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Original Article

Ultrasound-assisted extraction of oleoresin and phenolic compounds from red ginger

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Abstract

Indonesia is one of the world's largest producers of ginger, which is widely used in traditional medicine, food preservation, and flavoring. Zingiber officinale var. rubrum, or red ginger, is particularly valued for its high oleoresin and essential oil content, as well as its strong pungency. Conventional extraction methods, such as Soxhlet and maceration, are time-consuming and often result in low yields. In this study, ultrasound-assisted extraction (UAE) was explored as a more efficient alternative. The effects of different solvents (96% ethanol, ethyl acetate, and water) and extraction times (50, 90, 130, and 170 minutes) on the refractive index, total phenolic content, antioxidant activity, gingerol content, and oleoresin yield were evaluated using an ultrasonic bath with a solid-to-solvent ratio of 1:4. Water yielded the highest oleoresin content (17.7%) after 50 minutes, while ethanol produced the highest total phenolic content (196.2 mg GAE/g), antioxidant activity (IC50: 4.8 ppm), and gingerol content (63.4 mg/g) after 170 minutes. The optimal condition for obtaining oleoresin that met essential oil oleoresin (EOA) quality standards was extraction with 96% ethanol for 50 minutes, yielding a dark brown oleoresin with a refractive index of 1.4902 and a yield of 9.7%. These findings highlight the potential of UAE as a rapid and effective method for extracting high-quality bioactive compounds from red ginger.

Keywords: antioxidant, gingerol, oleoresin, red ginger, ultrasound-assisted extraction

1. Introduction

Ginger (*Zingiber officinale* Rosc.) is one of the most renowned herbs in the world. It has a wide range of applications as a traditional remedy, such as preventing and treating several types of cancer (Mao *et al*., 2019) and relieving sore throats, nausea, dyspepsia, and fever (Maghraby, Labib, Sobeh, & Farag, 2023; Zhang *et al*., 2022). Besides, ginger is also known as a preservation agent and a flavor and aroma enhancer in food products. Due to its benefits to human health, the production of ginger is increased annually to meet the consumers' demand. According to the *Badan Pusat Statistik* (Indonesian Central Bureau of Statistics) (BPS, 2023), the total production of ginger in Indonesia was 174,380 tons in 2019, then its production increased by 5% in 2020 before escalating to 307,241 tons in 2021. There are several types of ginger in Indonesia, including white ginger (*Zingiber officinale* Rosc. var. *Officinale*), emprit ginger (*Zingiber officinale* var. *amarum*), and red ginger (*Zingiber officinale* var. *rubrum*) (S. Zhang *et al*., 2022).

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Among all of them, the red ginger (*Zingiber officinale* var. *rubrum*) contains the highest level of essential oil (2.6-3.9%) and oleoresin (3%) (Panjaitan, Saragih, & Purba, 2012). Red ginger has a higher concentration of essential oils than other ginger varieties commonly used as medicinal ingredients. This characteristic is evident in its distinct aroma and pungent taste, which result from a blend of essential oils, including shogaol and gingerol. Red ginger has been found to contain these compounds in greater amounts, with gingerol levels averaging between 23–25% and shogaol ranging from 18–25%.

Oleoresin extracted from red ginger (*Zingiber officinale* var. *rubrum*) has a viscous texture, mainly containing essential oil, fixed oil, and resin. It has a longer shelf life, a stronger aroma, and a spicier taste compared to fresh ginger or ginger powder. The main bioactive compound in red ginger oleoresin is gingerol which contributes to the characteristics of oleoresin (Nurhadi, Suriati, Tensiska, Saputra, & Sukri, 2020). It has potential as an antioxidant, anticancer, anti-inflammation, and antimicrobial agent (Jayanudin, Rochmadi, Fahrurrozi, & Wirawan, 2019). Therefore, the oleoresin of red ginger can be used as a natural source of antioxidant, anticancer, anti-inflammation, or antimicrobial agents.

The extraction method is one of the main factors affecting the yield of oleoresin apart from the type of solvent, temperature, particle size, time (Kumar, Srivastav, & Sharanagat, 2021), pH, and components in a sample (Do *et al*., 2014). Previous works have demonstrated the extraction of red ginger oleoresin using 6 h of maceration (Nurdiana, Pamungkas, & Wahyudi, 2021) and 150 min of Soxhlet extraction (Wijaya, Paramitha, & Putri, 2019) with a yield of 2.62% and 11.66 %, respectively. However, the yield was relatively low and required a long extraction time.

