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Ultrasound Assisted Extraction of Cinnamon Bark Essential Oil with Physicochemical Characterization

Syakilla Adha Nandianta[1], Ratnawati Ratnawati[1]*, Ridho Prasetyo[1,2]
[1]Department of Chemical Engineering, Faculty of Technic, Universitas Diponegoro, Tembalang, Semarang, Central Java, 50275, Indonesia
[2]Chemistry Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Sekaran Campus, Gunungpati, Semarang, Central Java, 50229, Indonesia

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Abstract

Indonesia's biodiversity is extremely diverse, one example being its aromatic plants, which make it one of the world's largest producers of essential oils. Cinnamon is one such plant, almost all parts of which can be used, including the bark. Its main components consist of 60-85% cinnamaldehyde and 5-10% eugenol. The Ultrasound Assisted Extraction method is used in this extraction. The purpose of this study is to determine the effect of using the UAE extraction method on variations in temperature, time, and the ratio of raw materials to solvents. The extraction process was carried out at 30°C, 40°C, 50°C, and 60°C; 5, 10, 20, 30, 40, 50, and 60 minutes; and ratio of 1:6, 1:8, and 1:10. The essential oil several tests, such as yield, refractive index, optical rotation, acid number, antioxidant IC_{50}, SEM, FT-IR, and GC-MS. The results showed that there was an effect of temperature, time, and the ratio of material to solvent used. The use 40°C and 30 minutes produced the highest oil yield of 2.28% and cinnamaldehyde 87.89%.

✉ Correspondence address:
Department of Chemical Engineering, Faculty of Technic, Universitas Diponegoro
E-mail: ratnawati.hartono@gmail.com

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1. Introduction

Indonesia, as a country rich in natural resources, is one of the world's leading producers of essential oils. According to data compiled by Statistics Indonesia (BPS) (BPS, 2017), Indonesia has exported essential oils to 102 countries around the world. With this achievement, the value of Indonesia's essential oil exports has increased year by year. The increasing global demand for essential oils has driven Indonesia to increase its essential oil production (Mordor Intelligence, 2025). Essential oils are widely used for aromatic purposes and food products. Some aromatic plants that can be used as source of essential oil include patchouli, cinnamon, lemongrass, ginger, cloves, jasmine, ylang-ylang, eucalyptus, sandalwood, and vetiver, among many others (Yuniarto et al., 2022).

Every part of cinnamon plant contains essential oil. However, bark and leave are the parts commonly used to produce the essential oil which is proven to contain antioxidants and antimicrobials (Tamim et al., 2025). Cinnamon essential oil includes cinnamaldehyde, eugenol, linalool, coumarin, flavonoids, and several other compounds (Do et al., 2024). Cinnamon oil extracted from cinnamon bark has higher content of cinnamaldehyde than that extracted from cinnamon leaves, which contain more eugenol (Hasibuan et al., 2024). Cinnamaldehyde in cinnamon bark oil, ranging from 60% to 75% (G. Chen et al., 2021), while the eugenol content is only 5% to 10%.

Various extraction methods have been applied to produce cinnamon oil, such as steam distillation (Elyemni et al., 2019), hydro distillation (Chen et al., 2021), supercritical CO_2 extraction (Lee et al., 2024), and more recently, the use of microwave (Gaikwad et al., 2025) and ultrasonic waves (Phu et al., 2022). Several previous studies have revealed that the essential oils obtained vary widely, ranging from 0.05 to 3.5% (Yu et al., 2020), depending on several factors such as extraction methods, extraction solvents, raw material characteristics, and plant origin.

Many conventional methods for extracting essential oil from cinnamon bark have several drawbacks, such as long processing times, low yields, higher energy consumption, inefficiency, and the possibility for degradation of active compounds due to exposure to high temperatures (Kurniasari et al., 2019). The use of newer methods, known as green extraction methods, such as the use of microwave and ultrasonic waves, is considered superior to conventional methods (Modi et al., 2019).

The use of green extraction methods has several advantages, including higher product purity, a smaller amount of solvents, a shorter extraction time, a less energy consumption, and no degradation of active compounds in the raw materials (Kutlu et al., 2022). However, microwave-assisted extraction also has shortcomings, such as potential degradation of heat-sensitive compounds due to high-temperature "hot spots" during extraction which may generate unwanted off-flavors and high setup costs (Zahar et al., 2021). Meanwhile, the use of the ultrasound-assisted extraction method is considered more effective and efficient because it can increase the penetration of the solvent used in the cellular matrix due to the cavitation phenomenon that occurs in the ultrasonic process (Ojha et al., 2020).

