The Chemistry of Ginger: From Root to Spice
GC-MS Profiling and Comparative Analysis of Key Compounds in Fresh, Paste, and Powdered Ginger

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Abstract

Ginger (*Zingiber officinale* Roscoe) is a medicinal plant known for its various bioactive compounds and volatile oils, which give it a distinct aroma, flavor, and medicinal properties. This study conducts a comparative analysis of camphene content and compound profiles in three forms of ginger: fresh, powdered, and paste.

Ginger samples were sourced, homogenised, and analysed by gas chromatography-mass spectrometry (GC-MS) following hydro-distillation and liquid-liquid extraction. Method validation included assessments of recovery, matrix effects, linearity, and repeatability. Camphene was selected as the primary marker for quantitative analysis, with carvone serving as the internal standard.

Quantitative analysis indicated that ginger powder had the highest camphene concentration (702.39 µg/g), followed by paste (398.64 µg/g), and fresh ginger (89.97 µg/g), with ANOVA and Tukey's post-hoc tests confirming significant differences across groups. Principal component analysis (PCA) and PERMANOVA further highlighted distinct profiles in the chemical composition across the three ginger types, although not statistically significant due to sample variability. Meanwhile, over 30 compounds were identified for qualitative analysis and categorised into monoterpenes, sesquiterpenes, and diketones.

Overall, this study highlights how ginger's form influences essential oil composition, offering valuable insights for product formulation and quality control in food and medicinal uses.

Keywords: Ginger, hydro-distillation, camphene, carvone, and volatile oils.

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1. Introduction

Ginger (*Zingiber officinale Roscoe*) is a widely used spice and medicinal plant renowned for its pungent flavor and numerous health benefits. The bioactive compounds in ginger, including gingerols, shogaols, and volatile oils, contribute to its distinctive aroma, flavor, and medicinal properties. Phytochemical studies have demonstrated that ginger and its extracts contain polyphenolic compounds, exhibiting pharmacological properties, including high antioxidant and anti-inflammatory effects [1, 2]. Fresh ginger, with its high moisture content (approximately 90% on a wet basis), is susceptible to microbial proliferation, which can result in economic losses and foodborne illnesses [3, 4]. While drying is the primary processing method for fresh postharvest commodities to suppress microbial growth and prevent specific biochemical reactions [5] dried ginger can then be further processed into ginger powder, spices, and medicine. However, an inappropriate drying process can result in significant losses of and conversions of volatile compounds, which can adversely affect the nutrients, physical properties, and essential oils [6]. In addition, Ginger paste is an alternative product that can be stored for a long period without significant alteration of its freshness and can also be considered a minimally processed food; however, the quality of the paste deteriorates during storage [7]. It is essential to analyse these compounds in various forms of ginger (fresh, dried, and paste) to comprehend their chemical composition, which may vary due to processing and storage methods.

Hydrodistillation (HD) is a commonly used method for extracting volatile oils from plant materials [8]. The conventional HD process involves heating a mixture of water and plant materials to evaporate the oils, followed by the liquefaction of the vapours in a condenser, providing an essential oil extract suitable for further analysis. However, this method has the drawback of potentially losing volatile compounds [9].

Gas chromatography-mass spectrometry (GC-MS) is an advanced analytical technique that provides precise qualitative and quantitative analysis of volatile compositions, facilitating a detailed examination of their composition and concentration [10]. GC-MS can concurrently isolate, determine, and quantify various volatile compounds. This research aims to compare the chemical composition of fresh, dried, and paste ginger, as well as analyse the impact of different forms of ginger on essential oil composition, using GC-MS to provide a comprehensive profile of the chemical constituents.

2. Materials and Methods

2.1 Materials

Three different types of ginger were purchased: fresh ginger from ICA Supermarket, sourced from China; Santa Maria ginger powder, also from China; and Thai Dancer ginger paste, sourced from Thailand and purchased in Sweden.