Numerous studies have demonstrated that employing ultrasound-assisted extraction (UAE) for various plant species can attain elevated extraction yields in reduced time and/or at lower temperatures (Goltz, Ávila, Barbieri, Igarashi-Mafra, & Mafra, 2018; Jovanović *et al*., 2017; Ochoa, Durango-Zuleta, & Osorio-Tobón, 2020). Ultrasound is an exceptional energy source that improves extraction processes, boosts extraction yields, and ensures high product quality. It generates cavitation, thermal, and mechanical effects, which cause the acceleration of release and diffusion of components in the solvent. Moreover, UAE is particularly effective at lower temperatures, making it ideal for extracting thermolabile compounds. To the best of the authors' knowledge, the use of UAE in extracting oleoresin from red ginger has not been studied. Therefore, this study aims to investigate the effects of type of solvent and extraction time on the yield of oleoresin, gingerol content, total phenolic content, antioxidant activity, and the quality of oleoresin in terms of refractive index.

2. Materials and Methods

2.1 Materials

Red ginger was supplied from the red ginger farm in Sukun District, Malang, Indonesia. Folin-Ciocalteu reagent, DPPH (2,2-diphenyl-1-picrylhydrazyl), gallic acid, ascorbic acid, and gingerol were bought from Merck (Darmstadt, Germany). Ethanol 96% and ethyl acetate were purchased from Merck (Darmstadt, Germany).

2.2 Preparation of red ginger

Red ginger rhizomes (aged 8-9 months) were peeled and washed with running tap water. After drained, the red ginger was finely chopped using a crusher to a thickness of 3 mm. The pieces were then dried using an oven at a temperature of 50 °C until they reached a constant weight. Subsequently, the red ginger was ground with a grinder and sieved to obtain a particle size of 80 mesh.

2.3 Extraction of the red ginger

The powder was placed in a 50 mL screw cap bottle with a solid-to-solvent ratio of 1:4. Three types of solvent used were ethanol 96%, water, and ethyl acetate. The extraction was performed using an ultrasonic bath (Elmasonic S60H, United Kingdom) operating at a constant frequency of 37 kHz. Ultrasound-assisted extraction (UAE) was conducted in pulse mode with 10-minute intervals. During sonication (on-phase), the temperature increased by approximately 2°C, while in the off-phase, the temperature returned to its initial value. No active temperature control was applied during the process. Extraction time was varied at 50, 90, 130, and 170 minutes. The extract was then centrifuged (Thermo Scientific Labofuge 200-1) at 3,500 rpm for 17 minutes to separate the supernatant and residue. Subsequently, the supernatant was concentrated using a rotary vacuum evaporator at a pressure of 23 mBar, 30 rpm, and a temperature of 40°C. The concentrated supernatant was designated as red ginger oleoresin. The yield of oleoresin was calculated with the formula in Equation 1.

$$\text{Yield (\%)} = \frac{\text{Mass of red ginger oleoresin (g)}}{\text{Mass of red ginger powder (g)}} \text{ X } 100\% \quad (1)$$

2.4 High-performance liquid chromatography (HPLC) analysis

The concentration of gingerol was analyzed using HPLC (LC-20AD, Shimadzu, Japan) equipped with a UV-Vis detector and a C18 column (5 μm in particle size, 4.6 × 250 mm, Shim-pack VP-ODS, Shimadzu, Japan). An isocratic elution of water and acetonitrile with a ratio of 35:65 (v/v) at a flow rate of 1 mL/min with ultraviolet (UV) detection at 280 nm, was used. The HPLC method was performed using a C18 stainless steel column (250 mm length, 4.6 mm diameter, 5 μm particle size) with a 20 μl injection volume, 1 ml/min flow rate, and detection at 280 nm. A 200 ppm gingerol stock solution was prepared in methanol, and a series of standard solutions (5-35 ppm) were made by dilution, filtered, and transferred to HPLC vials. Sample preparation involved dissolving 25 mg of oleoresin in methanol for water-solvent samples and 2 mg in 96% ethanol or ethyl acetate for other solvent samples. The mobile phase was a mixture of 35% water with glacial acetic acid and 65% acetonitrile, filtered and homogenized before being transferred to the chromatography reservoir. The analysis was performed over a 4-minute runtime, and the gingerol concentration in the

samples was determined from the chromatogram.

