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A preliminary investigation of *China Ginger* and *Kuching Local Ginger* species: Oil extracts and synthesis towards potential greener insect repellent

Fong Fei Wong [a], Mohammad Omar Abdullah [a,b,*], Yik Rong Hii [a], Sze Ying Chang [a], Noraziah Abdul Wahab [a], Hafizah Abdul Halim Yun [a], Mohd Zaidi Jaafar [c], Augustine Agi [d]

[a] *Department of Chemical Engineering & Energy Sustainability (ChemES), Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Sarawak, Malaysia*
[b] *OSYIHM Farm, Balai Ringin, Serian, C/o OSYIHM Enterprise, Lot 8532, Muara Tabuan Land District, 93350 Kuching, Sarawak, Malaysia*
[c] *Department of Petroleum Engineering, Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia*
[d] *Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Pahang, Malaysia*

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ABSTRACT

Ginger essential oil (*Zingiber officinale*) is the volatile oil extracted from ginger rhizome. Compared to chemical synthetic repellent, green insect (in particular mosquito) repellent would be favoured by the public as it is environmentally friendly and does not cause harm to the human's health. The focus of this study is on the comparison study between *China Ginger* and *Kuching Local Ginger* essential oil aim towards utilization as the greener mosquito repellent. In this study, the ginger essential oils are extracted greener method i.e. via hydro distillation process for 7 h. The percentage oil yield for China and *Kuching Local Ginger* are 0.158 wt% and 0.264 wt%, respectively. The extracted ginger essential oils are further subject to Fourier Transform Infrared Spectroscopy (FTIR) and Gas Chromatography- Mass spectrometry (GC-MS) analysis. Based on the FTIR spectrum graph generated, both types of ginger essential oils essentially having the similar function groups including phenolic compounds, alcohol primer, alkena methyl group, aromatic compound, carbonyl compound, carboxylic acid, hydroxyl group. From the GC-MS results it revealed that the most abundant chemical constituents presented in both *China Gniger* and *Kuching Local Ginger* essential are: α-Zingiberene (7.88% and 7.03%), α-Curcumene (6.04% and 6.49%), α-Citral or Genarial (3.81% and 7.86%), β-Bisabolene (3.06% and 4.62%), β-Sesquiphellandrene (5.83% and 5.95%), β-Sesquisabinene (0.07% and 0.51%), β-Selinenol (3.97% and 2.26%), Zingiberenol (5.16% and 1.64%), [6]-Shogaol (0.33% and 0.23%), trans-Sesquisabinene hydrate (1.72% and 2.87%), trans-Geranylgeraniol (3.51% and 2.81%), Camphene (1.17% and 0.56%), Eucalyptol (2.68% and 1.81%), Citronellol (1.76% and 1.55%), Neral (2.82% and 6.03%), and Geraniol (1.62% and 2.29%) respectively. *Kuching Local Ginger* essential oil is found marginally superior insect repellent characteristics due to its higher monoterpene compounds in the essential oil.

1. Introduction

One of the most efficient ways to eliminate the mosquitoes from the residential houses is using the chemical-based mosquito repellent. Most insect repellents operate by creating a vapour barrier around the treated surface, preventing arthropod and insects from coming into contact with the surface Nerio et al. (2010). When making commercial mosquito repellents, non-biodegradable synthetic compounds like N-diethyl-3-methylbenzamide ($C_{12}H_{17}NO$), allethrin, N ($C_{19}H_{26}O_3$), and dimethyl phthalate ($C_{10}H_{10}O_4$) are usually used. These chemicals have the potential to pollute the environment and causes health hazards when used on a large scale (Khater, 2012). Many researchers e.g. Pavela and Benelli (2016) reported that inhaling the repellent chemicals substantially would result in allergic reactions and serious respiratory problems. These toxic compounds may potentially cause cancer if inhaled in prolonged periods of time, and can even can be lethal if inhaled in large

* Corresponding author at: Department of Chemical Engineering & Energy Sustainability (ChemES), Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), 94300 Kota Samarahan, Sarawak, Malaysia,.
E-mail addresses: amomar@unimas.my, amomar13@gmail.com (M.O. Abdullah).

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quantities. Besides, based on the survey reported by Rediff (2015), ~ 11.8% of people who used chemical-based mosquito repellents reported a variety of health problems, including breathing difficulties, headaches, discomfort in the eyes, bronchial irritation, coughing, colds, running noses, skin infections, and asthma. With growing public safety concerns, there is an increasing interest in the usage of natural products derived from plants because natural derivatives are more ecologically friendly, biodegradable and affordable by many.

The use of insecticides based on plant extracts is currently highly promising from the alternatives of protection against insects. Many plant extracts that contain substances with insecticidal effects also include a large group of the so-called essential oils (EOs) (Senthil-Nathan, 2020).

Although EOs make up just a small proportion of a plant's total composition, they contribute to the unique features that make aromatic plants useful in the food as well as their wide applications in the industrial fragrance as well as in the pharmaceutical sectors. Essential oils are comprised of a complex and varied composition that includes a large number of elements, including hydrocarbons and oxygenated molecules. The odor of these compounds is essentially a consequence of the mixture of the smells of each of the compounds individually. Trace constituents are especially essential since they contribute to the oil's distinctive natural scent. As a result, it is critical that the natural proportions of the constituents are preserved throughout the extraction of essential oils from plants (Aziz et al., 2018).

EOs possess a large number of chemicals which have adulticidal activity being reported from plants notably in the Lamiaceae, Miliaceae, Rutaceae, and Zingeberaceae (Chellappandian et al., 2018).

Over the recent years, several EOs have been employed in environmentally friendly and commercial repellents formulations (Tisgratog et al., 2016). For instance, AlSalhi et al. (2020) reported that the *Kaempferia galangal* rhizome essential oil (EO) and its major chemical constituents are promising larvicidal agents highly potential use as effective and eco-friendly mosquitocidal formulations. Narayanankutty et al. (2021) investigated the use of Mango ginger (*Curcuma amada Roxb.*) rhizome essential oils as source of environmental friendly insecticides and antibacterial agents using a variety of extraction methods. The results of their study have shown that the microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), steam distillation (CSD), and hydrodistillation (CHD) were all having high larvicidal activity against *Aedes, Culex*, and *Armigeres* species. The present study only focus on the CHD method. According to a previous study published by Madreseh-Ghahfarokhi et al. (2018), *Culex theileri* Theobald, 1903 is a wide-distributed species of mosquitoes in different parts of world. It is a large distinct mosquito species through which the repellent activity of ginger essential oil has been studied extensively. It was deduced that different type of the ginger essential oils used produce different insect repellent performance.

Hence, the intention of the present research is to investigate the chemical compositions for two different type of ginger essential oil which are extracted from *China Ginger* and *Kuching Local Ginger* – via greener hydro distillation method, thereafter estimate its potential in terms of insect (mosquito) repellent activity.

2. Methodology

This section discusses on the sample preparation of gingers, extraction of gingers using hydro distillation method, separation of condensate and characterization of ginger essential oils using Fourier Transform Infrared Spectroscopy (FTIR) and Gas Chromatography-Mass spectrometry (GC-MS) analysis.

2.1. Sample Preparation of Gingers

Both *China Ginger* and *Kuching Local Ginger* was purchased from local supermarket in Farley Supermarket, Kuching, Sarawak. The sample ginger rhizomes were sorted to separate the healthy gingers from the damaged, dried, and rotten ones. Then, the sorted healthy ginger rhizomes were brushed and washed by using clean water to remove the soil, dirt or impurity substances attached on the surface of gingers. The cleaned ginger rhizomes were then air-dried in a tray/colander to remove of the excess water from the surface at room temperature. The ginger rhizomes were further cut or chopped into pieces with thickness of ± 0.1 cm using the knife without peeling the skins of the gingers. Finally, the cut ginger rhizomes were stored in an airtight high-density polyethylene bag for further experiment work.

2.2. Extraction of Gingers Using Hydro Distillation Extraction

Both of the *China Ginger* and *Kuching Local Gingers* had been extracted using same hydro distillation method under same operating parameters. The preparation method of the hydro distillation followed the procedure described by (Mehani et al., 2016; Narayanankutty, 2021). The round bottom flask was first measured of its weight. Then, the cut pieces of ginger rhizomes were inserted into the round bottom flask until 7/10 filled. The weight of the round bottom flask with ginger rhizomes was weighted to get the net weight of the ginger sample. The round bottom flask was further put on the heating mantle and jointed to the condenser. A beaker was put at the end of the condenser to collect the condensate. The cooling water/tap water was flowed through the condenser using the rubber tubing once the heating mantle was switched on to heat the mixture in the round bottom flask. Then, the process was conducted for 7 h of distillation. Finally, the collected condensate extraction is stored for separation process. The overall set up hydro distillation apparatus was shown in Fig. 1.

2.3. Separation of condensate

The collected condensate was first poured into separatory funnel. N-hexane was added into the separatory funnel to dissolve all the oil that was presented in the condensate. Two layers was formed in the separatory funnel and the upper layer was collected in the beaker while the bottom layer was discarded. The collected mixture of n-hexane and ginger essential oil (upper layer) was heated on the hot magnetic plate to evaporate the n-hexane. The separation process can be stopped when the temperature exceeded 75 °C. The remain residues in the beaker was the ginger essential oil. Then it was weighted and calculated for the percentage of the essential oil yield using the following formula in Eq. (1).

$$Percentage\ of\ essential\ oil\ yield = \frac{Mass\ of\ the\ essential\ oil}{Mass\ of\ the\ ginger\ sample} \times 100\% \quad (1)$$

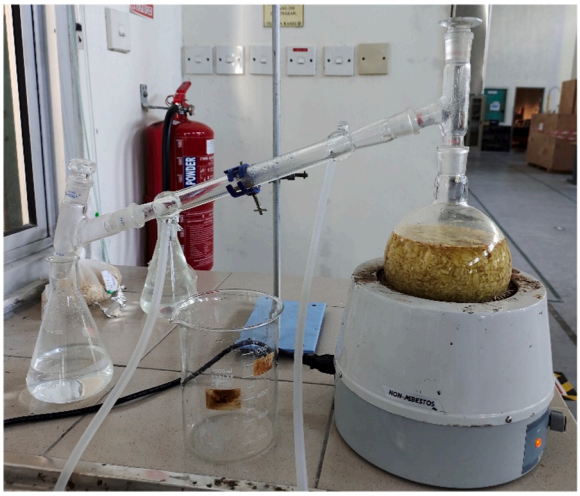


Fig. 1. Hydro distillation extraction apparatus set up.