2.2 Preparation of Standards Compounds and Internal Standard

The solvent used for this experiment was iso-octane (2,2,4-trimethyl pentane) with a boiling point t_b of 99°C. Camphene (M =136.2 g/mol, t_b = 159°C), α-pinene (M = 136.2 g/mol, t_b = 156°C) and borneol (M = 154.2 g/mol, t_b = 212°C) were used as standard compounds. Meanwhile, 1-octanol (M = 130.2 g/mol, t_b = 194°C) and carvone (M = 150.2 g/mol, t_b = 231°C) were used as internal standards.

Stock solution of Internal Standard: Approximately 50 mg of the standard was weighed into an appropriate container, and then 12.5g of iso-octane was added.

Stock solutions of the standard compounds and internal standard were prepared using iso-octane as the solvent with concentrations of about 4mg/g. Standard solutions containing about 160µg/g of substances were prepared from the stock solution of the standard compounds.

2.3 Sample Preparation

Fresh ginger samples were crushed into smaller pieces using a clean and dried mortar and pestle to increase the surface area and ensure homogeneity. This makes it easier to extract essential oils during the distillation. The ginger powder and paste samples were thoroughly mixed to further homogenize the samples.
Approximately 3.5g of different types of samples were carefully weighed directly into a boiling flask using a calibrated analytical balance. Subsequently, 0.2g of internal standards were added into the same flask, followed by the addition of 40 mL of Milli-Q water. The mixture was thoroughly mixed and ready for distillation. The samples were prepared in triplicate.

2.4 Hydro distillation (HD) Set up

Hydro distillations were carried out using the laboratory's setup **(**See Supplementary Chapter A**)**, which consists of an extraction column (inner diameter: ~ 8cm), a boiling flask, a heating mantle, a retort stand, a distilling connecting head, a receiver and a condenser. The boiling flask containing the sample, internal standard and milli-Q was heated for 1.5 hours to continuously produce steam, which flowed through the extraction column into the receiving flask. The heating mantle temperature controller was placed at heat setting 6 and a series of extraction experiments were carried out at different times and days. In all experiments, the boiling flask was wrapped with aluminium foil to maintain the temperature. Once each

distillation was completed, the set-up was allowed to cool down, and the receiving flask was carefully separated from the condenser.

2.5 Liquid-Liquid Extraction (LLE)

After distillation, 1mL of the upper layer (organic phase) from the distillate was collected using a calibrated syringe into a centrifuge tube. 1 mL of the iso-octane was added to the organic phase and was vortex for 5 minutes, followed by centrifuging solution for 5 minutes at 2500 rpm. The upper layer of the centrifuged solution was collected into 1.5 mL calibrated tubes. The sample was concentrated to about 100µL with nitrogen gas.

2.6 GC-MS Analysis

All extracts were analyzed on a GC-MS system which included an Agilent 8860 GC-MS system equipped with a DB-5 capillary column (30 m x 0.25 mm i.d. fused silica coat with 0.25 µm 95%Methyl and 5% phenyl-polysiloxane film) connect to a quadrupole MS detector with EI ionization. The temperature program used was as follows: Initial temperature of 70 °C was maintained for 1 min, then heated to 130 °C at 10 °C/min, then increased to 170 °C at 4 °C/min and to 200 °C at 10 °C/min and subsequently to 300 °C at 25 °C/min, where it was held for 5 min.

A manual injection with around 1 µl volume with a split ratio of 1 of 50. Helium was used as carrier gas with a 0.5 ml/min flow rate. All data were obtained by Scan mode 50 – 300 m/z. The Mass Hunter data handling software and NIST mass spectral library were used for data analysis and compound identification.