2.5 Total phenolic content (TPC)

A 100 ppm gallic acid stock solution was prepared, and then diluted to obtain concentrations of 20, 40, 60, and 80 ppm. Each concentration of the gallic acid solution (0.5 mL) was mixed with 2.5 mL of 10 M Folin-Ciocalteu reagent and 2 ml of 7.5% Na_2CO_3 and allowed to stand for 30 minutes at room temperature before measuring the absorbance at 765 nm. Then, the calibration curve was plotted between gallic acid concentration (x-axis) and absorbance (y-axis). The absorbance of the oleoresin sample was measured using the same method and its concentration was obtained using the calibration curve. The total phenolic content of each sample was calculated using Equation 2.

$$TPC = \frac{V \times C \times DF}{m} \quad (2)$$

TPC = Total phenolic content (mg GAE/g)
V = volume of oleoresin (mL)
C = concentration of the phenolic compounds in the oleoresin (mg/mL)
DF = dilution factor
m = mass of oleoresin (g)

2.6. Antioxidant activity analysis

The analysis of antioxidant activity was carried out using the DPPH (2,2-diphenyl-1-picrylhydrazyl) method. First, 0.1 mM DPPH solution was prepared and its maximum absorbance was measured by UV-Vis spectrophotometer (Shimadzu UV-1900, Japan). It was found that its maximum absorbance was at 514 nm. Then, a control solution was made of 3 mL DPPH 0.1 mM and 3 mL methanol. Subsequently, the ascorbic acid solution was prepared at concentrations of 2, 4, 6, 8, and 10 ppm. A 3 mL sample of each ascorbic acid solution was mixed with 3 mL of DPPH 0.1 mM and left for 30 min at room temperature before its absorbance was analyzed using a spectrophotometer. The same procedure was implemented with the oleoresin sample. The inhibition percentage of the oleoresin was calculated as in Equation 3. The value of IC50 was determined by plotting the curve between concentrations and their absorbances.

$$\text{Inhibition (\%)} = \frac{A - B}{A} \times 100 \quad (3)$$

A = Absorbance of control
B = absorbance of the sample

3. Results and Discussion

3.1 Yield of oleoresin

There are several parameters affecting the yield of extraction, including type of solvent, temperature, particle size, time (Kumar, Srivastav, & Sharanagat, 2021), pH, and components in a sample (Do *et al*., 2014). In this study, the type of solvent (water, ethanol 96%, ethyl acetate) and extraction time (50, 90, 130, and 170 min) were investigated to understand their effect on the yield of red ginger oleoresin. The results illustrated in Figure 1 show that the use of ethyl acetate resulted in the lowest yield of oleoresin, while the highest was obtained using water. Water, as a highly polar solvent, extracts not only oleoresin components like gingerol and shogaol but also water-soluble compounds such as polysaccharides, proteins, sugars, and minerals, leading to a higher total yield but lower oleoresin purity (Yulianto *et al*., 2022). This broad extraction capability reduces selectivity compared to less polar organic solvents (S. Zhang *et al*., 2022). The presence of these additional compounds is further confirmed by the refractive index analysis (Table 1), where water-based extracts showed the lowest values, indicating deviation from the standard oleoresin properties due to the co-extraction of various polar components.

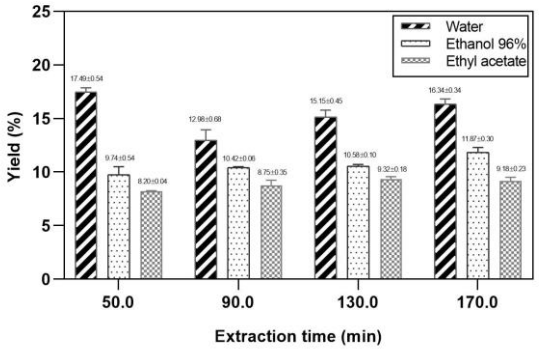

Figure 1. The effect of solvent type and extraction time on the yield of the red ginger oleoresin

Figure 1 also shows the effect of extraction time on the yield of red ginger oleoresin. In general, oleoresin yield increased with the extraction time. This is because the longer the extraction time, the longer the contact time between the red ginger powder and the solvent (Fakhrudin, Anam, & Andriani, 2015). However, at a certain time, the yield of oleoresin declined because the solubility of oleoresin in a solvent has reached its maximum point (Christou, Stavrou, & Kapnissi-Christodoulou, 2021). This phenomenon can be observed in the oleoresin extracted by ethyl acetate at 170 min.