2.4. Ginger Essential Oils Analysis Using Fourier Transform Infrared Spectroscopy (FTIR)

Both of the *China Ginger* and *Kuching Local Ginger* essential oils were analysis for their functional compounds by using Shimadzu Fourier Transform Infra-Red (FTIR Model: IRAFFINITY-1) where the ginger essential oils were dropped on the prism of the FTIR spectrometer. The samples were analyzed with FTIR spectra (resolution 4 cm^{-1}) in transmittance mode. The spectral range was recorded from range 400 cm^{-1} to 4000 cm^{-1}. The FTIR spectrum graphs generated was used to determine the types of the vibration mode and the functional groups present in the ginger essential oil.

2.5. Ginger Essential Oils Analysis Using Gas Chromatography-Mass spectrometry (GC-MS)

Both of the ginger essential oils were analyzed using Agilent Technologies 7890 A Gas Chromatography- Mass spectrometry (GC-MS: Model 3171 A) with HP-5 elastic quartz capillary column (30 m × 2.5 cm) with film thickness of 0.25 μm and desorbed for 5 min at 250 ℃. High purity helium gas was used as the carrier gas and flow at rate of $1ml/\text{min}$. The oven program was set with initial temperature at 50 ℃ (held for 1 min) then ramped to 120 ℃ at rate of $5℃/\text{min}$, held for 40 min at 120 ℃, and then continue ramped to 250 ℃ at rate of $3℃/\text{min}$. Samples (1 μl) were injected at 250 °C with split/splitless injector (20:1 split ratio) in the splitless mode flow. Mass detector was conducted with electronic impact (EI) mode at 70 eV with source temperature of 250 ℃, scanning rate of 1 scan per second and mass acquisition range between 35 and 550 amu. The generated GC–MS chromatograms was used to detect the compounds presented within the ginger essential oil by comparing its retention time and the peak of the particular component to the mass spectra that are documented into National Institute of Standards and Technology (NIST) library (Ding et al., 2012).

3. Results and discussion

3.1. Extraction of ginger essential oil

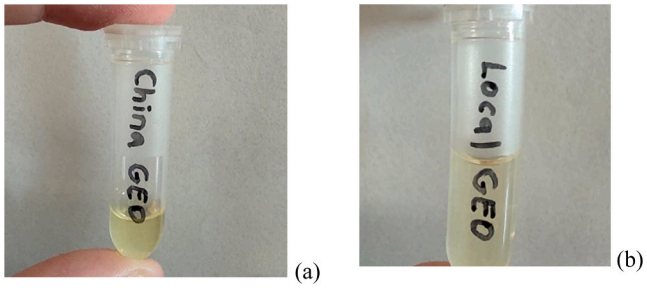
3.1.1. Percentage yield of China ginger essential oil

Fig. 2(a) is a photo showing the final product of the *China Ginger* essential oil which was extracted by using hydro distillation. The *China Ginger* essential oil shows a transparent pale yellow colour with a spicy aroma of ginger smell.

Table 1 shows the amount of the weight of *China Ginger* that had been conducted for hydro distillation extraction in this experiment.

At the end of the ginger essential oil extraction, there is 3.16 g of ginger essential oil had been obtained. Hence, the percentage of essential oil yield is:

$$Percentage\quad of\quad essential\quad oil\quad yield = \frac{3.16g}{2000g} \times 100\%$$



(a) (b)

Fig. 2. (a) *China Ginger* essential oil; (b) *Kuching Local Ginger* essential oil.

Table 1
Data collection of *China Ginger* for ginger essential oil extraction.

Experiment no.	Weight of ginger (g)
1	565.61
2	565.96
3	259.15
4	609.28
Total	**2000**

$$Percentage\quad of\quad essential\quad oil\quad yield = 0.158wt.\%$$

3.1.2. Percentage yield of Kuching Local Ginger essential oil

Fig. 2(b) shows the final product for the *Kuching Local Ginger* essential oil which extracted by using hydro distillation. The *Kuching Local Ginger* essential oil also shows a transparent pale yellow colour with a spicy aroma of ginger smell.

Table 2 shows the amount of the weight of *Kuching Local Ginger* that had been conducted for hydro distillation extraction in this experiment.

At the end of the ginger essential oil extraction, there is **5.28 g** of ginger essential oil had been obtained. Hence, the percentage of essential oil yield is:

$$Percentage\quad of\quad essential\quad oil\quad yield = \frac{5.28g}{2000g} \times 100\%$$

$$Percentage\quad of\quad essential\quad oil\quad yield = 0.264wt.\%$$

3.1.3. Comparison percentage yield of ginger essential oil between China Ginger and Kuching Local Ginger

Based on the result obtained, the percentage of essential oil yield for *China Ginger* is 0.158 wt% (fresh ginger basis) while the percentage essential oil yield for *Kuching Local Ginger* is 0.264 wt% (fresh ginger basis). It can be noticed that the percentage of essential oil yield of *Kuching Local Ginger* is much higher than the *China Ginger*. The percentage yield of *Kuching Local Ginger* is around 1.67 times higher than the *China Ginger* essential oil. This possible due to the higher volatile oils contained in *Kuching Local Ginger* comparing to the *China Ginger* whereby *Kuching Local Ginger* can be extracted out for 5.28 g of essential oil compared to *China Ginger* which only can be extracted out for 2.16 g of ginger from the same total mass of 2 kg fresh ginger by using same extraction method.

According to the research done by Nandi et al. (2013) and Alhassane and Zhang (2007), by using same method of hydro distillation extraction method, China cultivated ginger had given result of 0.21% and 0.22% percentage oil yield on the fresh basis respectively. These percentages are comparable to the results obtained in this experiment, which came very close to the reported range. This lent credence to the authenticity of the present findings.

However, the obtained percentage oil yield for both type of ginger does not reflect the optimal percentage of oil output. This is in accordance to Syafitri et al. (2018) that the volatile oils found in ginger may make up anywhere from 1% to 3% of the weight of fresh ginger. This may due to the dryness of the ginger used as well as the hydro distillation time applied.

Table 2
Data collection of *Kuching Local Ginger* for ginger essential oil extraction.

Experiment no.	Weight of ginger (g)
1	494.13
2	410.28
3	557.99
4	537.63
Total	**2000**

3.2. Fourier Transform Infrared Spectroscopy (FTIR) Analysis

3.2.1. FTIR spectrum result for China Ginger essential oil

Fig. 3 shows the FTIR spectrum graph analysis for *China Ginger* essential oil in transmission mode.

Based on the peak shown in the FTIR spectrum graph for Fig. 3, the type of vibration mode with its corresponding functional compound are tabulated as shown in Table 3.

According to Fig. 3, the wavelength of the infrared spectrum is in the range of 731.02 cm^{-1} to 3680.18 cm^{-1}. There are 12 functional compounds found in the *China Ginger* essential oil. Firstly, an OH stretching vibrating mode with hydrogen bonding is seen at wavelengths of 3680.18 cm^{-1} in the spectra of *China Ginger* essential oil. Due to the following appearance of spectra at the wavelength of 1024.2 cm^{-1}, 883.4 cm^{-1}, 823.6 cm^{-1}, and 731.02 cm^{-1}, the presence of this wide absorption band provides evidence that hydroxyl compounds do in fact exist. As a result, research demonstrates that *China Ginger* essential oil may include alcohol or phenolic compounds that have the ability to act as antioxidants. Some examples of these chemicals are gingerols, zingerone, and shogaols. This conclusion is consistent with the findings of the research conducted by Halimin et al. (2022), who also discovered the phenolic compounds at wavelengths ranging from 1369.46 cm^{-1} to 806.25 cm^{-1}.

After that, the existence of a narrow band at 2958.8 cm^{-1}, 2922.16 cm^{-1}, and 2862.36 cm^{-1} can be referred to aliphatic molecules, which are recognised as the carboxylic acid group. This finding is reinforced by the prior researches done by Farshbaf-Sadigh et al. (2019), which also found that at wavelength range from 3022 cm^{-1} to 2872 cm^{-1} are validated to be attributed to carboxylic acid group for ginger essential oil. This finding can be attributed to the fact that ginger essential oil contains a high concentration of carboxylic acid. In addition, this finding is also associated with the research of Jayanudin and Rochmadi (2017) who stated that the peak wavelength that occurred at 2924.7 cm^{-1} in the spectra of ginger oleoresin are classified as an OH-H group. There is a possibility that the existence of these carboxylic acid molecules in ginger oil is due to the presence of fatty acids in that ginger oil.

Other than that, the vibration of the ring aromatic stretching at a peak wavelength of 1448.54 cm^{-1} provided evidence of the presence of C═C aromatic compounds. This band may provide evidence that the ginger essential oil contains aromatic ring-structured chemicals such as zingiberene, curcumene, and bisabolene which made up of aromatic ring structure. These results are in line with the findings of Halimin et al. (2022) which identified present of C═C aromatic compounds at same peak of 1448.54 cm^{-1} in ginger essential oil. Apart from that, research done by Purnomo et al. (2010) which reported that the presence of C═C aromatic compounds are observed at 1514.98 cm^{-1} and 1449.41 cm^{-1} in the fresh ginger.

