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Kurniawan Yuniarto Mr
Department of Agricultural Engineering, Ubiversity of Mataram, Mataram 83125, Indonesia,
kurniawan2006@unram.ac.id

Bruce Ari Welt Prof
Department of Agricultural and Biological Engineering, University of Florida, Florida 32610, USA,
bwelt@ufl.ac.id

Cahyo Mustiko Okta Muvianto Dr
Department of Electrical Engineering, University of Mataram, Mataram 83125, Indonesia,
c.muvianto@unram.ac.id

Abdul Muiz Mr
Department of Agricultural Engineering, Ubiversity of Mataram, Mataram 83125, Indonesi,
abdulmuiz831@gmail.com

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Ultrasound Application for Oil Extraction of Lemongrass Parts

Kurniawan Yuniarto[1], Bruce Ari Welt[2], Cahyo Mustiko Okta Muvianto[3], and Abdul Muiz[1]

1. Department of Agricultural Engineering, Ubiversity of Mataram, Mataram 83125, Indonesia
2. Department of Agricultural and Biological Engineering, University of Florida, Florida 32610, USA
3. Department of Electrical Engineering, University of Mataram, Mataram 83125, Indonesia

*E-mail: kurniawan2006@unram.ac.id

Abstract

Power ultrasound creates acoustic cavitation bubbles that encourage shears within food substances. Applying ultrasound improves solvent diffusion into the matrix plant cellular and hence breaks down bioactive substances. This research aims to extract lemongrass oil using ultrasound-assisted extraction (UAE). The essential oil was extracted from different lemongrass parts, such as corm, stalk, and leaf. Then, a 37 kHz UAE was applied below the solvent vapor pressure temperature under different periods, i.e., 15, 30, and 60 min. The solvent temperature logarithmically increased from 28 ℃ to 53 ℃ during 20 min of the ultrasound treatment. Acoustic power was obtained from a graphic plot by approximately 35.68 kJ for the initial 20 min and by 31.14 kJ for the remaining UAE period. The lemongrass oil obtained a higher yield from the corm section about 3 and 1.4 times compared to stalk and leaf components. The extracted lemongrass oil produced a yellowish color from the leaf and stalk and a yellow-red color from the corm. The refractive index varied between 1.389 and 1.422, and the specific gravity was from 0.89 to 0.97 g/cm^3. The lemongrass leaf produced the highest citral content and more saturated lipid acids than unsaturated in the lemongrass essential oil.

Keywords: extraction, lemongrass, parts, ultrasound

1. Introduction

Extraction is a unit operation largely applied in several fields and industries. Solvent extraction is a method where mass transfer is driven during the extraction process to solubilize target substances. The solvent extraction method is limited by polarity, particle size, volume, sample moisture, and temperature [1]. Recently, ultrasound has been introduced as an extraction method that influences many fields of modern chemical technology and is widely supported in food processing applications [2]. Interestingly, ultrasound-assisted extraction (UAE) encourages green and economical techniques for food and natural products. In numerous applications, UAE shows decreases in the extraction time, less energy used and carbon dioxide emissions, production of high-purity extracted products, and reusable solvent use [3], [4]. By contrast, conventional processing methods have an energy consumption problem and produce gas emissions that do not comply with legal emission requirements.

The UAE method relates to the acoustic cavitation phenomenon where microbubbles are produced and collapsed during the ultrasound treatment [5]. Oscillation and collapsing bubbles are followed by many physical changes, such as shear forces, turbulence, and shock waves. Heat is generated in a medium due to the absorbance of ultrasonic energy from waves, resulting in mechanical, physical, and chemical effects [6]. Hence, ultrasound power is generated in liquid via the acoustic cavitation mechanism, where sound waves are transmitted, which alternately compress and stretch the molecular structure of the medium through which they pass [7]. Acoustic cavitation provides different benefits, such as concentrating acoustic energy in a tiny volume [8].

Ultrasound methods have been effectively applied for food processing, such as compound extraction from various matrices. Ultrasonic waves generate compressions and expansions around the solid matrix surface and create a sponge effect. The sponge effect results in the creation of microchannels that facilitate solvent diffusion for extraction purposes [1]. The cavitation effect is created during the sonication treatment, which implies the collapse of microscopic bubbles in the liquid. The cavitation energy improves mechanical effects, which cause cell walls to rupture and encourages solvent diffusion into the cells to gain a great yield extract [9–12]. Hence, the power of ultrasound is applied to low and high powers based on the frequency range.