On the other hand, with water as the solvent, the highest yield is obtained at the 50-minute extraction time, which is 17.5%. The cavitation induced by ultrasound facilitated the release of gingerol into the solvent. Initially, the majority of gingerol within the plant cells diffused rapidly during the early stages of extraction, resulting in a sharp rise in extraction yield within the first 50 minutes. Nevertheless, extraction times exceeding 30 minutes led to the degradation of gingerol, causing a subsequent decrease in the oleoresin yield (Xu & Pan, 2013).

The ANOVA results indicate that extraction time does not have a significant impact on yield (p-value = 0.46), suggesting that increasing the duration of extraction does not necessarily enhance the extraction efficiency. In contrast, solvent type significantly influences extraction yield (p-value = 0.001), indicating that the choice of solvent plays a crucial role in determining the extraction outcome. Among the solvents tested (water, ethanol 96%, and ethyl acetate), water consistently yielded the highest extraction percentages, while

ethyl acetate showed the lowest efficiency. These findings highlight the importance of solvent selection in optimizing extraction processes, whereas extending the extraction time may not be a critical factor.

3.2 Total phenolic content (TPC) analysis

Phenolics in plants share a uniform chemical configuration consisting of an aromatic ring with hydroxyl substituents and are classified into several groups, such as phenolic acids, flavonoids, and tannins (Ayad & Akkal, 2019). They exhibit various antioxidant activities, including scavenging singlet oxygen, donating hydrogen atoms, and acting as reducing agents (Hatami, Emami, Miraghaee, & Mojarrab, 2014). Due to these benefits, it is crucial to investigate the total amount of phenolics in oleoresin obtained. In this study, TPC was measured using Folin-Ciocalteu method. Phenolics serve as electron donors and Folin Ciocalteu reagent serves as the oxidant. Specifically, the electron transfer from phenolic compounds to phosphomolybdic/phosphotungstic acid complexes in an alkaline medium produces a color change from yellow to blue. The degree of color change upon completion of the reaction is directly correlated with the reducing activity of the phenolic compounds (Pérez, Dominguez-López, & Lamuela-Raventós, 2023). The TPC of oleoresin extracted using different solvents at various extraction times can be seen in Figure 2.

Figure 2 shows that the solvent type and extraction time have a significant effect on the extraction of phenolic compounds. Among the solvents, ethanol-extracted oleoresin gave the highest TPC followed by ethyl acetate and water. Phenolic compounds are primarily extracted using organic solvents and their aqueous solutions. In general, the extraction of phenolic compounds increased with solvent polarity, because phenolic compounds are generally polar due to their hydroxyl groups attached to aromatic rings (Alara, Abdurahman, & Ukaegbu, 2021). Ethanol (0.654), which has a higher polarity index compared to ethyl acetate (0.228) (Reichardt, 1999), shows better performance in extracting phenolic compounds from the red ginger in this study. Polar solvents excel at dissolving polar compounds due to intermolecular forces such as hydrogen bonding and dipole-dipole interactions. As the solvent's polarity rises, it becomes better at breaking the bonds between phenolic compounds and the plant matrix, making it easier for them to be released into the solvent. However, water-extracted oleoresin demonstrated a lower TPC when measured against ethanol-extracted oleoresin even though water's polarity index (1.0) is higher than ethanol's. This may occur because water is more polar than the polarity of phenolic compounds. According to the law of similarity and intermiscibility ("like dissolves like"), solvents with a polarity index close to that of the solute are expected to be the most effective. Alcohols, such as ethanol, are widely used as universal solvents in the extraction of phenolic compounds (Zhang, Lin, & Ye, 2018).