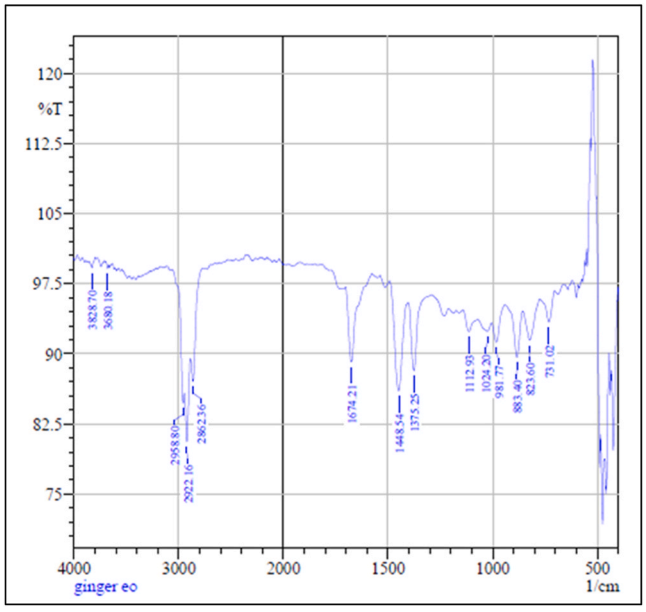


Fig. 3. FTIR spectrum graph for *China Ginger* essential oil.

Table 3
Functional groups and compounds existed in *China Ginger* essential oil FTIR spectrum graph.

No.	Wavelength (cm^{-1})	Vibration Type	Functional Compound
1	731.02	OH bond	Phenol
2	823.6	OH bond	Phenol
3	883.4	OH bond	Phenol
4	1024.2	C-OH stretch	Alcohol primer ($-CH_2OH$)
5	1112.93	C-O-C stretch dialkyl ether	Ether (R-O-R)
6	1375.25	CH_3 bond stretch	Alkena, methyl $-CH_3$
7	1448.54	Ring aromatic stretch	C═C aromatic
8	1674.21	C═O stretch	Carbonyl compound
9	2862.36	OH stretch, H-bonded	Carboxylic acid (RCOOH)
10	2922.16	OH stretch, H-bonded	Carboxylic acid (RCOOH)
11	2958.8	OH stretch, H-bonded	Carboxylic acid (RCOOH)
12	3680.18	OH stretch, H-bonded	OH group

Besides, *China Ginger* essential oil had shown a vibration C═O stretching at wavelength of 1674.21 cm^{-1} that indicates the presence of the carbonyl compound in ginger essential oil. This carbonyl group may involve for the ester, aldehyde and ketone groups in ginger oil. For instance, the presence of the monoterpenes compound such as neral, camphene, citral, citronellol, limonene, geranial, eucalyptol, geranyl acetate and decanal in *China Ginger* essential oil. In the study done by Farshbaf-Sadigh et al. (2019) had proven the existence of the carbonyl compound in ginger essential oil at peak of 1678 cm^{-1} and 1640 cm^{-1}. Last but not least, vibration of C-O-C stretch dialkyl ether and CH_3 bond stretch at wavelength of 1112.93 cm^{-1} and 1375.25 cm^{-1} indicated the present of ether and alkena methyl group in the *China Ginger* essential oil.

3.2.2. FTIR spectrum result for Kuching Local Ginger essential oil

Fig. 4 shows the FTIR spectrum graph analysis for *Kuching Local Ginger* essential oil in transmission mode.

Based on the peak shown in the FTIR spectrum graph for Fig. 4, the type of vibration mode with its corresponding functional compound are tabulated as shown in Table 4.

The infrared spectrum of fresh *Kuching Local Ginger* rhizome essential oil as shown in Fig. 4 is in the wavelength range of 883.4 cm^{-1} to 3425.58 cm^{-1}. There are 13 functional compounds found but only 10 compounds are identified as peak No. 7, 8, and 9 are not recognized. This unrecognized peak is most likely caused by the significantly lower energy vibration that the infrared spectrophotometer could not pick up on, see e.g. Purnomo et al. (2010).

First of all, an OH stretching vibrating mode with hydrogen bonding is seen at wavelengths of 3425.58 cm^{-1} in the spectra of *Kuching Local Ginger* essential oil. The existence of spectra at the wavelengths of 1033.85 cm^{-1} and 883.4 cm^{-1} demonstrates that this band is associated with hydroxyl compounds. Consequently, the study reveals that the essential oil extracted from *Kuching Local Ginger* may include alcohol or phenolic chemicals that have the capacity to perform the role of antioxidants such as gingerols, zingerone, and shogaols. Earlier, Halimin et al. (2022) also detected phenolic chemicals at wavelengths ranging from 1369.46 cm^{-1} to 806.25 cm^{-1}, which is consistent with the result obtained in this analysis. Halimin et al. (2022) tested on the *Iban* ginger

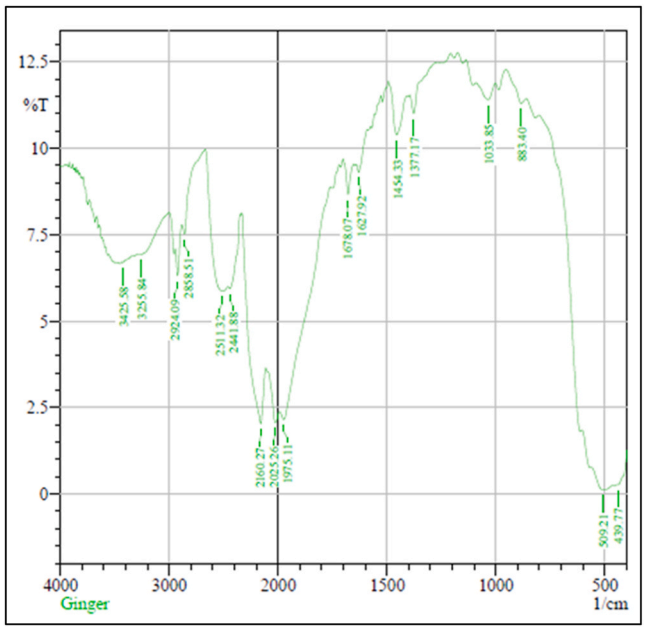


Fig. 4. FTIR spectrum graph for *Kuching Local Ginger* essential oil.

Table 4
Functional groups and compounds existed in *Kuching Local Ginger* essential oil FTIR spectrum graph.

No.	Wavelength (cm^{-1})	Vibration Type	Functional Compound
1	883.4	OH bond	Phenol
2	1033.85	C-OH stretch	Alcohol primer (-CH_2OH)
3	1377.17	CH_3 bond stretch	Alkena, methyl -CH_3
4	1454.33	Ring aromatic stretch	C═C aromatic
5	1627.92	C═O	Carbonyl compound
6	1678.07	C═O	Carbonyl compound
7	1975.11	-	-
8	2025.26	-	-
9	2160.27	-	-
10	2858.51	OH stretch, H-bonded	Carboxylic acid
11	2924.09	OH stretch, H-bonded	Carboxylic acid
12	3255.84	OH stretch, H-bonded	OH group
13	3425.58	OH stretch, H-bonded	OH group

extract produced via Soxhlet extraction method.

Furthermore, a narrow band of 2924.09 cm^{-1} and 2858.51 cm^{-1} is found in the *Kuching Local Ginger* essential oil infrared spectrum which can be described to aliphatic molecules and identified as the carboxylic acid group. This finding is adopted by the previous researches done by Farshbaf-Sadigh et al. (2019), which also found that at wavelength range from 3022 cm^{-1} to 2872 cm^{-1} are confirmed to be assigned to presence of carboxylic acid group in *Kuching Local Ginger* essential oil. This finding indicated that presence of high concentration of carboxylic acid is possible in ginger essential oil. In addition, Jayanudin and Rochmadi (2017) also proven the existence of OH-H group through the peak wavelength that occurred at 2924.7 cm^{-1} in the spectra of ginger oleoresin.

Aside from that, confirmation of the presence of C═C aromatic compounds was supplied by the vibration of the ring aromatic stretching at a peak wavelength of 1454.33 cm^{-1}. This band may give proof that the ginger essential oil includes aromatic ring-structured compounds such as zingiberene, curcumene, and bisabolene. These chemicals are all composed of aromatic ring structure. These findings coincide with earlier findings of Halimin et al. (2022), who found that ginger essential oil contains C═C aromatic compounds at the peak of 1448.54 cm^{-1}. This discovery is in agreement with the present findings. In addition to this, study conducted by Purnomo et al. (2010) found that the fresh ginger extract oil contains C═C aromatic compounds, which were detected at 1515.94 cm^{-1} and 1451.33 cm^{-1}.

In addition, the *Kuching Ginger* essential oil demonstrated a vibration known as C═O stretching at a wavelength of 1678.07 cm^{-1} and 1627.92 cm^{-1}. This indicates the presence of a carbonyl compound in the *Kuching Local Ginger* essential oil. There is a possibility that this carbonyl group is involved in the ester, aldehyde, and ketone groups that are found in ginger oil. For example, ginger essential oil contains monoterpene compounds such as neral, camphene, citral, citronellol, limonene, geranial, eucalyptol, geranyl acetate, and decanal. The research carried out by Farshbaf-Sadigh et al. (2019) established without a reasonable doubt the presence of the carbonyl compound in ginger essential oil at peaks measuring 1678 cm^{-1} and 1640 cm^{-1}. Moreover, the vibration of CH3 bond stretch at a wavelength of 1377.17 cm-1 confirmed the presence of an alkena methyl group in the Kuching native ginger essential oil, as demonstrated by Farshbaf-Sadigh et al. (2019).