Prior research on essential oil extraction from cinnamon bark using ultrasonic extraction has been carried out by Modi et al (2019), which investigated variations in ultrasonic power, ultrasonic amplitude, and pulse ratio using n-hexane as the solvent, resulting in an oil yield of 4.64%. Meanwhile, Phu et al (2022), who varied the extraction methods, there are hydrodistillation and ultrasonic extraction using two different solvents, n-hexane and water, resulting in an oil yield of 2.32% at a temperature of 40°C and a frequency of 25 kHz. A similar study was also conducted by Lee et al (2018), who varied the concentration of the ethanol solvent and achieved an oil yield of 0.76% at a frequency of 40 kHz and a power of 700 W. Another investigation was conducted by Michalczyk et al (2015), who studied variations in the solvents used, resulting in an oil yield of 0.405% using n-hexane as the solvent, at a temperature of 25°C, for 30 minutes, at a frequency of 35 kHz, and with a material-to-solvent ratio of 5:6. Based on previous studies, it appears that the evaluation of the effects of varying temperature, time, and the ratio of raw material to solvent has not been extensively explored. Therefore, the objective of this study is to evaluate the effects of varying time, temperature, and the ratio of raw material on the ultrasonic-assisted extraction of essential oil from cinnamon bark. This paper presents novel observation of mass transfer kinetics in the ultrasonic-assisted extraction of essential oil from cinnamon bark.

2. Method

2.1. *Materials*

The dried cinnamon bark which was obtained from local market of Banyumas, Indonesia. N-hexane (CAS Number 110-54-3), KOH (CAS Number 1310-58-3), and ethanol (CAS Number 64-17-5) were purchased from Sigma-Aldrich Indonesia.

2.2. *Ultrasound-assisted Extraction*

The cinnamon bark was washed, dried, ground, and sieved to pass a 60-mesh sieve. Twenty five grams of cinnamon bark powder (CBP) was placed in a 250 mL Erlenmeyer flask. A certain amount of n-hexane (150, 200, and 250 mL) as the solvent was added to the CBP. The flask was put into an ultrasound device (Elmasonic EASY 30H) equipped with a thermostatic water bath. The bath was set to a specified temperature (30, 40, 50, and 60°C). After the specified temperature was reached, the ultrasound was turned on for a certain time (5, 10, 20, 30, 40, 50, and 60 minutes). Then the mixture was for 15 minutes to separate the residual CBP from the supernatant. The supernatant was filtered using a vacuum filter. The filtrate was evaporate in a rotary vacuum evaporator to separate the essential oil from the solvent. The oil was stored in a dark, tightly sealed bottle for further analysis. The schematic of Ultrasound-assisted extraction shown in Figure 1.

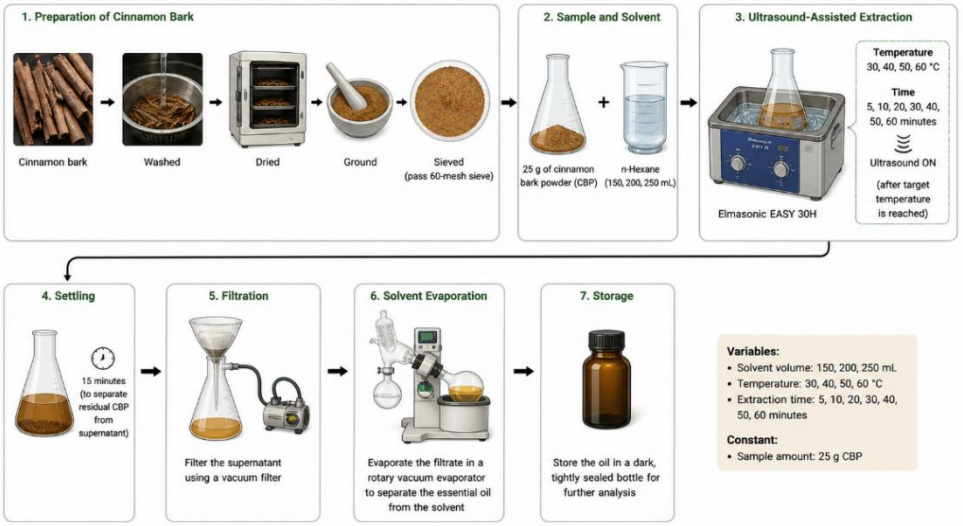

Figure 1. Schematic UAE Extraction of Cinnamon Oil

2.3. *Sample Characterization*

2.3.1. *Yield*

The essential oil obtained was weighed to determine the oil yield. The yield was calculated using the following equation (1) (Jadhav et al., 2021).