Several studies have investigated the effects of high ultrasonic power on material alterations [8]. Generally,

the efficiency of UAE is established from the product yield of a target extract by pulling up the ultrasound power, drying materials to enhance solvent penetration, and increasing the temperature. Furthermore, UAE optimization has influenced some variables to pass the liquid inside the ultrasonic device and then to cross the wall of the sample container, including time processing, frequency, solvent, particle size, and mass ratio [13]. UAE is commonly used to analyze essential oil in plants by observing some parameters, such as yield, chemical compounds, antioxidant activity, and purity. A low frequency was studied to enable α-linolenic acid extraction from sunflower oil at 50 ℃ for 2 h [14]. A flavonoid-rich extract was obtained from *Celastrus hindsii* leaf using UAE power of 40 kHz at 40 ℃ for 29 min [15]. Phenolic compounds of pumpkins and peaches reached an optimal condition at a temperature of 41.45 ℃ and power of 44.60% for 25 min [13], [16]. UAE was also studied to optimize the total flavonoid content from Dendranthema indicum var. aromaticum with ethanol and acetic acid as the extraction solvents at a volume ratio of 70%:2%. The optimized extraction conditions were as follows: extraction time, 40 min; solid/liquid ratio, 1:23 g/mL; and temperature, 60 ℃ [17]. The an optimized extraction yield and physicochemical properties of extracted essential oil from a *Cinnamomum cassia* bark were examined using ultrasound, with a ratio of solid (g) and water (mL) of 1:7 and power of 500 W [18, 19]. Raspberry was extracted to examine physicochemical properties, fatty acid compositions, and antioxidant activities. The optimal conditions predicted through response surface methodology were a sonication time of 37 min and an extraction temperature of 54 ℃. A previous researcher reported a comparison between UAE and conventional extraction of antioxidants from pomegranate peel. Continuous UAE at the same intensity level increased the antioxidant yield by 24% and reduced the extraction time by 90% [20].

Essential oil production has also been reported from other plant sources, such as lemongrass. The combination of ultrasound and pre-irradiation resulted in more lemongrass essential oil than steam distillation [21]. The extraction of Turkish lemongrass was modeled using ultrasound at different variables, such as temperature, time, and power, resulting in the absence of interaction between temperature and time on the essential oil yield [22, 23]. However, information on the physicochemical properties of lemongrass oil from a different plant part has not been observed yet. In this research, we observed the refractive index, density, and composition analysis of lemongrass oil from different parts of lemongrass using ultrasound extraction in bath equipment.

2. Methods

Sample preparation. Fresh lemongrass was harvested from East Lombok at mature conditions. The lemongrass was sorted based on a stalk diameter between 1.8 and 2.0 cm. For the pretreatment, lemongrass was initially dried at ambient temperature for 3 days. Next, the lemongrass was sliced into three sections: corm, stalk, and leaf. Each section was cut at an average width of 4 mm. Sliced lemongrass was placed in an oven dryer at 60 ℃ for 6 h. The moisture content of the dried lemongrass was measured, and the dried lemongrass was stored in a permeable glass jar. Then, 90% ethanol was prepared from diluted 99.9% absolute ethanol (Merck, Germany) with aquadest.

Ultrasonic extraction. The UAE of lemongrass used the ultrasonic bath method [24] with slightly different treatments. Cut lemongrass was placed in a volume flask and poured with 90% ethanol by the ratio of 1:5 w/v. Extracts were produced in an ultrasonic bath (Elmasonic S 300 H) with three lemongrass segments (corm, stalk, and leaf) and ultrasonic duration of 15, 30, and 60 min. The Elmasonic S 300 H was filled with 7 L of water before starting the ultrasonic operation. The ultrasonic power was set effective at 300 W.

Volume flasks were placed in the ultrasonic bath, where a flask was embedded with a digital PLC thermostat (Omron ECW 5 L) to investigate the solvent temperature profile during extraction. Then, the extract was filtered using 100 mesh stainless steel sieving and proceeded evaporation. A rotary vacuum evaporator (Heidolph Instruments, Germany) was used to evaporate the ethanol or solvent at 50 rpm, 50 ℃, and 175 mBar. The lemongrass essential oil was harvested and centrifuged (Dragon, China) at 3000 rpm for 15 min. Extraction is a unit operation largely applied in several fields and industries. Each treatment was replicated three times.