3.2.3. Comparison FTIR spectrum result between China and Kuching Local Ginger essential oil

Based on the interpretation done for both FTIR spectrum graph of China and *Kuching Local Ginger* essential oils, there are some similar peaks occurred in both FTIR spectrum at the peak around 850 cm^{-1} (phenol group), 1030 cm^{-1} (alcohol primer group), 1375 cm^{-1} (alkena, methyl group), 1450 cm^{-1} (C═C aromatic group), 1670 cm^{-1} (carbonyl compound), 2900 cm^{-1} (carboxylic group), and 3400 cm^{-1} (OH group).

This indicated that the functional groups present in both of the ginger essential oils are relatively similar even though they are occurred at different number wavelengths. Both of the ginger essential oils have the same functional groups of phenolic compounds, alcohol primer, alkena methyl group, aromatic compound, carbonyl compound, carboxylic acid, hydroxyl group. However, *China Ginger* essential oils has an extra existence of functional group which is ether. But since both of the ginger essential oils possessed same functional groups, it can be deducted that the functional groups represent in the ginger rhizomes not really affected by the type or origin of the ginger rhizomes (Halimin et al., 2022).

3.3. Gas Chromatography- Mass spectrometry (GC-MS) Analysis

3.3.1. GC-MS result for China Ginger essential oil

Fig. 5 shows the gas chromatogram generated from the GC-MS analysis for the *China Ginger* essential oil. Each of the peak occurred in the gas chromatogram is labelled from 1 to 100.

Each of the peak occurred in the gas chromatogram has its individual retention time, peak area and also the percentage of the identified compounds present in *China Ginger* essential oil. All the data analysis for each peak is tabulated in Table 5.

According to the GC-MS analysis results shown in Fig. 5, a total of 90 types of chemical constituents (exclude the repeating chemical constituent) were detected for *China Ginger* essential oils, of which the highest levels are: 1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)− 2-methyl-, [S-(R*,S*)]- (α-Zingiberene) 7.88%; Benzene, 1-(1,5-dimethyl-4-hexenyl)− 4-methyl- (α-Curcumene) 6.04%; Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)− 6-methylene-, [S-(R*,S*)]- (β-Sesquiphellandrene) 5.83%; (1 R,4 R)− 1-methyl-4-(6-Methylhept-5-en-2-yl)cyclohex-2-enol (Zingiberenol) 5.16%; 2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]- (β-Selinenol) 3.97%; 2,6-Octadienal, 3,7-dimethyl-, (*E*)- (α-Citral or Genarial) 3.81%; 1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethylidene)-, (E,E)- (β-Germacrene) 3.58%; 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol) 3.51%; (S,Z)− 2-Methyl-6-(p-tolyl)hept-2-en-1-ol ((*Z*)-Nuciferol) 3.29%; β-Bisabolene 3.06%; Neral 2.82%; 6,10-Dodecadien-1-yn-3-ol, 3,7,11-trimethyl- (Dehydronerolidol) 2.70%; Eucalyptol 2.68%; 1 H-Benzocyclohepten-9-ol, 2,4a-.beta.,5,6,7,8,9,9a-.beta.-octahydro-

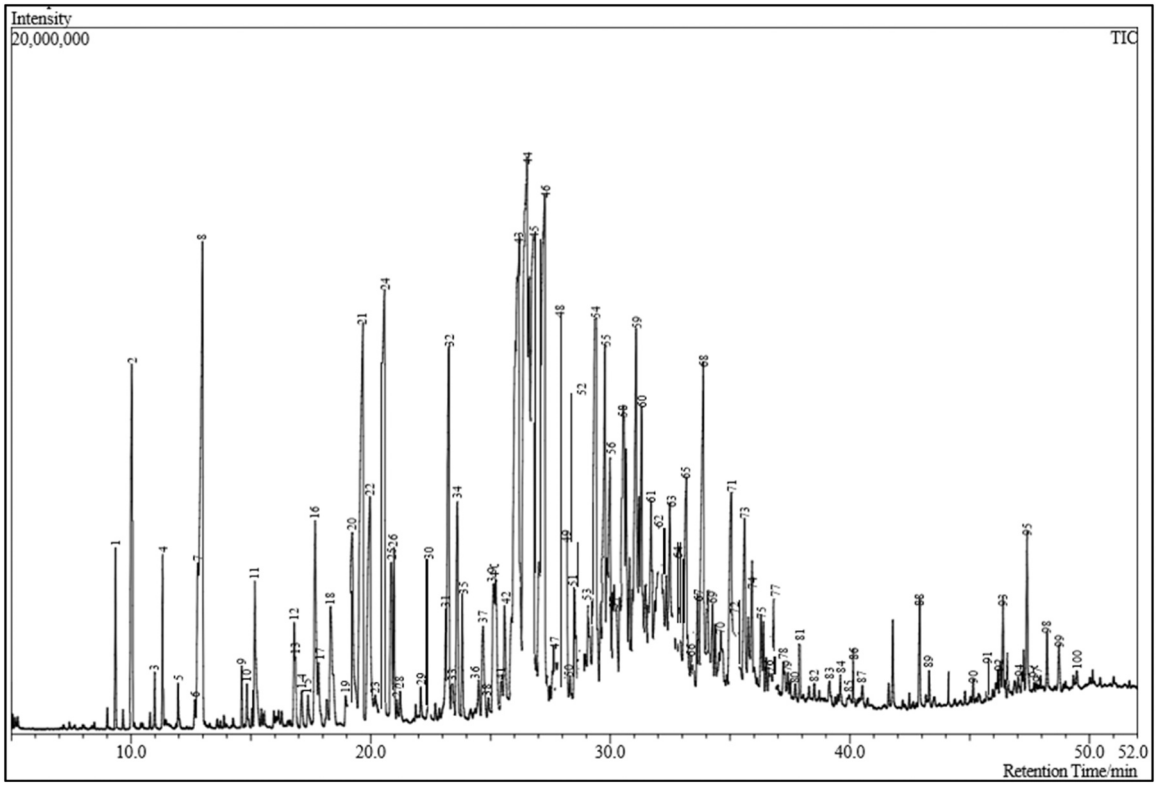


Fig. 5. Gas chromatogram graph for *China Ginger* essential oil.

3,5,5,9–.beta.-tetramethyl- (Himachalol) 2.50%; 2(1 H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-7.alpha.-isopropyl-4a.beta.,8a.beta.-dimethyl- 2.12%; (5 R,10 R)− 6,10-Dimethyl-2-(propan-2-ylidene)spiro[4.5]dec-6-en-8-one (Vetivenol) 1.90%; Citronellol 1.76%; trans-Sesquisabinene hydrate 1.72%; (E)− 3-Methyl-5-((1 R,4aR,8aR)− 5,5,8a-trimethyl-2-methylenedecahydronaphthalen-1-yl)pent-2-enoic acid (Copalic acid) 1.66%; Geranyl acetate 1.65%; Geraniol 1.62%; Humulane-1,6-dien-3-ol 1.62%; 5,9-Undecadien-2-ol, 6,10-dimethyl- 1.56%; iso-Bornyl methacrylate 1.45%; Spiro[4.5]decan-7-one, 1,8-dimethyl-8,9-epoxy-4-isopropyl- 1.27%; Bicyclo[2.2.1]heptane, 2,2-dimethyl-3-methylene-, (1 S)- (Camphene) 1.17%; τ-Cadinol 1.09%; and Lanceol, cis (cis-Lanceol) 1.09%.

3.3.2. *GC-MS result for Kuching Local Ginger essential oil*

Fig. 6 shows the gas chromatogram generated from the GC-MS analysis for the *Kuching Local Ginger* essential oil. Each of the peak occurred in the gas chromatogram is labelled from 1 to 100.

Based on the individual retention time and peak area occurred for each peak in the gas chromatogram in Fig. 6, its chemical compounds name is identified and the percentage of the identified chemical compounds present in *Kuching Local Ginger* essential oil is stated. Table 6 shows chemical constituents data analysis for each peak in the *Kuching Local Ginger* essential oil.

According to the GC-MS analysis results shown in Fig. 6, a total of 92 types of chemical constituents (exclude the repeating chemical constituent) were detected for *Kuching Local Ginger* essential oils, of which the highest levels are: 2,6-Octadienal, 3,7-dimethyl-, (*E*)- (α-Citral or Genarial) 7.86%; 1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)− 2-methyl-, [S-(R*,S*)]- (α-Zingiberene) 7.03%; Benzene, 1-(1,5-dimethyl-4-hexenyl)− 4-methyl- (α-Curcumene) 6.49%; Neral 6.03%; Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)− 6-methylene-, [S-(R*,S*)]- (β-Sesquiphellandrene) 5.95%; α-Farnesene 4.69%; β-Bisabolene 4.62%; trans-Sesquisabinene hydrate 2.87%; trans-Geranylgeraniol 2.81%; Geraniol 2.29%; 2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)] (β-Selinenol) 2.26%; Eucalyptol 1.81%; 1 H-Benzocyclohepten-9-ol, 2,4a-.beta.,5,6,7,8,9,9a-.beta.-octahydro-3,5,5,9–.beta.-tetramethyl- (Himachalol) 1.81%; β- Acorenol 1.78%; (1 R,4 R)− 1-methyl-4-(6-Methylhept-5-en-2-yl)cyclohex-2-enol (Zingiberenol) 1.64%; Cyclohexanemethanol, 4-ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]- (Elemol) 1.58%; Citonellol 1.55%; 1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (*E*)- (trans-Nerolidol) 1.55%; endo-Borneol (Borneol) 1.46%; 6,10-Dodecadien-1-yn-3-ol, 3,7,11-trimethyl (Dehydronerolidol) 1.46%;; 4-Hexen-1-ol, 5-methyl-2-(1-methylethenyl)-, acetate (Lavandulol) 1.28%; Humulane-1,6-dien-3-ol 1.26%; L-α-Terpineol 1.20%; 3-Cyclohexen-1-ol, 1-(1,5-dimethyl-4-hexenyl)− 4-methyl- (Iso-β-bisabolol) 1.14%; and Cyclohexene, 4-ethenyl-4-methyl-3-(1-methylethenyl)− 1-(1-methylethyl)-, (3R-trans)- (σ-Elemene) 1.13%.