$$\text{Yield} = \frac{\text{Weight of essential Oil (g)}}{\text{Weight of raw material (g)}} \times 100\% \quad (1)$$

2.3.2. *Refractive Index*

The refractive index of essential oil is measured using an Abbe refractometer 98.490 (EUROMEX Microscopen B.V., Holland). The measurement was done at 20°C.

2.3.3. *Optical Rotation*

The optical rotation of essential oils is measured using a polarimeter (WXG-4 Full-Circle Manual Polarimeter) according to the ISO 592:1998 standard. The measurement was conducted at 20°C. The optical rotation of essential oils is calculated using equation (2) (Tran Le et al., 2025).

$$[\alpha]_{\lambda}^{T} = \frac{\alpha}{l \times c} \quad (2)$$

where $[\alpha]_{\lambda}^{T}$ is spesific rotation at T (°C) and wavelength λ (589 nm), α is measured optical rotation on the polarimeter (degrees), l is length of the polarimeter tube (dm), and c is concentration of oil in the sample.

2.3.4. *Antioxidant Inhibition*

The antioxidant activity of essential oils was measured using the DPPH method with a UV-Vis spectrophotometer at a wavelength of 517 nm. The antioxidant activity of essential oils was calculated using the following equation (3) (Liu et al., 2019). The antioxidant activity test was conducted using sample concentrations 10, 30, 50, 70, 90, and 100 ppm and the blank solution was prepared by adding 200 μL of methanol without adding of DPPH or essential oil sample.

$$\text{Antioxidant Inhibition} = \frac{A_C - A_S}{A_C} \times 100\% \quad (3)$$

where $\boldsymbol{A_C}$ and $\boldsymbol{A_S}$ are the absorbance of control and sample, respectively.

2.3.5. *Acid Number*

The acid value of essential oils is measured by alkalimetric titration using 0.1 N KOH solution as the titrant and phenolphthalein as the indicator. Ten ml of 96% ethanol is added to the essential oil sample. The titration is performed by titrating the sample with 0.1 N KOH solution until the endpoint is reached (4) (Azriyenni et al., 2022).

$$\text{Acid Number} = \frac{\text{V} \times \text{N} \times 56.1}{\text{W}} \quad (4)$$

where V and N are is the volume (ml) and the normality of KOH solution, W is the weight of essential oil sample (g), and 56.1 is the molecular weight of KOH.

2.3.6. *Solubility in Alcohol*

This solubility of the CBEO in alcohol was conducted by adding five ml of 70% ethanol to 1 ml of the essential oil sample in one ml increments. The essential oil was considered soluble in alcohol when the sample, which was initially yellow like cinnamon oil, turned clear, transparent, and homogeneous (Mungwari et al., 2025).

2.3.7. *Fourier Transform-Infrared (FT-IR)*

The FT-IR test was conducted to determine the functional groups detected in cinnamon bark essential oil (Li et al., 2013). The analysis was executed using an FT-IR apparatur (Perkin Elmer, Model Frontier S/N: 96772). The FTIR spectrum was scanned over the wavenumber range of 4000–450 cm^{-1} with a resolution of approximately 1 cm^{-1}, so provide high spectral detail for the identification of functional groups.

2.3.8. *Chemical Composition (GC-MS)*

The composition of the CBEO was analyzed using a GC-MS apparatus (Shimadzu GCMS-2010 Plus). The GC–MS analysis was carried out using a DB-5MS capillary column. Helium was employed as the carrier gas with a column flow rate of 0.52 mL/min. The oven temperature was initially set at 60 °C, then increased to 150 °C at a rate of 3 °C/min, followed by a further increase to 250 °C at a rate of 10 °C/min, and finally held at 250 °C for 10 minutes.

2.4. *Scanning Electron Microscopy (SEM) of Cinnamon Bark Powder (CBP)*

The SEM test was conducted to observe the surface of cinnamon powder particles before and after ultrasonic extraction treatment. The test was conducted at magnifications of 200x, 500x, 1000x, and 3000x. The test was conducted using a SEM (JEOL JSM-6510LA SEM-EDX). The SEM analysis was conducted at an accelerating voltage of 10 kV and the sample was coated with a thin layer of gold (Au) to enhance conductivity and improve image quality.