Extraction power. A thermocouple was placed in a glass jar during the ultrasound treatment. The thermostat was set at 60 ℃ and manually recorded every minute for 60 min. The temperature was used to determine the heat transfer during extraction. The acoustic power can be calculated using Equation 1 [25]:

$$P_{aco} = m\ C_p\ dT/dt, \quad (1)$$

where P_{aco} is the acoustic power, dT/dt is the temperature change rate, C_p is the specific heat of ethanol, and m is the mass of ethanol. Then, plotting temperature versus time results in acoustic energy.

Yield (%). The yield was calculated using the equation $\mathrm{RO}u = (M/Bm) \times 100$, where M is the mass of the extracted oil (g) and Bm is the initial plant biomass (g). Tukey's test was used with a 5% significance level [26].

$$\text{Essential oil yield (\%)} = \mathrm{M/Bm} \times 100 \quad (2)$$

Refractive index and density. Lemongrass oil was subjected to Abbe refractometry at 20 ℃ to measure the

refractive index using a digital Abbe refractometer (DR-A1, Atago, Tokyo, Japan). Then, the lemongrass oil density was determined based on NTC 336 using a density bottle (Blaubrand, Germany) [27].

GC–MS analysis of essential oil. The chemical composition of the volatile and semi-volatile fractions of the essential oil was determined by gas chromatography coupled with mass spectrometry (GC–MS). GC–MS analysis was performed through a direct injection of essential oil into a gas chromatograph (Agilent 6890 Plus, Wilmington, Delaware, USA) equipped with a mass selective detector (Agilent Technologies 5973) operated in the full-scan mode. HP5-MS column was used with a head column pressure of 9.3 psi. GC–MS spectra were obtained under the following conditions: carrier gas, He; flow rate, 1.0 mL/min; split, 1:100; injection volume, 1.0 µL; injection temperature, 250 ℃. The oven temperature progress included an initial hold at 50 ℃ for 2 min, a rise to 80 ℃ at 2 ℃/min, a rise to 150 ℃ at 5 ℃/min, a rise to 200 ℃ at 10 ℃/min, and a rise to 300 ℃ at 20 ℃/min for 5 min.

3. Results and Discussion

Acoustic power. In this research, the solvent temperature was recorded for the extraction time. Figure 1 describes the actual temperature profile of ethanol during the ultrasound treatment. The solvent temperature profile trend similarly changed to the soybean oil sample [28]. The ethanol temperature dramatically increased at the first 20 min of extraction and had a slight temperature change during the remaining ultrasound treatment. At the initial 20 min, the ethanol temperature raised by 25 ℃ during the ultrasound treatment. Then, the temperature slightly increased up to 6 ℃ at the end of 40 min of the ultrasound period. The medium absorbed the ultrasonic energy waves resulting from heat [6]. In addition, the ultrasound mechanism involved cavitation, and associated shear disruption occurred with intense local heating and increasing temperature [29]. The medium-temperature dynamics during the ultrasonic extraction can undergo three steps: 1) temperature increase, 2) constant temperature, and 3) temperature decrease.

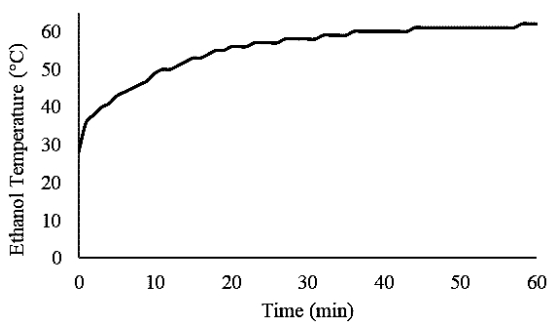


Figure 1. Ethanol Temperature Alterations During Ultrasonic Bath UAE of Lemongrass

The increasing temperature was affected by some factors, such as localized cavitation, bubble generation, and little heat dissipation during sonication [28]. Thus, an equilibrium temperature stage was achieved between the heat dissipation of the medium and the absorbed power [30]. The solvent temperature increased by about 18 ℃–20 ℃ and 20 ℃–23 ℃ during the ultrasonic bath at 130 and 35 kHz for 60 min, respectively [31].