3.3.3. *Comparison GC-MS result between China and Kuching Local Ginger essential oil*

Table 7 is a list of the common chemical constituents which presented in the ginger essential with its corresponding percentage of compound for China and *Kuching Local Ginger* essential oils based on the GC-MS results obtained in previous sections. A comparison graph had constructed to illustrate the difference percentage of each type of chemical constituents for China and *Kuching Local Ginger* essential oils as shown in Fig. 7.

According to the Fig. 7, *China Ginger* essential oil has the higher percentage of chemical compound for α-Zingiberene, β-Selinenol, Zingiberenol, [6]-Shogaol, trans-Geranylgeraniol, Camphene, Eucalyptol, Citronellol, and Neral compared to the *Kuching Local Ginger* essential oil. In other hand, *Kuching Local Ginger* essential oil has the higher percentage of chemical compound for α-Curcumene, α-Citral or Genarial, β-Bisabolene, β-Sesquiphellandrene, β-Sesquisabinene, trans-Sesquisabinene hydrate and Geraniol compared to the *China Ginger* essential oil.

While based on the tabulated Table 7 and constructed Fig. 7, it can be observed that both of the *China Ginger* and *Kuching Local Ginger* essential

Table 5
GC-MS analysis of chemical constituents of *China Ginger* essential oil.

Peak#	Retention time (min)	Peak Area	Compound name	Percentage of compound (%)
1	9.393	15046771	α-Pinene	0.42
2	10.046	41976825	Bicyclo[2.2.1]heptane, 2,2-dimethyl-3-methylene-, (1 S)- (Camphene)	1.17
3	10.985	4157630	Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methylene-, (1 S)- (L-β-Pinene)	0.12
4	11.324	14380024	β-Myrcene	0.40
5	11.966	3999071	Cyclohexane, 1-methylene-4-(1-methylethenyl)- (ψ-Limonene)	0.11
6	12.661	3076753	p-Cymene	0.09
7	12.791	21278481	D-Limonene	0.59
8	12.982	95760529	Eucalyptol	2.68
9	14.628	4704898	2-Carene	0.13
10	14.835	3687141	2-Nonanone	0.10
11	15.167	21424080	Linalool	0.60
12	16.810	9934323	6-Octenal, 3,7-dimethyl-, (R)- ((R)-(+)-Citronellal))	0.28
13	16.860	5637240	(+)− 2-Bornanone	0.16
14	17.124	4945820	7-Decen-2-one	0.14
15	17.381	4452032	endo-Borneol (Borneol)	0.12
16	17.688	33252920	Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, (1S-endo)- (Borneol)	0.93
17	17.834	8379412	3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R)- ((-)− 4-Terpineol)	0.23
18	18.336	25317956	L-α-Terpineol	0.71
19	18.959	4025407	Oxiranecarboxaldehyde, 3-methyl-3-(4-methyl-3-pentenyl	0.11
20	19.239	63037452	Citronellol	1.76
21	19.676	100735955	Neral	2.82
22	19.963	57838053	Geraniol	1.62
23	20.191	6820215	2-Decenal, (*E*)- (Decenal)	0.19
24	20.606	136464861	2,6-Octadienal, 3,7-dimethyl-, (*E*)- (α-Citral or Genarial)	3.81
25	20.857	25875541	Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, acetate, (1S-endo)- (trans-Bornyl acetate)	0.72
26	20.977	16741490	2-Undecanone	0.47
27	21.100	2551291	2,6-Octadien-1-ol, 3,7-dimethyl-, acetate (cis-Geranyl acetate)	0.07
28	21.229	3514143	2-Undecanol	0.10
29	22.090	4472891	Cyclohexene, 4-ethenyl-4-methyl-3-(1-methylethenyl)− 1-(1-methylethyl)-, (3R-trans)- (σ-Elemene)	0.13
30	22.438	20083079	6-Octen-1-ol, 3,7-dimethyl-, acetate (Citronellol acetate)	0.56
31	23.134	15194469	1,2,4-Metheno-1 H-indene, octahydro-1,7a-dimethyl-5-(1-methylethyl)-, [1S-(1.alpha.,2.alpha.,3a.beta.,4.alpha.,5.alpha.,7a.beta.,8 S*)]- (Cyclosativene)	0.42
32	23.297	59011163	Geranyl acetate	1.65
33	23.407	6274769	Cyclohexanemethanol, 4-ethenyl.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]- (Elemol)	0.18
34	23.637	33208549	Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1.alpha.,2.beta.,4.beta.)]- (β-Elemene)	0.93
35	23.848	13043256	(1 S,5 S)− 2-Methyl-5-((R)− 6-methylhept-5-en-2-yl)bicyclo[3.1.0]hex-2-ene (Episesquithujene)	0.36
36	24.514	5392502	Caryophyllene	0.15
37	24.697	17859642	Bicyclo[3.1.1]hept-2-ene, 2,6-dimethyl-6-(4-methyl-3-pentenyl)- (α-Bergamotene)	0.50
38	24.913	2570459	(1 S,5 S)− 4-Methylene-1-((R)− 6-methylhept-5-en-2-yl)bicyclo[3.1.0]hexane (β-Sesquisabinene)	0.07
39	25.155	23655460	(*E*)-β-Famesene	0.66
40	25.245	22713702	Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)− 6-methylene-, [S-(R*,S*)]- (β-Sesquiphellandrene)	0.63
41	25.468	5766037	Humulene	0.16
42	25.591	19948787	Alloaromadendrene	0.56
43	26.195	215946768	Benzene, 1-(1,5-dimethyl-4-hexenyl)− 4-methyl- (α-Curcumene)	6.04
44	26.549	281982068	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)− 2-methyl-, [S-(R*,S*)]- (α-Zingiberene)	7.88
45	26.830	109427804	β-Bisabolene	3.06
46	27.294	185890776	Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)− 6-methylene-, [S-(R*,S*)]- (β-Sesquiphellandrene)	5.20
47	27.646	14849843	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-, (*Z*,*E*)- (Farnesol)	0.42
48	27.904	102244416	1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethylidene)-, (E,E)- (β-Germacrene)	2.86
49	28.194	25934049	1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethylidene)-, (E,E)- (β-Germacrene)	0.72
50	28.330	6758663	Dodecanoic acid	0.19
51	28.505	21536314	Di-epi-α-cedrene-(I)	0.60
52	28.821	61502476	trans-Sesquisabinene hydrate	1.72
53	29.080	33651631	1 H-Cycloprop[*e*]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]- (1 H-Cycloprop[*e*]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]- (Spatulenol)	0.94
54	29.409	90937252	(1 R,4 R)− 1-methyl-4-(6-Methylhept-5-en-2-yl)cyclohex-2-enol (Zingiberenol)	2.54
55	29.830	93758457	(1 R,4 R)− 1-methyl-4-(6-Methylhept-5-en-2-yl)cyclohex-2-enol (Zingiberenol)	2.62
56	30.028	59469212	(E)− 3-Methyl-5-((1 R,4aR,8aR)− 5,5,8a-trimethyl-2-methylenedecahydronaphthalen-1-yl)pent-2-enoic acid (Copalic acid)	1.66
57	30.158	39044318	τ-Cadinol	1.09
58	30.561	142137677	2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]- (β-Selinenol)	3.97
59	31.112	89513554	1 H-Benzocyclohepten-9-ol, 2,4a-.beta.,5,6,7,8,9,9a-.beta.-octahydro-3,5,5,9-.beta.-tetramethyl- (Himachalol)	2.50
60	31.342	96773891	6,10-Dodecadien-1-yn-3-ol, 3,7,11-trimethyl- (Dehydronerolidol)	2.70
61	31.706	57951904	Humulane-1,6-dien-3-ol	1.62
62	32.035	117546216	(S,Z)− 2-Methyl-6-(p-tolyl)hept-2-en-1-ol ((*Z*)-Nuciferol)	3.29
63	32.514	67858863	(5 R,10 R)− 6,10-Dimethyl-2-(propan-2-ylidene)spiro[4.5]dec-6-en-8-one (Vetivenol)	1.90
64	32.779	39093649	Lanceol, cis (cis-Lanceol)	1.09
65	33.170	60370549	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	1.69
66	33.383	16418324	2,6,11-Dodecatrienal, 2,6-dimethyl-10-methylene- (β-Sinensal)	0.46

(*continued on next page*)

Table 5 (*continued*)