The TPC of oleoresin from water (23.0 mg GAE/g oleoresin) is lower than that of ethyl acetate (152.4 mg GAE/g oleoresin) and ethanol 96% (196.2 mg GAE/g oleoresin). It may be as a consequence of phenolics that are soluble in ethanol or ethyl acetate having more phenol groups than those soluble in water. Furthermore, it is also possible that non-phenolic compounds, such as carbohydrates or proteins have

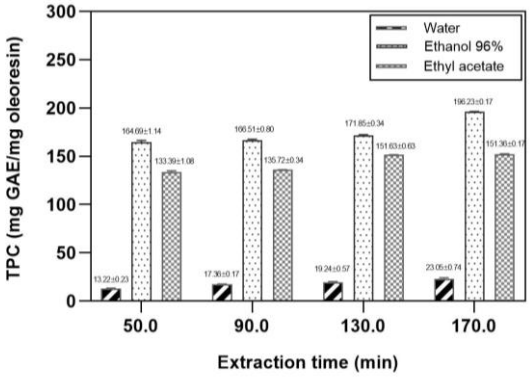

Figure 2. The effect of solvent type and time of extraction on TPC of the red ginger oleoresin

higher solubility in water (Do *et al*., 2014), which contributes to its higher yield and lower TPC.

By employing ethanol 96%, the TPC at extraction times of 50 minutes and 170 minutes increased from 164.7 mgGAE/g oleoresin to 196.2 mg GAE/g oleoresin. For ethyl acetate solvent, the TPC at extraction times of 50 minutes and 170 minutes was elevated from 133.4 mgGAE/g oleoresin to 152.4 mgGAE/g oleoresin. Correspondingly, the TPC of oleoresin extracted by water also increased from 13.2 mgGAE/g oleoresin to 23.0 mgGAE/g oleoresin. This indicates that the phenolic components in the oleoresin sample increased with extraction time. Moreover, compared to utilizing other solvents, there was still a noticeable increase in the TPC value at 170 minutes while using 96% ethanol solvent. This suggests that higher TPC values can be obtained at longer extraction durations since the ethanol solvent has not yet reached a stable equilibrium. The longer the extraction time, the longer the contact between the sample and the solvent. This leads to increased time for the solvent to penetrate and dissolve the phenolic components contained within the cells (Fakhrudin *et al*., 2015).

The ANOVA results show that both factors significantly influence TPC extraction. Extraction time exhibits a statistically significant effect (p-value = 0.037), indicating that increasing extraction duration can enhance phenolic compound extraction. More notably, solvent type significantly impacts TPC yield (p-value = 0.000), suggesting that solvent polarity and composition play a crucial role in phenolic extraction efficiency. These findings highlight the importance of optimizing both solvent type and extraction duration to maximize phenolic compound extraction.

3.3 Antioxidant activity

There are several methods for investigating the antioxidant activity, such as Total Antioxidant Activity (TAA, which is expressed as equivalent of ascorbic acid), reducing power through transformation of Fe^{3+} to Fe^{2+}, and DPPH radical scavenging activity (Do *et al*., 2014). This study employed DPPH radical scavenging activity method to evaluate the antioxidant activity of red ginger oleoresin because of the short amount of time required for analysis. The capacity of oleoresins to neutralize the DPPH radical, assessed by IC50, varied depending on the solvent employed. A lower IC50 value reflects greater antioxidant efficacy. The effect of

solvent type and extraction time on the IC50 value of the red ginger oleoresin is depicted in Figure 3.

The IC50 value indicates the amount of sample required to inhibit 50% of the free radical DPPH concentration, which is obtained by linear regression examination. Figure 3 shows that for each solvent type, the longer the extraction time, the smaller the IC50 value. This suggests that the concentration of phenolic constituents in the oleoresin sample rose as the extraction time was extended, and then the concentration of DPPH was reduced by the phenolics. In addition, despite yielding significantly higher oleoresin content, it is evident that the oleoresin extracted with water solvent exhibits a lower ability to reduce free radical activity compared to the ethyl acetate and ethanol 96%. From this result, it was found that antioxidant activity is proportional to the phenolic content in the oleoresin. Higher phenolic content has a higher potential to inhibit free radical DPPH.

