic-assisted maceration method, which is IDR 7,875,496 / kg. and obtains a profit of IDR 6,675,496 / kg. Therefore, the microwave-assisted extraction method can be used to increase agarwood oil production.

Key words: Added value, Agarwood oil, Extraction, Microwave, Ultrasonic.

INTRODUCTION

Agarwood oil, derived from the resinous heartwood of Aquilaria species, is highly valued for its diverse applications and therapeutic properties. The extraction of agarwood oil can be achieved through various methods, including hydrodistillation and steam distillation, which are essential for commercial purposes such as perfumery and medicinal uses (Kahar, 2021). The oil is characterized by a complex mixture of aromatic compounds, predominantly sesquiterpenes and chromone derivatives, which contribute to its unique fragrance and pharmacological effects (Huang *et al.,* 2022; Liu *et al.,* 2013).

The economic significance of agarwood oil cannot be overstated, as it is among the most expensive essential oils globally, with prices ranging from USD 30,000 to USD 50,000 per liter (Kumar *et al.,* 2022). This high market value is attributed to its limited supply and the labor-intensive processes involved in its production. The demand for agarwood oil has surged, with prices increasing dramatically over the years, reflecting its status as a luxury item in various cultures.

Microwave-assisted extraction utilizes microwave energy to heat the solvent and the plant material, facilitating the release of essential oils. This method has been shown to reduce extraction time significantly while increasing the yield of essential oils compared to conventional methods. For example, MAE can extract essential oils in a fraction of the time required for hydro distillation, which typically takes several hours (Cardoso Ugarte *et al.,* 2013). The efficiency of MAE is attributed to the rapid heating and the ability to penetrate the plant matrix, which enhances the solubility of the volatile compounds (Jiao *et al.,* 2013). Studies indicate that MAE can produce higher concentrations of key aromatic compounds, such as sesquiterpenes and chromones, which are crucial for the therapeutic and olfactory qualities of agarwood oil (Thuy *et al.,* 2018; Wang *et al.,* 2018).

In summary, the added value of agarwood oil extracted through microwave-assisted and ultrasonic-assisted methods lies in its ability to enhance yield, preserve

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chemical integrity and promote sustainable practices. These modern extraction techniques represent a significant advancement in agarwood oil production, aligning with economic and environmental considerations.

MATERIALS AND METHODS

The primary raw material used is agarwood (Aquilaria malaccensis), which grows in the former mining area in Sawahlunto City and the chemical used is methanol solvent (P.A). Extraction of agarwood oil was carried out in the laboratory of the Faculty of Agricultural Technology andalas University. This research was conducted from February to October 2024. The tools used are Digital Analytics, Watt meter Type B, Ultrasonic Type Bath 60-70 Hz, Microwave Oven 450 W, Rotary Evaporator type BUCHI R215, Gas Chromatography and Mass Spectrometry (GC-MS), chemical glassware and analytical balance, Data processing Added Value using Microsoft Excel by performing calculations and displaying results in the form of diagrams, graphs and Tables.

Study area

This study consists of several aspects of the identification of the added value of agarwood oil, the first is aimed at extracting agarwood oil using several methods, namely microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE) and a combination of MAE and UAE, then calculating the Life Cycle Costing (LCC) and the added value of agarwood oil using the Hayami method.

Ultrasonic-assisted agarwood oil extraction

A sample of agarwood powder was weighed 5 grams, dissolved in 100 ml of methanol p.a. in an Enlemeyer container, then maceration was carried out in ultrasonic bath equipment for 60 minutes. Then, the oil was separated from the solvent using a rotary evaporator. Then, the agarwood oil yield was measured and calculated using equation (i)

$$\text{Yield\%} = \frac{\text{Oil weight}}{\text{Raw materials weight}} \times 100\% \quad \text{....(i)}$$

Microwave-assisted agarwood oil extraction

The agarwood sample was weighed 5 grams, dissolved in 100 ml of methanol in an Enlemeyer container, then maceration was carried out in a microwave for 3 minutes until the boiling point of the methanol solvent was reached, then left for 60 minutes and then the solvent was separated from the oil using a rotary evaporator, then the agarwood oil yield was measured and calculated using equation (i).