Peak#	Retention time (min)	Peak Area	Compound name	Percentage of compound (%)
67	33.643	21836261	cis-Z-α-Bisabolene epoxide	0.61
68	33.926	75857189	2(1 H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-7.alpha.-isopropyl-4a.beta.,8a.beta.-dimethyl-	2.12
69	34.274	51725211	iso-Bornyl methacrylate	1.45
70	34.631	25828103	geranyl-α-terpinene	0.72
71	35.094	55817234	5,9-Undecadien-2-ol, 6,10-dimethyl-	1.56
72	35.205	33732501	6-Isopropenyl-4,8a-dimethyl-1,2,3,5,6,7,8,8a-octahydro-naphthalen-2-ol	0.94
73	35.640	45375567	Spiro[4.5]decan-7-one, 1,8-dimethyl-8,9-epoxy-4-isopropyl-	1.27
74	35.930	30355280	1 S,3 R,4 S,5 R,6S-1-Hydroxy-2,2,3,4,5,6-hexamethyl-8-oxo-7,9-dioxatricyclo[4.2.1.0(3,5)]nonane	0.85
75	36.299	26455335	(2 R,3 R,4aR,5 S,8aS)− 2-Hydroxy-4a,5-dimethyl-3-(prop-1-en-2-yl)octahydronaphthalen-1(2 H)-one (Santalcamphor)	0.74
76	36.634	11825689	Dibutyl phthalate	0.33
77	36.855	18641423	(Eeee)− 5,9,16,20-tetramethyl-1,12-dioxa-4,9,15,20-cyclodocosatetraen-2,13-dione	0.52
78	37.230	8844808	Acorenone B	0.25
79	37.430	5918708	5,9-Undecadien-2-ol, 2,6,10-trimethyl-	0.17
80	37.728	2407979	Formic acid, 3,7,11-trimethyl-1,6,10-dodecatrien-3-yl ester	0.07
81	37.905	5058789	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.14
82	38.522	4059375	5-Isopropyl-6-methyl-hepta-3,5-dien-2-ol	0.11
83	39.154	3519424	Nerolidol isobutyrate	0.10
84	39.630	5245351	4,8,13-Cyclotetradecatriene-1,3-diol, 1,5,9-trimethyl-12-(1-methylethyl)- (4,8,13-Duvatriene-1,3-diol)	0.15
85	39.980	3093220	Undec-10-ynoic acid, undec-2-en-1-yl ester	0.09
86	40.180	4977611	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.14
87	40.529	4075572	2,4(1 H,3 H)-Pyrimidinedione, 1,1′-(1,3-propanediyl)bis[5-methyl- (1,1′-Trimethylenebis(thymine)	0.11
88	42.918	11971452	1-(4-Hydroxy-3-methoxyphenyl)dec-4-en-3-one ([6]-Shogaol)	0.33
89	43.305	4802736	(Z)− 3,7-Dimethylocta-2,6-dien-1-yl palmitate (Palmitic acid)	0.13
90	45.155	2962272	1 H-3a,7-Methanoazulene, 2,3,4,7,8,8a-hexahydro-3,6,8,8-tetramethyl-, [3R-(3.alpha.,3a.beta.,7.beta.,8a.alpha.)]- (α-Cedrene)	0.08
91	45.730	6520670	Dotriacontane	0.18
92	46.180	3159921	(3 R,5 S)− 1-(4-Hydroxy-3-methoxyphenyl)decane-3,5-diyl diacetate ([6]-Gingerdiol 3,5-diacetate)	0.09
93	46.394	22422997	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.63
94	47.030	6849494	trans-Geranylgeraniol	0.19
95	47.401	25837949	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.72
96	47.680	3461376	5,9,13,17-Tetramethyl 4,8,12,16-octadecatetraenoic acid	0.10
97	47.880	4058138	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl- (Farnesol)	0.11
98	48.235	7969814	1,6,10,14-Hexadecatetraen-3-ol, 3,7,11,15-tetramethyl-, (E,E)- (Geranyl linallol)	0.22
99	48.728	7280675	Tetrapentacontane, 1,54-dibromo-	0.20
100	49.480	7212385	1 H-3a,7-Methanoazulen-5-ol, octahydro-3,8,8-trimethyl-6-methylene- (Cedrenol)	0.20
Total		3577970262		100.00

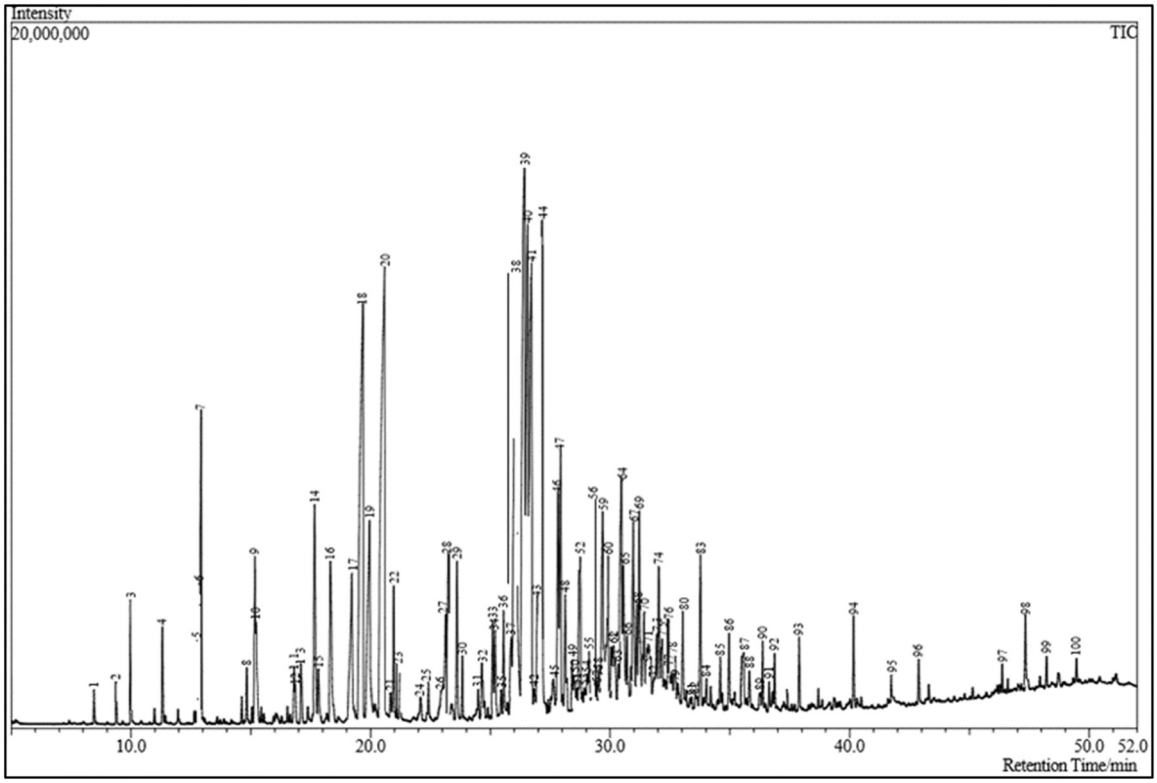


Fig. 6. Gas chromatogram graph for *Kuching Local Ginger* essential oil.

Table 6
GC-MS analysis of chemical constituents of *Kuching Local Ginger* essential oil.