3. Results and Discussion

3.1. *Chemical composition of cinnamon bark*

Table 1 presents the proximate analysis results of the cinnamon bark used in this study. The moisture content obtained was 13.715%, while Rana & Sheu (2023) reported 15.83%. The moisture content varies depending on several factors, such as the type of cinnamon plant used, the drying method, and the duration of storage of the dried cinnamon bark (Chen et al., 2020). The total ash and crude fiber content were 2.982% and 4.569%, respectively. Rana & Sheu (2023) found a slightly higher content for both total ash and crude fiber. However, the essential oil content obtained in this work was higher than that reported by (Rana & Sheu, 2023).

Table 1. Proximate analysis of cinnamon bark powder (CBP)

Component	Composition (%)	
	This work	[29]
Moisture	13.715	15.83
Total Ash	2.982	3.47
Crude Fiber	4.569	5.67
Essential Oil	1.615	0.4834

3.2. Effect *of ultrasound*

The effect of ultrasonication on the extraction of essential oil from CBP is presented in Table 2. Table 2 shows the effect of the ultrasonic process on the yield of essential oil, compared to the conventional maceration method. In the extraction process, temperature variations were used are 30, 40, 50, and 60°C, where each temperature produced optimal conditions with the highest yield at different times, but dominantly between 20 and 30 minutes. Therefore, to determine whether the ultrasonic extraction process has an effect, it will be compared with the conventional maceration method under its optimal conditions.

Using the same ratio of CBP/solvent (1/10) at various temperatures and time, it is shown that the oil yield in UAE are higher than that in the maceration. This is due to cavitation during the ultrasonication process, which generates micro-bubbles that can break down cellular tissue more deeply, allowing the oil's active compounds to be released more easily from the matrix (Yusof et al., 2016). Consequently, the diffusion process of oil components from matrix into the solvent is more efficient. However, yield decreases at high temperatures for both methods. This decrease in yield caused by the volatility and degradation of certain heat-sensitive components of the essential oil over time (Bucur et al., 2023).

Table 2. The essential oil yields in the UAE and maceration

Temperature (°C)	Yield (%)		
	t (min)	UAE	Maceration
30	20	1.32	0.80
40	30	2.28	0.84
50	20	1.84	1.12
60	30	2.16	0.92

In contrast, the maceration method tends to yield lower yields. This is because the maceration method essentially operates on the principle of passive mass transfer between the material and the solvent through diffusion and osmosis, without the aid of external energy (Khasanah et al., 2024). At higher temperature the viscosity of the solvent decreases which enhances molecular diffusion. However, since the process is dominated by slow diffusion, the temperature increase is insufficient to accelerate oil release (Sun et al., 2021). In other words, the primary mechanism of the maceration process is heavily constrained by the internal resistance of the cell walls, which act as barriers to mass transfer.

3.3. *Effect of ratio of CBP/solvent*

The effect of the ratio of CBP/solvent is presented in Table 3. The extraction was conducted at 50°C for 50 minutes.

Table 3. Effect of ratio of CBP/oil on the essential oil yield

CBP/Solvent ratio	Yield (%)
1 : 6	1.32
1 : 8	1.40
1 : 10	1.76

It is seen in Table 3 that the yield increases as the amount of solvent increases. The highest yield was obtained when the ratio of CBP/solvent was 1/10. This is in line with several previous studies that mention that the use of a 1:10 ratio in the essential oil extraction process is often the optimum condition (Dao et al., 2021). Some of the reasons for this include an increase in solvent volume, which can effectively influence the contact area between the solvent and the particles contained in the material, the quantity of solvent, which influences solvent saturation (Li et al., 2019), high concentration gradients between the solvent and the material, which are more effective in dissolving essential oil components, and the use of non-polar solvents that are very suitable for extracting non-polar compounds such as essential oils.

3.4. *Effect of extraction time*

Ultrasonic time affects the yield of cinnamon bark essential oil, as presented in Figure 2. Generally, increasing the process time, can increase the essential oil yield. However, excessively long times can also reduce the yield because active compounds may degrade and oxidize (Raza et al., 2017).