After that, these results were compared to the IC50 value of vitamin C, as it is widely acknowledged that vitamin C serves as a valuable supplier of electrons for free radicals in search of an electron to restore their stability. It can provide electrons to free radicals, thereby reducing their reactivity (Pehlivan, 2017). Based on the classification of antioxidant activity according to Molyneux (2004), a value in the range of 151–200 ppm, 101-150 ppm, and 50-100 ppm indicates a weak, moderate, and strong antioxidant intensity, respectively. The results of this study indicate that the antioxidant activity of red ginger oleoresin varies depending on the extraction solvent. Red ginger oleoresin extracted with 96% ethanol (IC50 = 4.84±0.44 ppm) and ethyl acetate (IC50 = 15.5±0.4 ppm) demonstrates strong antioxidant activity, though still lower than the positive control, vitamin C (IC50 = 3.3 ppm), which exhibits extremely strong antioxidant intensity. In contrast, the extract obtained using water as a solvent has a moderate antioxidant activity (IC50 = 79.00±0.29 ppm). These findings suggest that solvent polarity significantly influences the antioxidant potential of red ginger oleoresin, with ethanol and ethyl acetate being more effective in extracting bioactive compounds responsible for antioxidant activity.

Statistical analysis of IC50 values in relation to solvent extraction and extraction time revealed significant effects of both factors. The extraction time exhibited a *p*-value of 0.012, indicating a statistically significant impact on IC50, suggesting that variations in duration influenced the bioactive compound yield and its inhibitory concentration. Moreover, the solvent type had an even stronger effect, with a highly significant *p*-value of 0.000, highlighting its crucial role in determining extraction efficiency and bioactivity. These findings underscore the importance of optimizing both solvent selection and extraction duration to enhance the effectiveness of bioactive compound isolation.

3.4 Gingerol content

In identifying the concentration of gingerol in the red ginger oleoresin sample, the quantitative HPLC testing method is utilized. The identified gingerol concentration is expressed in parts per million (ppm), and this value is then used to determine the gingerol content in the red ginger oleoresin sample. The effects of solvent type and extraction time on the gingerol content are presented in Figure 4.

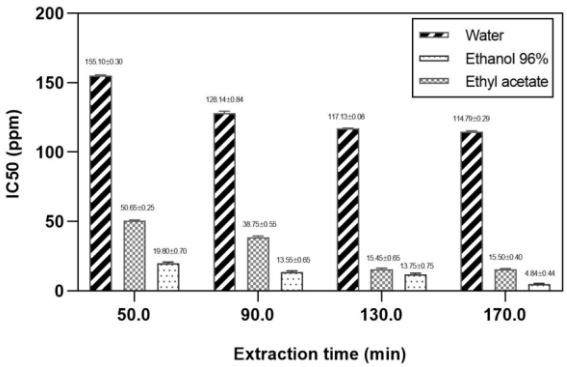

Figure 3. The effect of solvent type and time of extraction on the IC50 value of the red ginger oleoresin

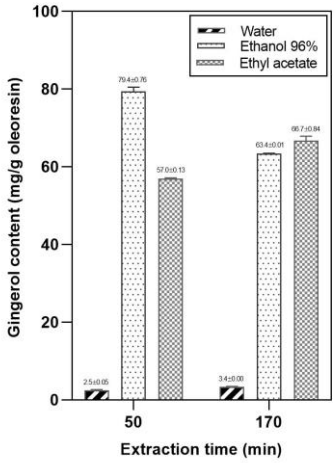

Figure 4. The effects of solvent type and time of extraction on the gingerol content.

The gingerol content in the ethanol 96% at extraction times of 50 minutes and 170 minutes was 79.4 mg/g and 63.4 mg/g, respectively. The high gingerol content in red ginger oleoresin extracted with ethanol 96% was obtained because a substance tends to dissolve in a solvent with similar polarity. Gingerol, the main component of ginger, has hydroxyl groups contributing to its polar nature. Because of this, gingerol dissolves better in water than in the two other solvents (Korua, 2019). Prolonged extraction time combined with the application of ultrasonic waves can increase the temperature, leading to the possibility of gingerol degradation into its derivatives. At high temperatures, gingerol may undergo dehydration reactions or lose water molecules, resulting in its conversion into shogaol. Additionally, gingerol may undergo retro-aldol reactions, leading to its conversion into zingerone compounds. These factors potentially contribute to a decrease in gingerol content with longer extraction times (Zhang *et al*., 2022).