Peak#	Retention time (min)	Peak Area	Compound name	Percentage of compound (%)
1	8.455	2537359	2-Heptanol	0.14
2	9.385	3115945	α-Pinene	0.18
3	10.006	9886588	Camphene	0.56
4	11.316	7515344	β-Myrcene	0.42
5	12.759	7026080	D-Limonene	0.39
6	12.849	11624471	β-Phellandrene	0.65
7	12.929	32286060	Eucalyptol	1.81
8	14.828	4457799	3-Diazo-1,7,7-trimethylbicyclo[2.2.1]heptan-2-one (Camphor)	0.25
9	15.171	15489109	Linalool	0.87
10	15.219	10719209	2-Nonanol	0.60
11	16.805	4778557	6-Octenal, 3,7-dimethyl-, (R)- [(R)-(+)-Citronellal)]	0.27
12	16.865	2838109	(+)− 2-Bornanone	0.16
13	17.095	6956617	Isoneral	0.39
14	17.684	25958791	endo-Borneol (Borneol)	1.46
15	17.836	5912948	3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R)- [(-)− 4-Terpineol]	0.33
16	18.339	21380894	L-α-Terpineol	1.20
17	19.228	27607065	Citronellol	1.55
18	19.682	107271032	Neral	6.03
19	19.959	40688787	Geraniol	2.29
20	20.603	139810185	2,6-Octadienal, 3,7-dimethyl-, (*E*)- (α-Citral)/ (Genarial)	7.86
21	20.834	3292627	Bicyclo[2.2.1]heptan-2-ol, 1,7,7-trimethyl-, acetate, (1S-endo)- (trans-Bornyl acetate)	0.19
22	20.967	11180502	2-Undecanone	0.63
23	21.223	5447187	2-Undecanol	0.31
24	22.088	2374640	4-Hexen-1-ol, 5-methyl-2-(1-methylethenyl)-, acetate (Lavandulol)	0.13
25	22.419	2948454	6-Octen-1-ol, 3,7-dimethyl-, acetate (Citronellol acetate)	0.17
26	22.955	5118515	5 H-Inden-5-one, 1,2,3,3a,4,7a-hexahydro-7a-methyl-, trans-	0.29
27	23.131	13371356	1,2,4-Metheno-1 H-indene, octahydro-1,7a-dimethyl-5-(1-methylethyl)-, [1S-(1.alpha.,2.alpha.,3a.beta.,4.alpha.,5.alpha.,7a.beta.,8 S*)]- (Cyclosativene)	0.75
28	23.241	22852682	4-Hexen-1-ol, 5-methyl-2-(1-methylethenyl)-, acetate (Lavandulol)	1.28
29	23.611	15613629	Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1.alpha.,2.beta.,4.beta.)]- (β-Elemene)	0.88
30	23.829	4969078	(1 S,5 S)− 2-Methyl-5-((R)− 6-methylhept-5-en-2-yl)bicyclo[3.1.0]hex-2-ene (Episesquithujene)	0.28
31	24.502	2059205	Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene- [(*Z*)-Caryophyllene]	0.12
32	24.649	7623276	σ-Elemene	0.43
33	25.120	10661651	(*E*)-β-Famesene	0.60
34	25.228	9067302	(1 S,5 S)− 4-Methylene-1-((R)− 6-methylhept-5-en-2-yl)bicyclo[3.1.0]hexane (β-Sesquisabinene)	0.51
35	25.453	3552519	Humulene	0.20
36	25.577	10810899	Alloaromadendrene	0.61
37	25.890	13232399	Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,8a-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,7.beta.,8a.alpha.)]- (Valencene)	0.74
38	26.081	109258220	Benzene, 1-(1,5-dimethyl-4-hexenyl)− 4-methyl- (α-Curcumene)	6.14
39	26.443	125029856	1,3-Cyclohexadiene, 5-(1,5-dimethyl-4-hexenyl)− 2-methyl-, [S-(R*,S*)]- (α-Zingiberene)	7.03
40	26.573	83522096	α-Farnesene	4.69
41	26.731	82244774	β-Bisabolene	4.62
42	26.825	3878073	Diallylmethylsilane	0.22
43	26.959	11744928	(1 R,2 S,6 S,7 S,8 S)− 8-Isopropyl-1-methyl-3-methylenetricyclo[4.4.0.02,7]decane-rel- (β-Copaene-4α-ol)	0.66
44	27.180	105898190	Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)− 6-methylene-, [S-(R*,S*)]- (β-Sesquiphellandrene)	5.95
45	27.635	8607623	2-Pentatriacontanone	0.48
46	27.824	28046388	Cyclohexanemethanol, 4-ethenyl-.alpha.,.alpha.,4-trimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,3.alpha.,4.beta.)]- (Elemol)	1.58
47	27.936	27603208	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (*E*)- (trans-Nerolidol)	1.55
48	28.125	17452096	1,5-Cyclodecadiene, 1,5-dimethyl-8-(1-methylethylidene)-, (E,E)- (β-Germacrene)	0.98
49	28.467	6249166	Benzene, 1-(1,5-dimethylhexyl)− 4-methyl- (α-Curcumene)	0.35
50	28.535	3388538	(2E,4 S,7E)− 4-Isopropyl-1,7-dimethylcyclodeca-2,7-dienol (Germacrene D-4-ol)	0.19
51	28.605	2467462	Caryophyllene oxide	0.14
52	28.752	17460790	trans-Sesquisabinene hydrate	0.98
53	28.925	6238264	6-Octenal, 7-methyl-3-methylene-	0.35
54	29.035	5109871	(1 R,7 S,E)− 7-Isopropyl-4,10-dimethylenecyclodec-5-enol	0.29
55	29.125	6416538	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-, (*Z*,*E*)- (Farnesol)	0.36
56	29.319	29271474	(1 R,4 R)− 1-methyl-4-(6-Methylhept-5-en-2-yl)cyclohex-2-enol (Zingiberenol)	1.64
57	29.415	4397856	Tricyclo[4.4.0.0(3,9)]decan-4-ol, stereoisomer	0.25
58	29.525	4341942	Isospathulenol	0.24
59	29.733	33584981	trans-Sesquisabinene hydrate	1.89
60	29.947	31613646	β- Acorenol	1.78
61	30.085	6707413	τ-Cadinol	0.38
62	30.151	12732020	α-Cadinol	0.72
63	30.345	6750301	geranyl-α-terpinene	0.38
64	30.512	40207334	2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]- (β-Selinenol)	2.26
65	30.595	20344969	3-Cyclohexen-1-ol, 1-(1,5-dimethyl-4-hexenyl)− 4-methyl- (Iso-β-bisabolol)	1.14
66	30.746	8718128	1,4-Dimethyl-7-(prop-1-en-2-yl)decahydroazulen-4-ol (Pogostol)	0.49
67	31.004	32253221	1 H-Benzocyclohepten-9-ol, 2,4a-.beta.,5,6,7,8,9,9a-.beta.-octahydro-3,5,5,9-.beta.-tetramethyl- (Himachalol)	1.81

(*continued on next page*)

Table 6 (*continued*)

Peak#	Retention time (min)	Peak Area	Compound name	Percentage of compound (%)
68	31.154	11617593	4-(1,5-Dimethylhex-4-enyl)cyclohex-2-enone	0.65
69	31.255	25990661	6,10-Dodecadien-1-yn-3-ol, 3,7,11-trimethyl (Dehydronerolidol)	1.46
70	31.453	14364086	trans-Geranylgeraniol	0.81
71	31.621	22355642	Humulane-1,6-dien-3-ol	1.26
72	31.825	8955074	Longifolenaldehyde	0.50
73	31.967	7383151	(E)− 2-Methyl-6-(p-tolyl)hept-2-en-1-yl acetate (Nuciferyl acetate)	0.41
74	32.057	16656440	2,6,10-Dodecatrienal, 3,7,11-trimethyl-, (E,E)- (Farnesal)	0.94
75	32.172	8500715	5-Isopropenyl-2-methyl-7-oxabicyclo[4.1.0] heptan-2-ol	0.48
76	32.448	20167901	Cyclohexene, 4-ethenyl-4-methyl-3-(1-methylethenyl)− 1-(1-methylethyl)-, (3R-trans)- (σ-Elemene)	1.13
77	32.585	5374566	8a(2 H)-Phenanthrenol, 7-ethenyldodecahydro-1,1,4a,7-tetramethyl-, acetate, [4as-(4a.alpha.,4b.beta.,7. beta.,8a.alpha.,10a.beta.)]-	0.30
78	32.726	8354874	Lanceol, cis (cis-Lanceol)	0.47
79	32.827	4773617	1 H-3a,7-Methanoazulene-6-methanol, 2,3,4,7,8,8a-hexahy6-Octenal, 3,7-dimethyl-, (R)-dro-3,8,8-trimethyl-, [3R-(3.alpha.,3a.beta.,7.beta.,8a.alpha.)]- (α-Cedrene)	0.27
80	33.066	11622675	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.65
81	33.405	2011450	Isolongifolol	0.11
82	33.555	2665715	Longifolenaldehyde	0.15
83	33.778	16252478	2(1 H)-Naphthalenone, 4a,5,6,7,8,8a-hexahydro-7.alpha.-isopropyl-4a.beta.,8a.beta.-dimethyl-	0.91
84	34.021	4153101	E,E,Z-1,3,12-Nonadecatriene-5,14-diol	0.23
85	34.599	3810454	(E)− 1-(6,10-Dimethylundec-5-en-2-yl)− 4-methylbenzene (Pentylcurcumene)	0.21
86	34.966	6952744	5,9-Undecadien-2-ol, 6,10-dimethyl-	0.39
87	35.570	8297498	3,5,9-Trimethyl-deca-2,4,8-trien-1-ol	0.47
88	35.820	4946785	2,2-Dimethyl-1-(3-oxo-but-1-enyl)-cyclopentanecarboxaldehyde	0.28
89	36.235	2640157	(2 R,3 R,4aR,5 S,8aS)− 2-Hydroxy-4a,5-dimethyl-3-(prop-1-en-2-yl)octahydronaphthalen-1(2 H)-one (Santalcamphor)	0.15
90	36.374	5112489	(E)− 1-(6,10-Dimethylundeca-5,9-dien-2-yl)− 4-methylbenzene (Gerany-p-cymene)	0.29
91	36.645	2875538	n-Hexadecanoic acid	0.16
92	36.870	4280388	(E)− 1-(6,10-Dimethylundec-5-en-2-yl)− 4-methylbenzene (Pentylcurcumene)	0.24
93	37.892	5999280	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.34
94	40.163	8218613	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.46
95	41.776	2677981	3-Decanone, 1-(4-hydroxy-3-methoxyphenyl)- ([6]-Gingerone)	0.15
96	42.887	4013983	1-(4-Hydroxy-3-methoxyphenyl)dec-4-en-3-one ([6]-Shogaol)	0.23
97	46.369	2188801	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.12
98	47.378	7724785	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)- (trans-Geranylgeraniol)	0.43
99	48.222	2838103	1,6,10,14-Hexadecatetraen-3-ol, 3,7,11,15-tetramethyl-, (E,E)- (Geranyl linallol)	0.16
100	49.466	2177260	Licarin A	0.12
Total		1779530834		100.00

Table 7
Comparison of chemical constituents between China and *Kuching Local Ginger* essential oils.

Type of Chemical Constituents	Percentage of Compound (%)	
	China Ginger Essential Oil	*Kuching Local Ginger* Essential Oil
α-Zingiberene	7.88	7.03
α-Curcumene	6.04	6.49
α-Citral or Genarial	3.81	7.86
β-Bisabolene	3.06	4.62
β-Sesquiphellandrene	5.83	5.95
β-Sesquisabinene	0.07	0.51
β-Selinenol	3.97	2.26
Zingiberenol	5.16	1.64
[6]-Shogaol	0.33	0.23
trans-Sesquisabinene hydrate	1.72	2.87
trans-Geranylgeraniol	3.51	2.81
Camphene	1.17	0.56
Eucalyptol	2.68	1.81
Citronellol	1.76	1.55
Neral	2.82	6.03
Geraniol	1.62	2.29

oils have the highest percentage of the chemical constitutes including the α-Zingiberene (7.88% and 7.03%), α-Curcumene (6.04% and 6.49%), β-Sesquiphellandrene (5.83% and 5.95%), β-Bisabolene (3.06% and 4.62%) respectively. This resulted is in line with the researches done by Nandi et al. (2013) and Azhari et al. (2017) which proven that fresh *China Ginger* and Malaysia ginger had shown the α-Zingiberene, α-Curcumene, β-Sesquiphellandrene, and β-Bisabolene as the most abundant chemical compound in the ginger essential oil. These components are classified as the terpene compound which can be found in the ginger essential oil. Terpene were demonstrated to have bioactivity of antibacterial, anti-inflammatory, antiulcerogenic, anticancer, and antioxidant properties according to the research done by Gonzalez-Burgos and Gomez-Serranillos (2012). Besides, terpene also having a high antioxidant property which is beneficial to human health.