As shown in the figure, at the beginning of the process, the yield increases with time. It could be due to fragmentation and sonoporation of the plant tissue, which enhance solvent exposure to the plant biomass. Early in the extraction process, longer exposure may allow the solvent to penetrate the solid matrix for a longer time, thereby breaking down cell walls and releasing the desired active compounds (Forghani et al., 2020). However, after 30 minutes, the yield starts to decline. It is possible that the concentration of the oil has reached equilibrium (Buanasari et al., 2018). Longer utrasonication may actually cause partial re-adsorption of the compounds onto the surface of the solid matrix and result in the decomposition of the active compounds (Xu & Pan, 2013).

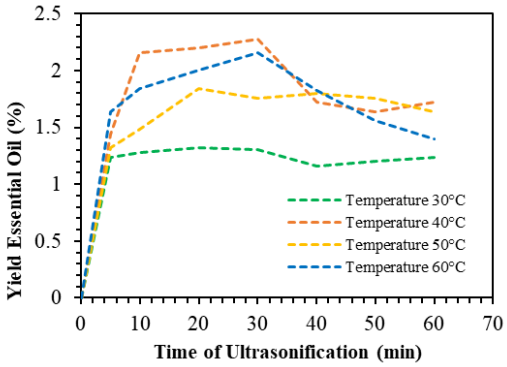

Figure 2. Effect time of ultrasonification on the essential oil yields

A longer processing time can degrade product quality, as evidenced by coalescence and aggregation processes (Naik et al., 2021). A decrease in yield can be caused by the degradation of thermally sensitive active compounds, leading to oxidation. It is these oxidized active compounds that result in the formation of hydroperoxides and other degradation products during production. The thermal degradation that occurs can cause the breakdown of compounds such as linalool into other compounds like β-myrcene and limonene. Additionally, the generated ultrasonic waves can produce hydroxyl radicals (•OH) from the breakdown of water molecules (Fischer et al., 2024). These decomposition products are highly likely to react with aromatic compounds and play a significant role in the degradation process of the compounds and the eduction in the quantity of major essential oil compounds such as cinnamaldehyde and eugenol.

3.5. *Effect of temperature*

The effect of temperature on the essential oil yield is depicted in Figure 3. In general, the yield increases as the temperature rises from 30 to 40°C, but it decreases at higher temperatures. As the temperature increases, more solvent evaporates and enters the cavitation bubbles. This will cause a cushioning effect on the collapsing bubbles and a diminishing of the intensity of the shock wave. It eventually lessens the degradation rate of the polymer at higher temperatures (Ratnawati & Indriyani, 2020).

Ultrasonic-assisted extraction process of cinnamon bark essential oil used temperatures of 30, 40, 50, and 60°C and times of 5, 10, 20, 30, 40, 50, and 60 minutes. The yield of cinnamon bark essential oil obtained showed that there were significant differences between variables. The yield obtained ranged from 1.6% to 2.28%, with the lowest yield btained at a temperature of 30°C for 5 minutes and the highest at a temperature of 40°C for 30 minutes. Increasing the temperature can increase the yield, but its use also needs to be regulated so that the active compund in the material matrix remain in a stable state (Kumar et al., 2021).

Similarly, increasing the time can also increase the yield, but its use also needs to be regulated because it can cause the active compounds to degrade (Forghani et al., 2020). The use of temperature and time is directly related to the ultrasonic cavitation process, where the collapse of microbubbles during cavitation can release local energy that can disrupt the stability of sensitive compounds in the raw material and lead to the degradation of active compounds (Tamim et al., 2025).

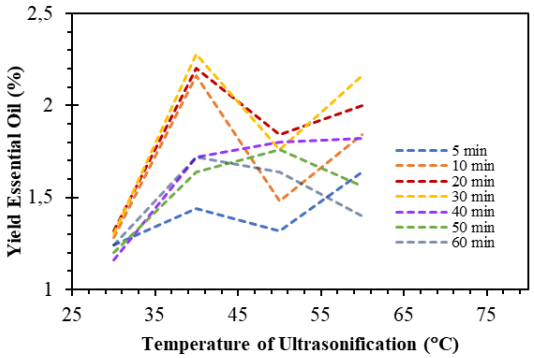

Figure 3. Effect temperature of ultrasonification on the essential oil yields

Overall, the highest essential oil yield at each temperature was obtained at 30 minutes. The yields obtained were 1.32%, 2.28%, 1.84%, and 2.16%, respectively. Figure 4 shows a graph of the highest essential oil yield at each temperature.