UAE generated acoustic energy in the form of ultrasonic waves that developed through a liquid medium. During cavitation, bubbles appeared due to the transition of energy from acoustic to cavitation, improving the temperature change [32]. Energy changes during the high-power ultrasound rely on conduction, cavitation, and attained uniform temperature within the bubbles [33]. This phenomenon explained the developing temperature of UAE of lemongrass oil. Then, UAE lemongrass was calculated based on the mass, specific heat, and heat rate (Kardos & Luche, 2001). Acoustic power was obtained from the graphic plot resulting at approximately 35.68 kJ for the initial 20 min and 31.14 kJ for the remaining UAE period. The acoustic energy decreased with increasing acoustic penetration [34].

Lemongrass oil yield. Ultrasound-assisted lemongrass extract yields were determined by some factors, including time, power, solvent, temperature, and plant component. Figure 2 shows the lemongrass yield after UAE depending on the time and component variables. The dried lemongrass was divided into three components (corm, stalk, and leaf), and time extraction was performed from 15 to 60 min by setting the ultrasound water bath temperature to 60 ℃. Based on the yield, a longer extract time produced a higher lemongrass oil quantity, and based on the lemongrass component used, the corm produced a larger extract yield than the stalk or leaf.

Based on the experimental data, the lemongrass oil extract yield increased following the time extension. As shown in Figure 2, excess time extraction generated energy transfer, which shows increasing solvent temperature due to acoustic cavitation surrounding

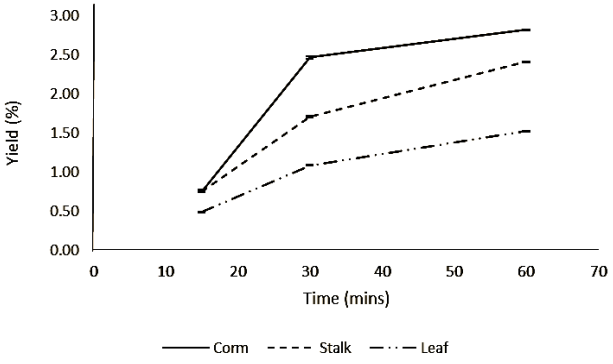


Figure 2. UAE Yield of Lemongrass Essential Oil

lemongrass particles. Then, the ultrasound bath power created vibrations and was transferred into a flask jar medium, which was filled with ethanol and lemongrass. The ethanol started to vibrate and created microbubbles promoting solvent diffusion into cell networks to extract lemongrass oil. The acoustic characteristics produced high pressure that promoted solvent with lower pressure in the cell network [2]. This result is similar with the investigation of sunflower extraction using 40 kHz ultrasound resulting in an increasing extraction yield as time expands [14].

The lemongrass essential oil yield varied from 0.49% to 2.83%. Based on the lemongrass components, the corm obtained the highest lemongrass oil than the other parts. The lemongrass oil source from the corm varied from 0.75% to 2.83%; the stalk produced 0.75%–2.42%; and the leaves obtained 0.49%–1.52% for 15–60 min extraction time under 37 kHz. The UAE lemongrass essential oil yield is higher than that of other extraction methods, such as microwave-assisted hydrodistillation (MAHD), which produced 0.35% for 90 min of extraction, and hydrodistillation, which produced 0.2% for 360 min [16]. However, a higher lemongrass essential oil yield of 4.4% was reported using supercritical fluid extraction of CO_2 at 35 °C, pressure of 25 MPa, and CO_2 flow of 18 L/h for 120 min [35]. Compared to the MAHD method, UAE resulted in 1.21% and 1.46% at 200 and 250 W for 90 min processing conditions, respectively [36].

Density and refractive index determine the lemongrass essential oil quality, oil purity, and favorable process. This research found that essential oil from lemongrass leaves resulted in higher density properties than in other parts, such as corm and stalk. The density of the lemongrass oil via ultrasound was 0.96, 0.93, and 0.92 g/mL for leaves, stalks, and corms, respectively. The time-dependent UAE of lemongrass showed that extending the extraction period resulted in a higher density number. The extracted lemongrass oil with UAE was higher than other extraction methods, i.e., 0.87–0.91 g/mL by distillation [37], 0.90 g/mL by Soxhlet extraction [38], and 0.87–0.91 g/mL by microwave-assisted extraction [39].