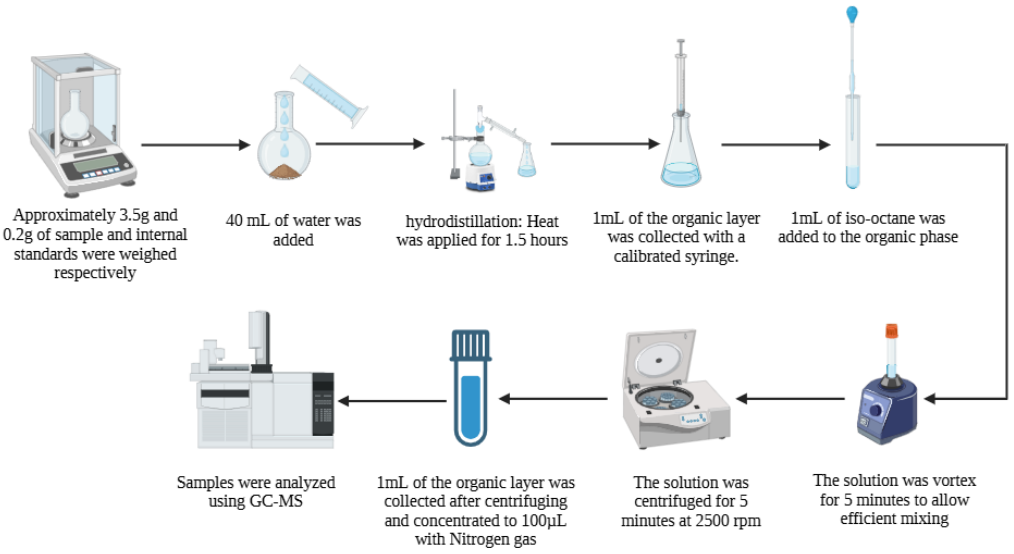

Figure 1 *General overview of the experimental procedure.*

2.6.1 Determination of retention time of standard and Marker selection

The standard solution of 160 µg/g of a-pinene, camphene, and borneol in isooctane and the internal standard solution of 160 µg/g of 1-octanol and carvone were prepared from 4 mg/g stock solution and injected into a GC-MS system to determine the retention time. The isooctane was also injected into the system as a blank to observe the background response.

One marker and one internal standard were selected for quantitative analysis based on the available standard, the marker amount, and the peak resolution.

2.7 Method Validation

The extraction and analysis methods regarding matrix effect, recovery, linearity, and repeatability were validated to ensure their suitability for analysis.

2.7.1 Matrix effect (ME)

For the study of the matrix effect, approximately 1 g of the sample distillate (upper layer) and solvent (isooctane) were weighed into a centrifuge tube. The sample was spiked with 40 mg of camphene stock solution, and 40 mg of two internal standards were added. In the case of the unspiked sample, the distillate was prepared without the addition of camphene. Both spiked and unspiked samples were prepared in triplicate. For the solvent blank, approximately 1 g of the solvent (isooctane) was weighed, and 40 mg of camphene, along with the two internal standards, were added. All samples and the solvent blank were vortexed for 5 minutes to ensure proper mixing. They were then centrifuged at 2500 rpm for 5 minutes, after which the solvent layer was collected for further analysis. The matrix effect was calculated using the formula below

$$\%\,ME = \frac{(Amount\ in\ spiked\ sample - Amount\ in\ unspiked\ sample)}{Amount\ in\ solvent\ blank} \times 100$$

2.7.2 Recovery

The recovery study was conducted in two phases to identify the stage at which most sample loss occurred. In the first phase, approximately 3.5 g of homogenized sample was weighed, and 0.04 g of camphene standard was added. Following this, around 0.2 g of both internal standards and 40 mL of Milli-Q water were added. The mixture was then distilled, followed by liquid-liquid extraction (LLE), and the sample was analyzed. This procedure was repeated in triplicate. In the second phase, the sample preparation was similar, but without adding camphene at the beginning. Instead, the sample was spiked with camphene just before the liquid-liquid extraction step. The recovery was calculated using the formula below.

$$\% \text{ Recovery} = \frac{(C_{spiked\ sample} - C_{\ unspiked\ sample})}{C_{added}} \text{x } 100\%$$

2.7.3 Linearity and Residual Analysis

Camphene and carvone were accurately weighed and dissolved in isooctane to make stock solutions of 4000 µg/g. These stock solutions were serially diluted to obtain calibration standard solutions. A seven-point standard calibration curve was established, covering a range from 25% to 225% of the average camphene content in samples, and the final concentration of camphene (µg/g) was 50 – 410 µg/g. Carvone was added to the calibration to obtain the final 160 µg/g concentration.

The calibration curve was created by plotting the ratio concentration between the standard (camphene) and the Internal standard (carvone) against the ratio of the area of the standard compound and the Internal standard. The residual analysis was performed to determine the relationship between the independent and dependent variables to ensure accurate quantification and linearity across this range.