Analysis of secondary metabolic using GC-MS

Gas chromatography and mass spectrometry (GC-MS) were used to identify the constituent compounds contained in agarwood resin. Following solvent separation, the sample was injected into the GC-2030 type column with an experimental protocol that included an injector temperature set to 250°C, column temperature 50°C and column flow at a speed of 1.16 mL/min until it reached

Table 1: Hayami method value added calculation template.

Variable	Unit	Value
Output, input and price		
Output	ml	(1)
Basic raw material	Kilogram (kg)	(2)
Direct labor	(WPD)	(3)
Conversion factor		(4) = (1) / (2)
Direct labor efficiency	WPD/kg	(5) = (3) / (2)
Output price	Rp/ml	(6)
Direct labor wages	Rp (Rupiah)	(7)
Revenue and profit		
Raw material price	Rp/kg	(8)
Other input price	Rp/kg	(9)
Output value = sales	Rp/ml	(10) = (4) × (6)
a. Added value	Rp/kg	(11a) = (10) – (8) – (9)
b. Added value ratio	%	(11b) = (11a) / (10) × 100
a. Direct labor income	Rp/kg	(12a) = (5) * (7)
b. Direct labor share	%	(12b) = (12a) / (11a) × 100
a. Profit	Rp/kg	(13a) = (11a) – (12a)
b. Profit level	%	(13b) = (13a) / (10) × 100
Reward for owners of production factors		
Margin	Rp/kg	(14) = (10) – (8)
a. Direct labor income	%	(14a) = (12a) / (14) × 100
b. Contribution of other inputs	%	(14b) = (9) / (14) × 100
c. Company profit	%	(14c) = (13a) / (14) × 100

Information : (WPD): Working people day, (kg): Kilogram, (ml): milligram, (Rp): Rupiah (currency of Indonesia, IDR).

15.7/min. The linear velocity was 39.0 cm/sec and the purge flow was 3.0 ml/min. The ion source temperature was maintained at 200°C and the interphase temperature was kept at 25°C. The analysis was conducted using the NX Program GCMS-TQ8050. After sample preparation, compounds derived from agarwood can be identified through retention time and mass spectral analysis.

Life cycle costing (LCC) calculation of extraction process

The calculation of the life cycle cost of the extraction process aims to see the costs incurred in carrying out the agarwood oil extraction process on a laboratory scale, the calculation is done by calculating the use of electrical energy by calculating the KWh (Kilowatt hour) value obtained at each stage of the agarwood oil extraction process, the KWh value obtained is converted to the cost of electricity per 1 KWh in rupiah (Rp. 1,444.70) according to Equation (ii).

Total life cycle cost = KWh Value × Rp. 1,444.70 …(ii)

Calculation of added value

The calculation using the Hayami method creates a calculation formulation using the Microsoft Excel worksheet table to obtain the added values of several extraction methods and the comparison between these added values can be calculated. In the Hayami method template, you can see the calculation to obtain the weight that will later be needed to see the portion of the difference in the results of the profit margin from one template. The Hayami Method value-added calculation template can be seen in Table 1.

Results and Discussion

Agarwood oil extraction

Extraction of agarwood oil was carried out using several solvent maceration techniques, maceration was carried out using four methods, namely microwave-assisted maceration for 3 minutes and ultrasonic-assisted maceration for 60 minutes. The highest extraction yield was obtained with microwave maceration of 0.096% compared to ultrasonic-assisted maceration with a yield of 0.093%. extraction using maceration and ultrasonic assistance can increase the yield or extract results and can maintain product quality (Kalla *et al.,* 2017; Gurjar and Raj, 2022; Patil *et al.,* 2018; Singh *et al.,* 2017). Comparison of agarwood oil yields can be seen in Table 2.