The component of lemongrass produced crude oil extract with different colors, where the green color is the produced source from the leaf and the yellow colors is from the stalk and corm. However, the refining process changed the lemongrass oil color, such as the green to yellow color from the leaf source and yellow to red-yellow color for the corm source. The yellowness of the lemongrass oil was more evident from the stalk extract than the leaf extract obtained via the supercritical fluid extraction method [40]. Then, the refractive index of the UAE of lemongrass oils was measured between 1.3811 and 1.4334 from 15 to 60 extraction times. The lemongrass leaf produced a higher refractive index among the other components and had extended extraction time too. Compared to other lemongrass oil extraction methods, UAE had a lower refractive index than microwave-assisted extraction [41] and distillation [42]. Statistically, the analysis did not show a significant difference among the time and component variables during UAE of lemongrass oil at 37 kHz.

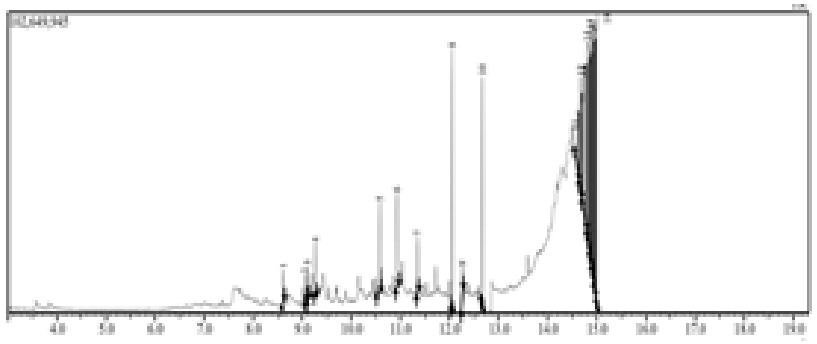
Chemical compounds. The extracted lemongrass oil contained 17 chemical constituents based on the GC–MS analysis. The chemical components can be classified into 18 kinds [43]. In the present research (Table 1), the major substances of the extracted lemongrass essential oil were citral and lipid acids. The citral component of the lemongrass oil was determined at 83.15% using UAE, whereas other research works reported citral substances based on hydrodistillation and microwave-distillation methods at approximately 83.85% and 93.28% [16] and 85.15% and 86.48% [36], respectively. The lemongrass essential oil quality, oil purity, and favorable process. This research found that lemongrass essential oil from the leaf resulted in higher density properties than other parts, such as corm and stalk. The density of the lemongrass oil obtained via UAE was 0.96, 0.93, and 0.92 g/mL for the leaves, stalks, and corms, respectively. The time-dependent UAE of lemongrass showed that extending the extraction period resulted in a higher density number. The lemongrass oil extracted via UAE were higher than those of other extraction methods, i.e., 0.87–0.91 g/mL via distillation [37], 0.90 g/mL by Soxhlet extraction [38], and 0.87–0.91 g/mL by microwave-assisted extraction [39].

Table 1. Chemical Substance of Lemongrass Oil

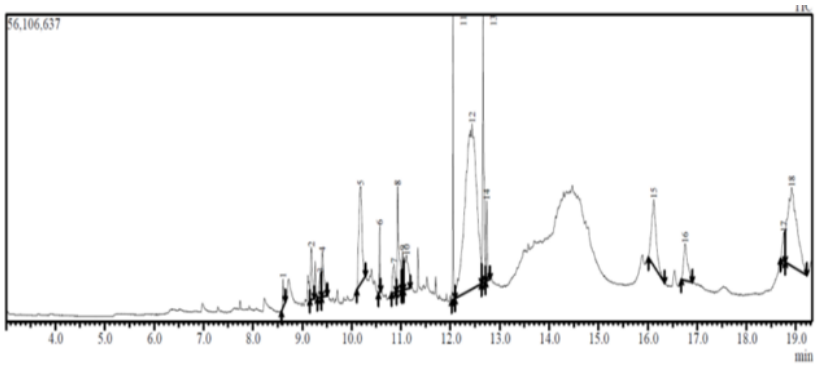
No.	Substances	Content (%)		
		Leaves	Stalks	Corms
1	Citral	83.15	59.4	78.37
2	Dodecanoic acid (CAS) Lauric acid	3.21	4.29	1.08
3	Tetradecanoic acid (CAS) Myristic acid	2.38	0	0
4	Hexadecanoic acid (CAS) Palmitic acid	1.47	16.67	2.5
5	9,12-Octadecadienoic acid	2.41	8.44	13
6	Octadecanoic acid (CAS) Stearic acid	5.27	5.27	0
7	9-Octadecenoic acid (Z)-, methyl ester Dodecanoic	0.95	5.09	5.83
8	Acid 1-(Hydrixymethyl)	2.31	0	0