2.7.4 Extraction Efficiency

Extraction efficiency is commonly used to express trueness in analytical methods. It measures the effectiveness of an extraction process, ensuring that the target analyte is extracted with minimal loss. It is a key parameter for validating analytical methods. The extraction efficiency is calculated using the formula below, where **R** represents recovery, and **ME** represents the matrix effect.

$$\%EE = \frac{\%R\ X\ \%ME}{100\%}$$

2.7.5 Repeatability

Each sample type was prepared in triplicate to evaluate the method's precision and robustness, and the method's repeatability was calculated as %RSD of the samples' camphene content (µg/g). The sample

preparation process was repeated under identical experimental conditions within a short time interval to ensure consistency in the results.

2.8 Compound identification and profiling

The mass spectra and the peak area of essential oil ginger samples were recorded and compared. The compounds were identified using the NIST mass spectral library Version 2.0 (NIST/EPA/NIH, USA) and by mass fragmentation pattern.

The multivariable analysis, Principal component analysis (PCA), was done with Metaboanalyst 6.0 software (https://www.metaboanalyst.ca/MetaboAnalyst/home.xhtml). Before the statistical analysis, the relative peak area of compound to carvone values was auto-scaled (the mean relative area value of each peak throughout all samples was subtracted from each relative peak area value, and the result was divided by the standard deviation) and transformed into a log scale due to the high magnitude between the variable values.

2.9 Quantitative analysis

Three replicates of each type of ginger sample were prepared and analysed by GC-MS. The peak areas of camphene and carvone were recorded. The results are expressed in camphene content as µg/g of sample, average content, and relative standard deviation in percentage. The differences in average camphene content among the groups were analysed using one-way ANOVA and Tukey's post hoc analysis.

3. Results and discussion

3.1 Determination of retention time of standard and Marker selection

No interfering peak was observed in the chromatogram, suggesting good selectivity of the separation method. The retention times of α-pinene, camphene, and borneol were 4.90, 5.10, and 8.34 minutes, respectively. The retention times of 1-octanol and carvone as internal standards were approximately 6.70 and 9.63 minutes, respectively.

Camphene was selected as a marker for quantitative analysis and comparison because it appeared in all types of samples. Carvone was selected as an internal standard for analysis because its structure is closer to the analyte and gives better recovery and higher resolution, as shown in Figure 2.

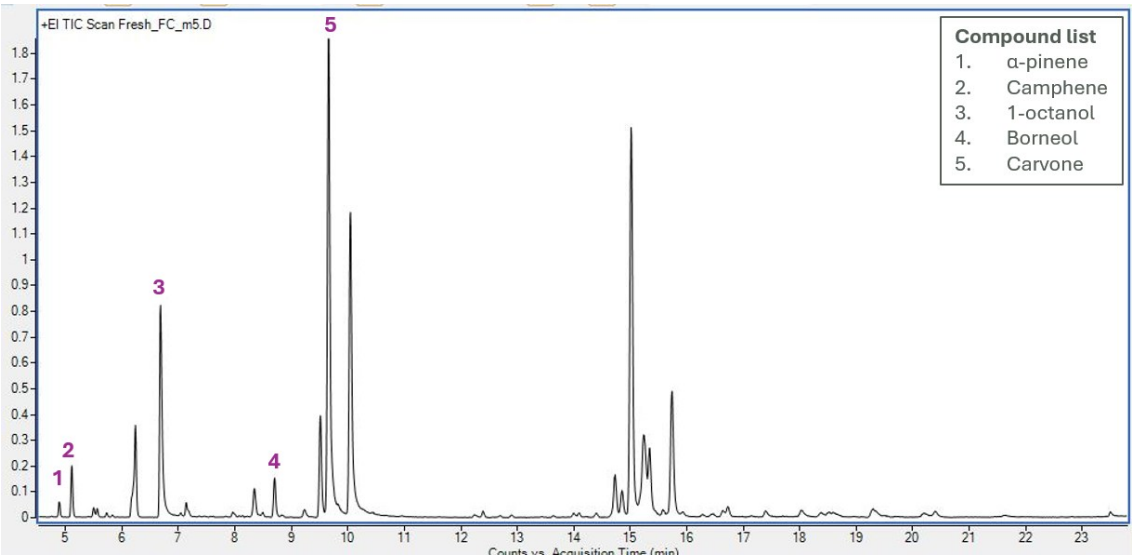

Figure 2 Chromatogram of fresh ginger extract in optimum condition. *The retention times of α-pinene, camphene, and borneol were 4.90, 5.10, and 8.34 minutes, respectively. The retention times of 1-octanol and carvone as internal standards were approximately 6.70 and 9.63 minutes, respectively.*