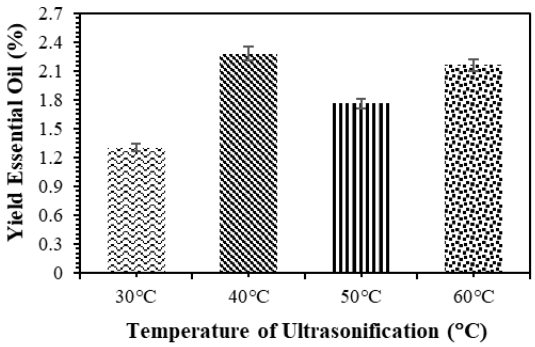

Figure 4. The highest essential oil yield (%) at at various temperature in extraction for 30 minutes

3.6. *Scanning electron microscopy (SEM)*

To elucidate the mechanism of the essential oil extraction process from cinnamon bark with UAE, morphological changes in the surface structure of cinnamon bark samples before and after ultrasonic processing were observed using SEM analysis, as shown in Figure 5. The image above was observed at 3000x magnification, where it can be seen that the surface structure observed before and after ultrasonic treatment is very clear. Before ultrasonic extraction treatment, the external structure of the observed sample remained intact, very smooth, compact, thick, and dense, and no significant disturbances were observed. The observed lignocellulose fibril microstructure was still tightly fused, and the non-porous cell surface indicated no deformation process (Li et al., 2022).

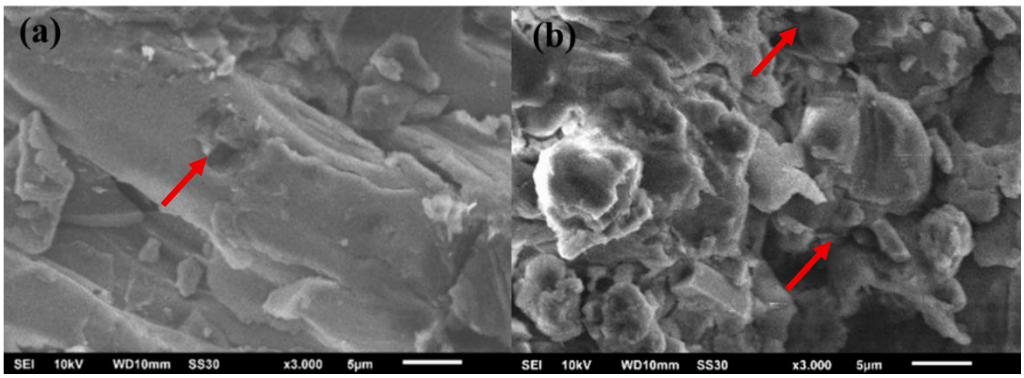

Figure 5. SEM Images of Cinnamon Bark Samples Before (a) and After (b) Ultrasonic Pretreatment

In contrast, after ultrasonic treatment, the structure of cinnamon bark was destroyed into small grains, numerous cracks, and gaps on the particle surface. Some observed irregular micro-holes resulting from collapse, cellulose fibers that appeared to be decomposed, separated from each other, hollow particle surfaces, and much fine debris (Nguyen & Harbison, 2017). Based on the results of SEM analysis, the extraction mechanism caused by cavitation bubbles generated near the surface of the

plant substrate will collapse after reaching a critical value of (Vinatoru et al., 2017). As a result, on the one hand, sonification will break up large particles and homogenize cinnamon bark particles and increase contact between cinnamon bark tissues. However, on the other hand, the cell walls of cinnamon bark tissues will be destroyed during the ultrasonic irradiation process, and contact will occur between active substances and intracellular. The ultrasonic process can destroy cinnamon bark tissues more deeply so that it can increase mass transfer, yield more oil, shorten extraction time, and improve oil quality.

3.7. *Cinnamon Oil Characterization*

Cinnamon bark essential oil underwent several tests afterwards. Table 4. below presents the results of tests on cinnamon bark essential oil.