In the ethyl acetate solvent, the gingerol content at extraction times of 50 minutes and 170 minutes increased from 56.9 mg/g to 66.7 mg/g. Ethyl acetate is a less polar compound capable of dissolving both polar and non-polar compounds, thus, prolonged extraction time leads to a greater dissolution of polar gingerol compounds (Srikandi, Humairoh, & Sutamihardja, 2020). On the other hand, the gingerol

content in the water solvent, identified at extraction times of 50 minutes and 170 minutes, was 2.5 mg/g and 3.4 mg/g, respectively. Compared to the gingerol content in the ethanol 96% and ethyl acetate, the gingerol content in the water solvent is much lower. Water is a polar compound with the ability to dissolve polar compounds. However, most organic compounds are difficult to dissolve in water due to weaker affinities towards polar water molecules and the high dielectric constant of water (Romulo, 2020).

Statistical analysis of gingerol content in relation to solvent extraction and extraction time showed varying levels of significance. The extraction time had a *p*-value of 0.835, indicating no significant effect on gingerol content, suggesting that extending or reducing the extraction duration did not substantially impact the yield. In contrast, the solvent type had a statistically significant effect, with a *p*-value of 0.030, demonstrating that the selection of solvent played a key role in gingerol extraction efficiency. These results emphasize the importance of selecting an appropriate solvent to maximize gingerol yield, while extraction time may not be an essential factor in the process.

3.5 Physical quality parameters of red ginger oleoresin

The refractive index is constantly used as a parameter in the quality standards of a sample. This is because the refractive index indicates the purity of a sample (Silla *et al*., 2019). In the quality standard for ginger oleoresin established by the Essential Oil Association (EOA) No. 243, the refractive index for ginger oleoresin is between 1.488 and 1.497 (Hartuti & Supardan, 2013). The effects of solvent and extraction time on the refractive index and color of red ginger oleoresin are summarized in Table 1.

It can be observed from Table 1 that the type of solvent has a significant impact on the refractive index and color of red ginger oleoresin. The quality of red ginger oleoresin extracted with ethanol 96% for 50 minutes has met the quality standard, exhibiting a refractive index of 1.492 nD. Besides that, at an extraction time of 170 minutes, the oleoresin showed a higher refractive index. However, oleoresins extracted with ethyl acetate and water solvents, both at extraction times of 50 and 170 minutes, were out of range in terms of refractive index. The discrepancy from the quality standard values may be attributed to the higher presence of impurities.

The quality standard for ginger oleoresin established by the EOA also includes the color of ginger oleoresin, which is a deep brown color. The results show that red ginger oleoresin extracted with ethanol 96% and ethyl acetate solvents meet the quality standard set by the EOA. Both of them have a dark brown color. Conversely, red ginger oleoresin extracted with water solvent has a light brown color. This difference can be attributed to the inability of water solvent to effectively dissolve the oleoresin from the red ginger. Resin is insoluble in water but can be dissolved in organic solvents like ethanol and ethyl acetate. Thus, red ginger oleoresin extracted with water solvent produced a lighter brown colored oleoresin compared to the other solvent types. The more oleoresin components extracted, the darker the color of oleoresin obtained.

Table 1. The effects of solvent and extraction time on refractive index and color of red ginger oleoresin

Solvent type	(min)	Refractive index	Color
Ethanol 96%	50	1.492	Dark brown
	170	1.503	Dark brown
Ethyl acetate	50	1.480	Dark brown
	170	1.474	Dark brown
Water	50	1.409	Light brown
	170	1.412	Light brown

4. Conclusions

The highest yield (17.7%) of red ginger oleoresin was obtained by employing UAE with water as the extraction solvent for 50 minutes. The highest antioxidant activity (4.8 ppm) was achieved by extraction using 96% ethanol for 170 minutes. According to the Essential Oil Association (EOA), their refractive index was out of range (1.488-1.497). The condition that fulfilled the quality standard of EOA was using 96% ethanol for 50 minutes, which produced a dark brown oleoresin with a refractive index of 1.4902.

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