3.2 Method validation

3.2.1 Matrix effect

The concentration of camphene content in 3 individual fresh ginger extracts (µg/g) and %ME was shown in Table 1. The matrix effect fluctuates from 29.02% to 108.05%, averaging 65.16% and 61.31% RSD, respectively.

Table 1 *Concentration of Camphene (µg/g) and %ME in the fresh ginger extract of Spiked Samples*

Solution	Camphene content (µg/g)		%ME
Spiked sample 1	326.31		108.05%
Spiked sample 2	183.31		58.41%
Spiked sample 3	98.65		29.02%
Unspiked sample	15.07		
Solvent blank	288.036		
		Average	65.16%
		%RSD	61.31%

The result suggests that this method has a high matrix effect and affects the area of carvone in both suppression and enhancement. The sample preparation or analysis method, such as sample purification, should be optimized to obtain less matrix effect. However, the variation between the fresh ginger sample extract was high, and the experiment should be performed in more replicates and in another type of sample to obtain more information.

3.2.2 Recovery

The recovery of the 3 fresh ginger sample extraction processes and the 1 recovery of liquid-liquid extraction are shown in Table 2. Although the %Recovery of liquid-liquid extraction gives a satisfying result at 63.73%, the recovery of the extraction process fluctuates more than 100%. This might result from the difference in extraction apparatus efficiency and the inhomogeneous fresh ginger sample.

Table 2 Recovery of the extraction process and LLE, presented as %Recovery

Recovery			
Recovery of the extraction process		Recovery of LLE	
Solution	%Recovery	Solution	%Recovery
Spiked sample 1	341.78%	Spiked sample	63.73%
Spiked sample 2	539.39%		
Spiked sample 3	-102.33%		
Average	440.58%		

%RSD	74.6 %	

3.2.3 Linearity and Residual Analysis

The calibration curve gives satisfaction linearity with $R^2 = 0.9970$, and no trend was observed in the residual plot, as shown in Figure 3. Moreover, the p-value of the intercept is greater than 0.05, indicating no significant difference from 0, and this calibration curve is suitable for the quantitative analysis of camphene in this experiment.

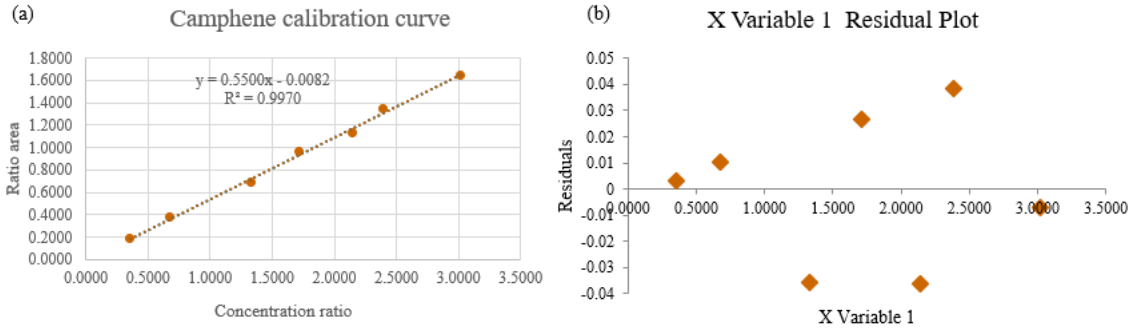

Figure 3 *(a) The calibration curve of camphene was plotted against the concentration ratio (x-axis) and area ratio (y-axis) between camphene and carvone. (b) The residual plot with no trend observed*

3.2.5 Extraction Efficiency

Due to the high %recovery of the extraction process, the recovery of LLE was used to calculate the extraction efficiency. The extraction efficiency in this method was 41.53% for fresh ginger. However, this value represents the LLE step extraction efficiency, and the experiment should be performed with more replications and using both ginger powder and ginger paste to obtain more reliable results.