Table 4. Characteristic of the cinnamon essential oil

Testing	Result
Organoleptic	
- Color	yellow
- Aroma	distinctive cinnamon
Yield	1.2%-2.28%
Solubility in alcohol (ethanol 70%)	Soluble at ratio of 1:1
Refractive index (at 20°C)	1.5695-1.585
Acid number	1.902 KOH/g
Optical rotation (at 20°C)	0°
Antioxidant content (IC_{50})	91 ppm
Cinnamaldehyde content	87.89%

Overall, the results of the organoleptic test showed that the oil had a distinctive cinnamon aroma and a light yellow color. The yellow color indicated that the sample did not undergo excessive oxidation during the process. The components that contributed to the yellow color were due to the presence of cinnamaldehyde, eugenol, cinnamyl acetate, and coumarin (Tamim et al., 2025). The yellow color produced is not intense because the concentration of organic pigments contained is not too high and there are no strong chromophores such as carotenoids (Mutlu et al., 2023). Meanwhile, the aroma produced is warm, sweet, spicy, and strong cinnamon. This is due to the content of cinnamaldehyde and eugenol compounds as well as n-hexane solvent, which is a non-polar aliphatic hydrocarbon with a straight carbon chain, resulting in a sharper aroma (Kumar & Deak, 2025).

The results of testing the solubility of essential oils in 70% ethanol show that essential oils are completely soluble at a ratio of 1:1. The results obtained were excellent and showed compliance with SNI 06-3734-2006. This indicates that essential oils have a polarity balance that is compatible with 70% ethanol solvent, which is semi-polar (Mushtaq et al., 2025). Cinnamon essential oil, which consists of cinnamaldehyde and eugenol compounds, interacts with each other through dipole-dipole forces and weak hydrogen bonds with ethanol solvent (Živković et al., 2025). This interaction results in homogeneous mixing of the solution without the formation of separate layers and shows the composition of pure essential oil that does not contain many non-polar fractions such as wax and resin.

The results of the refractive index testing of essential oils ranged from 1.5695 to 1.585. Overall, the results obtained were in accordance with the requirements of SNI 06-3734-2006. The refractive index values obtained can indicate the quality and purity of essential oils (López-Hortas et al., 2022). This is due to the positive correlation between the refractive index and the concentration of cinnamaldehyde contained, where an increase in aromatic aldehyde content is directly proportional to an increase in the refractive index value. The refractive index value shows an upward trend with increasing temperature and extraction time. However, an increase in the refractive index value at the highest process temperature of 60°C does not always indicate that the quality of the essential oil produced is better. This is because some of the volatile components of the oil can be lost and change the composition of the oil, which is more dominant in the heavy fraction (Kalua et al., 2010). Similarly, the time factor, using a longer time allows the solvent more time to penetrate the solid matrix, but if it is too long, it can also increase the oxidation of compounds, which can reduce the optical quality of the oil.

The acid number test results for essential oils were 1.902 KOH/g. The results obtained show that the acid number of essential oils is classified as low and that essential oils are of good quality (Picolloto et al., 2025). In terms of quality, a low acid value indicates that the essential oil is relatively stable against hydrolysis, the conversion of triglycerides into free fatty acids, and that the oil is not overly

contaminated by organic acids or process residues. This stability is important to prevent the formation of free fatty acids, which can cause rancidity and damage to the oil.

The optical rotation test results for essential oils were 0°. The results obtained show that the optical rotation meets the requirements of SNI 06-3734-2006. However, the results obtained should be in the range of -5 to 0° or rotate to the left (levitatory). The lack of conformity of the optical rotation results of essential oils is due to the measurement of the optical rotation value of essential oils that are not pure because of the addition of n-hexane solvent in the measurement. n-Hexane solvent is an achiral compound that does not have a chiral center and has a straight carbon chain so that it cannot bind hydrogen gas and cannot rotate the plane of polarized light, resulting in the detected optical rotation value of essential oil being 0° (Tran Le et al., 2025).

The results of inhibition and antioxidant content testing were 48.494% and 91 ppm, respectively. The results obtained show that the average % inhibition is classified as moderate. This value indicates the sample's ability to inhibit free radicals. In the DPPH test, this ability shows that the higher the inhibition %, the stronger the antioxidant activity (Mutlu et al., 2023). Meanwhile, the IC_{50} antioxidant content value is classified as a strong antioxidant (Blois, 1958). Although the inhibition % produced is moderate, the upward trend in inhibition values against concentration (ppm) shows strong results. These results are reinforced by several previous studies explaining that the IC_{50} value range of cinnamon bark essential oil is between 70 and 100 ppm. This is in line with the active compounds contained in cinnamon bark essential oil, namely cinnamaldehyde and eugenol. Cinnamaldehyde acts as a secondary antioxidant compound, but is less effective than eugenol, which acts as a primary antioxidant compound. The antioxidant levels produced are appropriate because the essential oil produced in this case comes from cinnamon bark, which is predominantly rich in cinnamaldehyde.