Agarwood oil profile from several extraction methods

Research shows that these compounds not only contribute to the aroma but also have potential therapeutic benefits, such as antimicrobial and anti-inflammatory properties. The profile of agarwood oil shows the differences in the compounds that make up agarwood oil from several extraction methods used, the ultrasonic-assisted maceration method shows the dominant compound that makes up agarwood oil is 1-Benzyl-4-chloro-5-methyl-2-phenylimidazole (29%) followed by (3R,3aR,4aS,5R,9aS) -3,5,8-Trimethyl-3a,4,4a,5,6,7,9,9a-octahydr (17.16%), then there is a change when compared to the microwave-assisted maceration method, namely showing a decrease in the two compounds, namely 1-Benzyl-4-chloro-5-methyl-2-phenylimidazole (21.43%), (3R,3aR,4aS,5R ,9aS) -3,5,8-Trimethyl-3a,4,4a,5,6,7,9,9a- octahydr (17.21%) and a new dominant compound appears 2-((2S,4aR)-4a,8-Dimethyl-1,2,3,4,4a,5,6,7-octahy- dronaphthalen with an amount of

Tabel 2: Yield from extraction methode.

Extraction method	Yield (%)
Ultrasonic-assisted agarwood oil extraction	0.093
Microwave-assisted agarwood oil extraction	0.096

Tabel 3: Agarwood oil profile ultrasonic assisted maceration method.

R.time	Nama senyawa	Area (%)
17.692	2-Butanone, 3-phenyl-	4.18
20.558	Hydrocinnamic acid	3.31
24.839	2-Butanone, 4-(4-methoxyphenyl)-	2.96
26.272	(3R,5aS,9aR)-2,2,5a,9-Tetramethyl-3,4,5,5a,6,7-hexahydro-2H	5.75
28,129	2-((2S,4aR)-4a,8-Dimethyl-1,2,3,4,4a,5,6,7-octahydronaphthalen	5.32
28.945	Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimethyl-7-(1-methylethe	0.37
31,313	2-Cyanoethyl acrylate	3.73
33.926	(3R,3aR,4aS,5R,9aS)-3,5,8-Trimethyl-3a,4,4a,5,6,7,9,9a-octahydro	1.64
35.017	(4aS,7R)-7-(2-Hydroxypropan-2-yl)-1,4a-dimethyl-4,4a,5,6,7,8	1.43
35.513	(3R,3aR,4aS,5R,9aS)-3,5,8-Trimethyl-3a,4,4a,5,6,7,9,9a-octahy	17.16
37.361	Hydroxyvalerenic acid	1.63
37.774	Hydroxyvalerenic acid	1.96
38.871	Cycloprop[e]indene-1a,2(1H)-dicarboxaldehyde, 3a,4,5,6,6a,6b-	8.17
40.189	Bicyclo[4.4.0]dec-2-ene-4-ol, 2-methyl-9-(prop-1-en-3-ol-2-yl)-	1.01
41.938	(3,8a-Dimethyl-5-methylidene-2-oxo-4a,6,7,8,9,9a-hexahydro-4H	4.89
42.823	2-Phenethyl-4H-chromen-4-one	5.32
49.894	1-Benzyl-4-chloro-5-methyl-2-phenylimidazole	29.05
51.640	Acetamide, N-(4-benzyloxyphenyl)-2-cyano-	2.09

11.28%. The profile of agarwood oil using ultrasonic-assisted maceration and microwave-assisted maceration methods and combinations can be seen in Table 3 and Table 4. Extraction of agarwood oil using the maceration method using solvents can show the characteristic components of agarwood after analysis using GC-MS (Satria *et al.,* 2025).

Life cycle costing of agarwood oil extraction

Life cycle costs are very important to know to see the efficiency of time and cost in the agarwood oil extraction process if viewed from the yield of the combined extraction process of microwave and ultrasonic maceration which produces the highest yield, but if we look at the efficiency of time and cost, it shows that microwave-assisted maceration is the most effective, namely with a shorter time and cheaper cost. The cost incurred for the agarwood oil extraction process for 24 hours is IDR 3,190 with a total extract of 12 grams. However, if we compare it with ultrasonic-assisted maceration, it costs quite a lot if the extraction process for 24 hours is IDR 12,760 with a lower extraction result than a microwave, namely 11 grams.