3.2.6 Repeatability

The repeatability was expressed in the percentage RSD of camphene content. The percentage RSD of camphene content in powder and paste ginger was satisfying at 4.73% and 2.19%, respectively. Meanwhile, the percentage of RSD of camphene content in fresh ginger was high at 48.79%, as shown in Table 4. This might be caused by the low homogeneity of fresh ginger and the high difference in essential oil content between the skin and the rhizome part.

3.3 Compound identification and profiling

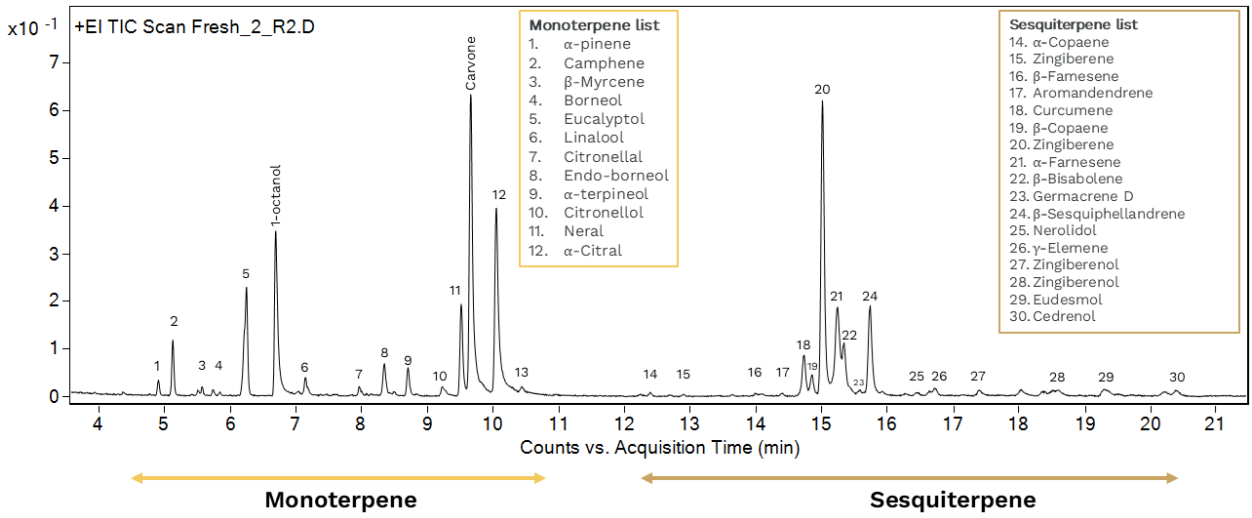

Figure 4 *Total Ion Chromatogram of fresh ginger extract with a list of compounds found. The first 12 minutes show elution of the Monoterpene group of compounds, and the second 12 minutes show elution of the sesquiterpene group of compounds.*

During this study, 30 compounds present in the ginger were identified (See Supplementary Chapter C**)** in three different forms: fresh, paste, and powder, using gas chromatography-mass spectrometry (GC-MS) spectra generated from electron impact ionisation. The resulting mass spectra and fragmentation patterns were compared to the NIST mass spectral library for tentative identification. Compounds and their isomers with a 60% or greater combined probability match were considered likely hits. To ensure accurate identification of these compounds, they were further evaluated in subsequent sample runs, confirming their presence based on their characteristic fragmentation patterns and retention times.

To improve data quality, compounds in trace amounts (less than 1% of the total integrated area) were excluded from the analysis, as their low abundance hindered reliable quantification. The retention times of the identified compounds were consistent to within one decimal point in minutes. The relative abundance of each compound was calculated as a percentage of the total integrated area of all detected compounds after removing noise and excluding trace compounds.