The component of lemongrass produced crude oil extract with different colors, where the green color is the produced source from the leaf and the yellow colors is from the stalk and corm. However, the refining process changed the lemongrass oil color, such as the green to yellow color from the leaf source and yellow to red-yellow color for the corm source. The yellowness of the lemongrass oil was more evident from the stalk extract than the leaf extract obtained via the supercritical fluid extraction method [40]. Then, the refractive index of the UAE of lemongrass oils was measured between 1.3811 and 1.4334 from 15 to 60 extraction times. The lemongrass leaf produced a higher refractive index among the other components and had extended extraction time too. Compared to other lemongrass oil extraction methods, UAE had a lower refractive index than microwave-assisted extraction [41] and distillation [42]. Statistically, the analysis did not show a significant difference among the time and component variables during UAE of lemongrass oil at 37 kHz.

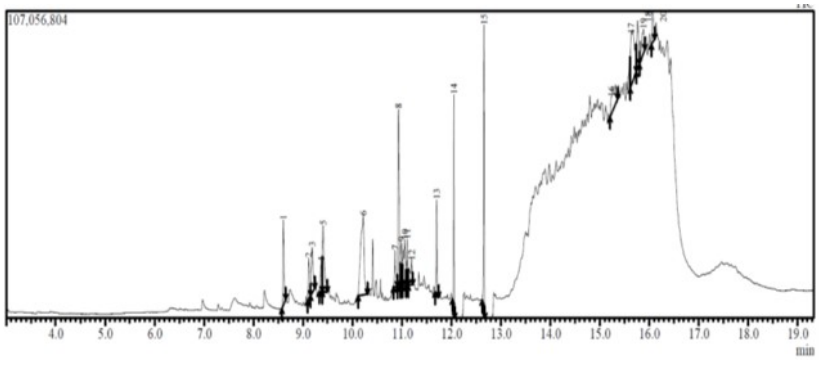
In Figure 3, the lemongrass leaves obtained a higher citral yield than the stalks and corms. The citral content from the lemongrass leaves was 83.15%, and those from the stalks and corms were 59.4% and 78.37%, respectively. Furthermore, leaves from eight lemongrass cultivars were investigated, varying between 70.86% and 91.6% using hydrodistillation extraction for 3 h [44]. Seven lipid acids were identified from the GC–MS assay consisting of saturated and unsaturated oil acid. The saturated oil acid was observed at approximately 3.21%, 2.38%, 1.47%, and 5.27% of lauric, myristic, palmitic, and stearic acid, respectively. Interestingly, Juniper camphor was present in the stalks and corms but absent in the leaves.



(a)



(b)



(c)

Figure 3. GCMS Lemongrass Oil (a. Leaves; b. Stalks; c. Corms)

4. Conclusions

The UAE technique was successfully used for lemongrass essential oil extraction. The solvent temperature sharply increased during 20 min in the UAE treatment and gradually inclined at the remaining 60 min extraction period. Acoustic power was obtained from the graphic plot resulting at approximately 35.68 kJ for the initial 20 min and 31.14 kJ for the remaining UAE period. The corm resulted in a yellow-red essential oil color and produced a higher yield than the other lemongrass parts. The leaf produced the highest refractive index and lowest density. The citral content was had a larger source from the leaf although Juniper camphor was not present. Lipid acid of the lemongrass oil extract was the major acid consisting of saturated oil. Statistical test results indicated the properties of extracted lemongrass oil represented by the yield, density, and refractive index, which did not significantly influence the lemongrass component and time extraction during a 60 min period.

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