The small cost incurred for room temperature maceration does not indicate a high yield. This is because there is no additional process to speed up the agarwood oil extraction process so the extraction process takes too long to produce maximum yield. Furthermore, the low extraction cost using microwave-assisted maceration has a good impact on yield and cost where the amount of cost incurred is not too large because only energy is used for 3 minutes so that the results obtained can be effective in extraction costs. A comparison of agarwood oil extraction cycle costs can be seen in Table 5. In calculating the life cycle cost of agarwood oil extraction, the most efficient extraction method is maceration using microwaves. This is due to the lower cost compared to the maceration method using ultrasonics (Cai *et al.,* 2022). The use of microwaves in the agarwood oil extraction process can provide advantages in cost efficiency, which is important in evaluating the total costs associated with the agarwood oil extraction process. Studies have shown that the use of microwaves in the extraction process can provide high efficiency in cost expenditures, making it a more economical choice in life cycle costing calculations (Dong *et al.,* 2021). The results of the life cycle costing calculation of agarwood oil can be seen in Table 5.

Added value of agarwood oil

The calculation of added value in the agarwood oil processing process is calculated using the Hayami method by presenting four processing processes, namely agarwood oil extraction using the room temperature maceration method, microwave-assisted maceration, ultrasonic-assisted maceration and combination maceration. The calculation of added value in the agarwood oil processing process is carried out by integrating input, output and price so that it is necessary to determine assumptions in the agarwood oil processing in the calculation of added value with the following approach:

1) Agarwood oil processing is carried out as much as one kilogram of agarwood sapwood.
2) The price of agarwood sapwood is set at IDR 1,500,000 / Kg.
3) The price of agarwood oil is set at IDR 300,000 / ml.
4) Production output data is taken from oil yield data based on each oil extraction method
5) The amount of output is calculated based on the yield of one kilogram of agarwood sapwood
6) Other input costs are taken from the cost of energy use in the Life Cycle Costing (LCC) of each extraction method and consumables.

Tabel 4: Agarwood oil profile ultrasonic assisted maceration method.

R.Time	Nama senyawa	Area (%)
17.697	2-Butanone, 3-phenyl-	5.29
20.491	Hydrocinnamic acid	3.74
24.841	2-Butanone, 4-(4-methoxyphenyl)-	3.04
26.276	(3R,5aS,9aR)-2,2,5a,9-Tetramethyl-3,4,5,5a,6,7-hexahydro-2H	5.57
26.901	3-(4-Methoxyphenyl)propionic acid	2.17
28.133	2-((2S,4aR)-4a,8-Dimethyl-1,2,3,4,4a,5,6,7-octahydronaphthalen	11.29
28.946	Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dimethyl-7-(1-methyleth	0.38
33.922	(3R,3aR,4aS,5R,9aS)-3,5,8-Trimethyl-3a,4,4a,5,6,7,9,9a-octahy	7.46
35.013	2,3,3-Trimethyl-2-(3-methylbuta-1,3-dienyl)-6-methylenecyclohexano	2.78
35.512	(3R,3aR,4aS,5R,9aS)-3,5,8-Trimethyl-3a,4,4a,5,6,7,9,9a-octahydr	17.21
36.468	(3aR,4aS,5R,9aS)-5,8-Dimethyl-3-methylene-3a,4,4a,5,6,7,9,9a-	0.75
37.356	(E)-5-((1S,5R,8aR)-5-Formyl-5,8a-dimethyl-2-methylenedecahydronaphthalen	3.48
37.768	(E)-5-((1S,5R,8aR)-5-Formyl-5,8a-dimethyl-2-methylenedecahydro	1.96
38.861	Cycloprop[e]indene-1a,2(1H)-dicarboxaldehyde, 3a,4,5,6,6a,6b-	6.54
42.815	2-Phenethyl-4H-chromen-4-one	4.87
49.795	1-Benzyl-4-chloro-5-methyl-2-phenylimidazole	21.43
51.596	Acetamide, N-(4-benzyloxyphenyl)-2-cyano-	2.02

Tabel 5: Results of life cycle costing calculations for agarwood oil.