A comparative analysis showed differences in the number of detected compound profiles of ginger powder, paste, and fresh ginger, highlighting the impact of processing and preservation on the chemical composition. Surprisingly, 24 confirmed compounds were detected in ginger powder compared to 16 confirmed detections in fresh ginger. The difference may arise due to better extraction or higher uniformity of the powder compared to the paste. The key compounds responsible for ginger's distinctive aroma – Zingiberene, β-Bisabolene, and β-Sesquiphellandrene – were detected in all three samples, and their relative

concentrations varied. Zingiberene was the most abundant compound across all samples, followed by β-Bisabolene and β-Sesquiphellandrene.

However, fresh ginger showed a higher proportion of more volatile compounds, such as Endo-borneol and Eucalyptol, compared to the powder and paste forms. Conversely, less volatile compounds had a higher percentage in processed ginger samples (powder and paste). This difference may result from losing volatile compounds during processing and storage.

For multivariable analysis, the separation pattern was observed in the PCA analysis, and the difference was observed in Pairwise PERMANOVA results, as shown in **Figure 5** and **Table 3**.

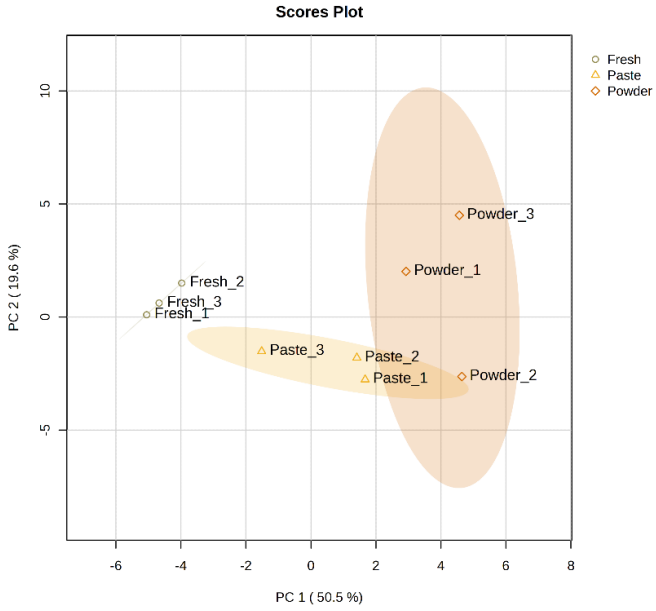

Figure 5 *PCA analysis of the compound profiles between fresh, paste, and powdered ginger. The 95% confidence region was displayed in a circle. Differences were observed between the sample groups.*

In **Table 3,** the Pairwise PERMANOVA profile comparison between samples. The differences between fresh and the other two groups (paste and powdered) seem stronger (based on the R^2), while paste and powdered ginger are more similar.

Table 3 *Pairwise PERMANOVA profile comparison between samples*

Comparison	F.Model	R^2	p-value	Summary
Powder-Paste	4.00	0.4998	0.1	No significant difference
Powder-Fresh	15.0	0.7901	0.1	No significant difference
Paste-Fresh	23.10	0.8524	0.1	No significant difference

While there appear to be differences in the compound profiles between fresh, paste, and powdered ginger, none are statistically significant ($p > 0.05$). This could be due to a small sample size or high variability in the data, especially inhomogeneity in fresh samples.

3.4 Quantitative analysis

In **Table 4** Shows the amount of camphene in the sample, calculated as µg/g of sample. The average amount of camphene was 702.39 µg/g in powder, 398.64 µg/g in paste, and 89.97 µg/g in fresh ginger.

Table 4 *Concentration of Camphene (µg/g) in powder, paste, and fresh ginger sample*

Replicate	Camphene content in the sample (µg/g)		
	Powder	Paste	Fresh
Sample 1	712.06	388.68	59.97
Sample 2	729.67	402.36	140.3
Sample 3	665.44	404.88	69.58
Average	702.39	398.64	89.97
%RSD	4.73%	2.19%	48.79%

The ANOVA analysis was performed to compare the difference between the average content of camphene from 3 different ginger forms, and a very small p-value (< 0.05) was observed, as shown in Table 5.