GCMS test results show that the detected content of cinnamaldehyde is greater than that of eugenol. These results are consistent because the essential oil is produced from Cinnamomum casia cinnamon trees and the bark of cinnamon trees used by (Dumas et al., 2021). Cinnamaldehyde and eugenol compounds were detected at 87.89% and 0.3%, respectively. Meanwhile, the remaining 8.06% consisted of coumarin compounds. Table 5 below presents the compound of cinnamon essential oil and Figure 6a below presents GC-MS chromatogram of cinnamon essential oil.

Table 5. Chemical Compounds of Cinnamon Essential Oil Detected

Peak	Retention Time	%Area	%Weight	Componen
1.	14.826	2.32	2.71	*α*-copaene
2.	17.208	0.23	0.40	*α*-bergamotene
3.	18.140	0.35	0.50	Cis-caryophyllene
4.	21.000	0.29	0.70	3-cyclohexene-1-methanol
5.	23.947	0.57	0.60	*α*-delta-cadinene
6.	32.734	87.89	6.71	2-propenal 3-phenyl Cinnamaldehyde
7.	33.120	0.3	0.48	Cubenol <1-EPI->DB5-1994
8.	38.563	8.06	28.91	2H-1-Benzopyran-2-one Coumarin

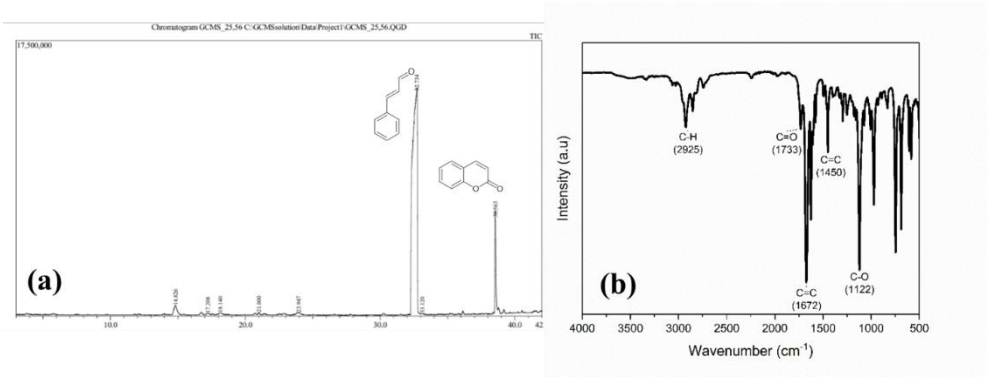

Figure 6. (a) GC-MS Chromatogram of Cinnamon Essential Oil; (b) FT-IR Analysis of Cinnamon Oil from Cinnamon Bark

The FTIR spectrum of cinnamon oil indicates the presence of key functional groups associated with bioactive compounds such as cinnamaldehyde and eugenol shown in Figure 6b. The absorption band at 1733 cm^{-1} corresponds to the carbonyl (C=O) group characteristic of aldehydes (cinnamaldehyde), while the band at 1672 cm^{-1} indicates a conjugated double bond system (C=C–C=O). The presence of eugenol is supported by phenolic and hydroxyl (O–H) groups, whereas the band at 1450 cm^{-1} confirms the aromatic structure (C=C of the benzene ring) (Sharma et al., 2019).The band at 2925 cm^{-1} represents aliphatic C–H stretching (alkanes), and the band at 1122 cm^{-1} corresponds to C–O stretching of ether or phenolic groups (Ulanowska & Olas, 2021).

Conclusion

Cinnamon essential oil was extracted by ultrasonication method from cinnamon bark (*Cinnamomum casia*). In the observation, the use of time and temperature greatly affected the efficiency of the extraction process. The study was conducted at temperatures of 30°C, 40°C, 50°C, and 60°C and times of 5, 10, 20, 30, 40, 50, and 60 minutes. The best cinnamon bark essential oil was obtained at a temperature of 40°C and a time of 30 minutes with a yield of 2.28%. Several tests were conducted on essential oil samples, such as FTIR, which detected the C=O group as cinnamaldehyde the main compound of essential oil, and GC-MS, which detected cinnamaldehyde at 87.89%. Several other tests were conducted, such as oil solubility in alcohol at a ratio of 1:1, oil refractive index of 1.583, acid number of 1.902 KOH/gram, optical rotation of 0°, and antioxidant IC_{50} of 91 ppm, which is classified as a strong antioxidant.

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