In addition, there is only a shogaol compound presented in both ginger essential oils which are [6]-Shogaol. The percentage of [6]-Shograol for *China Ginger* and *Kuching Local Ginger* essential oils is 0.33% and 0.23% respectively. [6]-Shogaol is a bioactive compound that contribute to the characteristic of odour and flavour of ginger. Present of [6]-Shogaol is beneficial as tt has been proven that [6]-Shogaol is more effective in exhibiting anticancer, antioxidative, and anti-inflammatory activities than another compound such as gingerol (Nair et al. 2021).

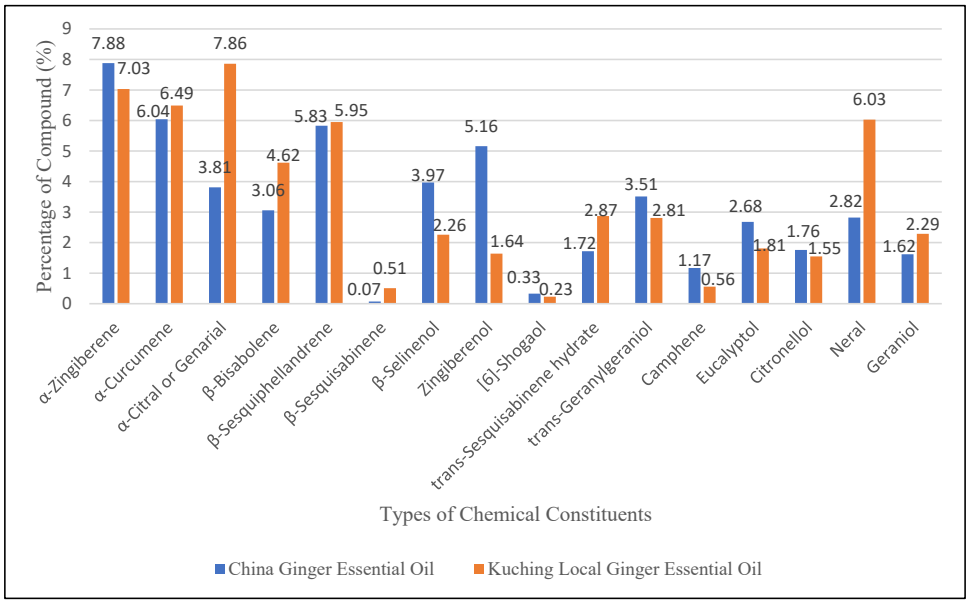


Fig. 7. Comparison of percentage chemical constituents for *China Ginger* and *Kuching Local Ginger* essential oils.

3.4. Selection of Ginger Essential Oil as Insect Repellent

The most importance key to act as the mosquito repellent is the scent of the essential oils as the odour masking. Mosquitoes can feel unpleasant to the pungent aroma released from the essential oils and naturally reduce the attractive of the mosquitoes and other insects to come nearby to the host (Muema et al., 2017). The monoterpene chemical compounds that responsible to the aromatic of the ginger essential oil including the camphane, eucalyptol, citronellol, geraniol, neral and geranial (α-Citral). When applied topically or sprayed in space, it has been proven that these monoterpene chemicals are just as effective as DEET in terms of rendering insects' unconscious and incapacitated (Regnault-Roger et al., 2012).

First, camphene is a monoterpene that has an offensive and pungent scent that is comparable to the smell of camphor. According to (Feng et al.,2019), camphene exhibited a level of insect repellency that was considered to be moderate. Besides, the aroma of eucalyptol is similar to that of fresh mint, and the taste is warm and peppery. It is most frequently discovered in eucalyptus oil and is a component that is frequently utilized in the production of mouthwash and cough suppressants. In the research done by Klocke et al. (1987), in spite of the fact that eucalyptol had no substantial mosquito larvicidal action, but it was relatively effective performance as feeding repellent and pupation repellent against adult *Aedes aegypti*. Citronellol, on the other hand, is a naturally occurring acyclic monoterpenoid that has an aroma that is both grassy and flowery, with a hint of rose. Due to the fact that it has a pleasant, flowery aroma, it is often a component that derives from natural sources and is used to personal care products as a fragrance. According to Saroj et al. (2020), the essential oil that is high in citronellol has demonstrated powerful insecticidal capabilities and repellency against *Spodoptera frugiperda* larvae.

In addition, geraniol is an acyclic monoterpene alcohol that has an odour that is similar to that of roses. It is a very important chemical component of the essential oils of plants including rose, lemongrass, and geranium. Geraniol, which is known to have insecticidal and repellent properties, is used as a natural pest control agent. It has low toxicity and considerably more repellent activity against female mosquitoes than citronella, and it can be used in both indoor and outdoor conditions (Chen and Viljoen, 2010). Furthermore, neral and geranial is a chemical that having a powerful lemon-fragrance. They can be extracted from the essential oils of plant species like lemon, and it plays a significant role in the production of fragrances and flavorings. Both neral and geranial are known to have actions that are antifungal, antimicrobial, and insecticidal in addition to activities that have a repellent effect against aphids and mosquitoes (Muema, et al., 2017).

Therefore, based on the GC-MS results which discover the percentage of each of the stated monoterpene compounds in *China Ginger* and *Kuching Local Ginger* essential oils, it can be noticed that the total of the percentage of stated monoterpene compounds in *China Ginger* essential oil is much less than the Kuching ginger essential oil with 16.09% and 20.1%, respectively. The higher the contain of these chemical monoterpene constituents in the ginger essential oil, the higher of the repellent ability of the ginger essential oil against the unwanted insect like mosquitoes. This perhaps infer that *Kuching Local Ginger* essential oil can have a higher insect repellent activity than the *China Ginger* essential oil. Hence *Kuching Local Ginger* essential oil is more suitable to be chosen as the superior repellent for future work. Moreover, interestingly it is to be noted that *n*-Hexadecanoic acid only found in *Kuching Local Ginger* (but not the *China Ginger*) albeit at a very low percentage of 0.16 wt%. A toxicity study conducted by Amala et al. (2021) have shown that the hexane extracts of *Epaltes pygmaea* in particular *n*-Hexadecanoic acid have shown significant larvicidal, growth retardant, enzyme inhibition, and midgut toxicity effects against the dengue vector *Aedes aegypti*.

Apart from that, the percentage oil yield for *Kuching Local Ginger* (0.264 wt%) is higher than the *China Ginger* (0.158 wt%) which is more feasible to be potentially utilized as green insect/mosquito repellent – as far as present study is concerned.

4. Conclusion and recommendations for further works

In this study, the research findings were meant to contribute to the expanse of green mosquitoes repellent development, particularly involving comparison between *China Ginger* and *Kuching Local Gingers*. Through the ginger essential oil extraction process by hydro distillation extraction for 7 h. *China Ginger* has a percentage oil yield of 0.158 wt%, whereas *Kuching Local Ginger* has a yield of 0.264 wt%. This probably due to the higher volatility of oil content in *Kuching Local Ginger* comparing to the *China Ginger*. In addition, FTIR analysis for both of the ginger had revealed that both types of ginger essential oils include the same functional groups, including phenolic compounds, alcohol primer, alkena methyl group, aromatic compound, carbonyl compound, carboxylic acid, and hydroxyl group, according to the developed FTIR

spectrum graph. Furthermore, from the GC-MS results it revealed that the most abundant chemical constituents presented in the both *China Ginger* and *Kuching Local Ginger* essential were: α-Zingiberene (7.88% and 7.03%), α-Curcumene (6.04% and 6.49%), α-Citral or Genarial (3.81% and 7.86%), β-Bisabolene (3.06% and 4.62%), β-Sesquiphellandrene (5.83% and 5.95%), β-Sesquisabinene (0.07% and 0.51%), β-Selinenol (3.97% and 2.26%), Zingiberenol (5.16% and 1.64%), [6]-Shogaol (0.33% and 0.23%), trans-Sesquisabinene hydrate (1.72% and 2.87%), trans-Geranylgeraniol (3.51% and 2.81%), Camphene (1.17% and 0.56%), Eucalyptol (2.68% and 1.81%), Citronellol (1.76% and 1.55%), Neral (2.82% and 6.03%), and Geraniol (1.62% and 2.29%) respectively. Consequently, based on the GC-MS results that reveal the percentage of each of the claimed monoterpene compounds in *China Ginger* and *Local Kuching Ginger* essential oils, it can be seen that the total of the claimed monoterpene compound percentage in *China Ginger* essential oil is significantly lower than that of the Kuching ginger essential oil, with 16.09% and 20.1%, respectively. The power of the ginger essential oil to repel mosquitoes increases with the concentration of these chemical monoterpene components in the oil. This suggested that the ginger essential oil from *Kuching Local Ginger* might be marginally more effective at keeping mosquitoes away than the ginger essential oil from *China Ginger*.

The toxicity and repellent activities of the ginger essential oils on mosquito species are to be tested and suggested herewith for further works in accordance to Yogarajalakshmi et al. (2020), Karthi et al. (2020), Amala et al. (2021) and Chellappandian et al. (2022).

CRediT authorship contribution statement

Fong Fei Wong: Methodology, Investigation, Data curation, Writing – original draft. **Mohammad Omar Abdullah**: Conceptualization, Methodology, Writing – review & editing, Supervising, Funding acquisition. **Yik Rong Hii:** Investigation, Data curation. **Sze Ying Chang:** Investigation, Data curation. **Noraziah Abdul Wahab:** Writing – review & editing. **Hafizah Abdul Halim Yun:** Writing – review & editing. **Mohd Zaidi Jaafar:** Writing – review & editing. **Augustine Agi:**Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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