Extraction method	Equipment	Energy (KWh)	Energy total (KWh)	1 KWh (Rp)	Cost total (Rp)	Extract (gr)	Cost total in 24 Hour (Rp)	Extract total in 24 Hour (gr)
Microwave-assisted agarwood oil extraction	Microwave	0.008	0.092	Rp.1.444.70	132.91	0.4862	Rp1.063	4
	Rotary evaporator	0.084						
Ultrasonic-assisted agarwood oil extraction	Ultrasonic	0.284	0.368	Rp.1.444.70	531.65	0.4678	Rp2.127	2
	rotary evaporator	0.084						

The results of the calculation of the added value of several agarwood oil extraction methods show that the method of processing agarwood oil using the microwave-assisted maceration method obtains a higher added value than other methods, namely Rs. 7,875,496 / kg. and gets a profit of Rs. 6,675,496/kg. Maceration using room temperature shows a method that is not recommended because it does not get any profit from the agarwood oil processing process. Apart from the microwave maceration method being the best method, the next method is the combination of microwave and ultrasonic maceration method which also shows a fairly good profit of Rs. 4,266,616/kg. The calculation of the added value of agarwood oil processing from several maceration methods can be seen in Table 6. Agarwood oil processing (*Aquilaria malaccensis*) is one of the businesses that has significant added value potential. In this context, the analysis of the added value and profit from agarwood oil processing can be done using methods that have been proven effective. Research shows that processing agarwood through microwave- assisted maceration can increase the economic value of raw materials that initially have low value into products with high value, then this agarwood oil can be marketed as a raw material in the perfume, cosmetics and traditional medicine industries (Wahyuni and Yuliana, 2021).

Furthermore, research conducted by (Triesty Isabel, 2018) showed that the extraction methods used in processing agarwood oil, such as microwave extraction and Soxhlet extraction, can affect the oil yield produced. More efficient methods in extraction can increase the amount of oil obtained, thus contributing to increasing the added value of the final product. Thus, choosing the right processing method is very important to maximize the benefits of this business. The results of the calculation of the added value of agarwood oil production can be seen in Table 6.

In the context of added value, it is important to consider the distribution of added value among business actors. Although there is no direct reference that discusses the distribution of added value in agarwood oil processing, it is important to note that fair distribution of profits to workers and capital owners also needs to be considered to maintain business sustainability. Therefore, strategies involving training and skills improvement for workers in agarwood oil processing can be an important step to increase the productivity and welfare of communities involved in the agarwood industry (Khairunnisa *et al.,* 2021). Overall, agarwood oil processing not only provides significant added value but also has the potential to increase the income of local communities. With the right approach in selecting processing methods and distributing added value, this business can become one of the pillars of a sustainable economy in agarwood-producing areas.

Tabel 6: Results of calculation of added value of agarwood oil production.

Variable	Unit	Ultrasonic-assisted agarwood oil extraction	Microwave-assisted agarwood oil extraction
Output, input and price			
Output	Ml	16	32
Basic raw material	Kilogram (kg)	1	1
Direct labor	(WPD)	8	8
Conversion factor		16	32
Direct labor efficiency	WPD/kg	8	8
Output price	Rp/ml	300.000	300.000
Direct labor wages	Rp (Rupiah)	150.000	150.000
Revenue and profit			
Raw material price	Rp/kg	1.500.000	1.500.000
Other input price	Rp/kg	233.016	224.504
Output value = sales	Rp/ml	4.800.000	9.600.000
a. Added value	Rp/kg	3.066.984	7.875.496
b. Added value ratio	%	64	82
a. Direct labor income	Rp/kg	1.200.000	1.200.000
b. Direct labor share	%	39	15
a. Profit	Rp/kg	1.866.984	6.675.496
b. Profit level	%	39	70
Reward for owners of production factors			
Margin	Rp/kg	3.300.000	8.100.000
a. Direct labor income	%	36	15
b. Contribution of other inputs	%	7	3
c. Company profit	%	57	82

CONCLUSION

The life cycle costing calculation shows that the most effective and cheapest extraction method is microwave-assisted maceration which costs Rp1,063 and has an extract yield of 4 grams during the 24-hour extraction process, then for the extraction process using the ultrasonic-assisted maceration method, an extract yield of 2 grams was obtained for 24 hours at a cost of Rp2,127. The results of the calculation of the added value from the comparison of agarwood oil extraction methods show that the agarwood oil processing method with the microwave-assisted maceration method obtains higher added value compared to the ultrasonic-assisted maceration method, which is Rp7,875,496/kg. and obtained a profit of Rp.6,675,496/kg. Therefore, the microwave-assisted extraction method can be used to increase the production of agarwood oil.

Disclaimers

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Conflict of interest

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