Table 5 *ANOVA analysis for average camphene concentration comparison between ginger forms*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	562609.22	2	281304.61	271.84	1.30E-06	5.14
Within Groups	6208.88	6	1034.81			
Total	568818.11	8				

This indicates that the null hypothesis can be rejected, concluding that the average camphene content from the different ginger forms is unequal. However, ANOVA cannot tell which groups differ, and Tukey's post-hoc analysis was performed to identify the differences among the sample groups.

Table 6 Tukey's post-hoc analysis of camphene content in the different samples.

Comparison	Abs mean diff	Diff-crit	Summary
Powder-Paste	303.75	85.47	Significant different
Powder-Fresh	612.43		Significant different
Paste-Fresh	308.68		Significant different

The post hoc analysis data in Table 6, with an absolute mean difference between all samples of more than an Honestly Significant Difference, suggests that the average camphene content between all groups is different. This implies that ginger powder has the highest amount of camphene, and fresh ginger has the lowest amount. However, the amount of camphene might depend on the water content in the sample, and the water content should be measured and corrected to obtain more accurate results.

4. Conclusion

This project aimed to investigate the compound profiles of fresh ginger, ginger paste, and ginger powder to understand how processing affects the concentration of key compounds, particularly camphene. Using GC-MS with EI ionisation, 30 compounds were identified and categorised into monoterpenes, dialkyl ketones, and sesquiterpenes. Fresh ginger exhibited a higher concentration of volatile monoterpenes, while processed forms (paste and powder) showed a greater abundance of less volatile sesquiterpenes. This shift likely results from the mechanical and thermal stresses ginger undergoes during processing and storage.

Quantitative analysis revealed significant variations in camphene content across the three forms, with powdered ginger containing the highest concentration, followed by paste and then fresh ginger. ANOVA and Tukey's post-hoc test confirmed that these differences were statistically significant. These findings suggest that to achieve comparable levels of camphene intake, the consumption of fresh ginger and ginger paste should be adjusted accordingly. Based on the recommended daily intake of 2 to 4 grams of powdered ginger [22], estimated equivalent amounts would be 15 to 30 grams of fresh ginger and 3 to 7 grams of ginger paste.

In conclusion, this project meets the objectives of profiling and quantifying the key compounds in essential oil from different forms of ginger samples. The results showed that the different forms of ginger hold different profiles, and the main compound profiling strategy using GC-MS in combination with quantitative and multivariable analysis can be further applied to investigate the profile compound from ginger in other factors, for example, origins, harvesting time, seasonal variation, storage, or manufacturing process.

For further improvement, the essential oil of ginger should be extracted using a more selective apparatus, such as the Clevenger apparatus, to obtain a higher-purity essential oil. The essential oil can be extracted in a larger batch to achieve a higher yield, and replicate analysis can begin with liquid extraction from the same batch of essential oil, thereby increasing the homogeneity of the sample and obtaining more accurate and precise amounts of the compound.

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6. Supplementary Chapter

Supplement Chapter A: Experiment setup

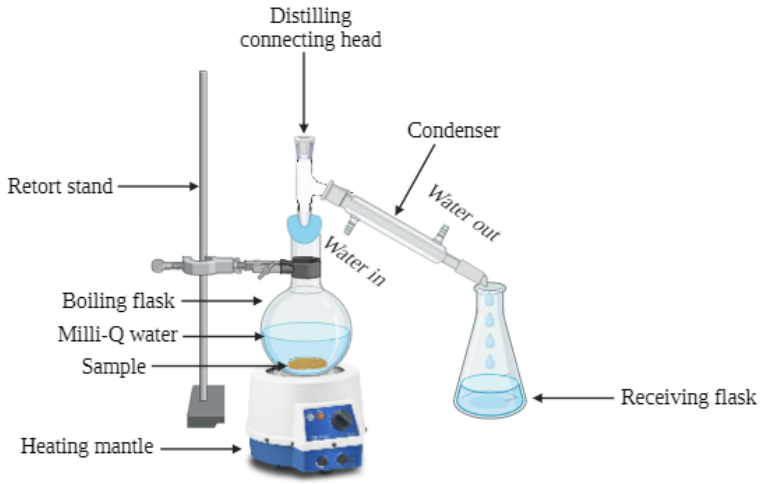

Figure 6 Distillation Apparatus Setup

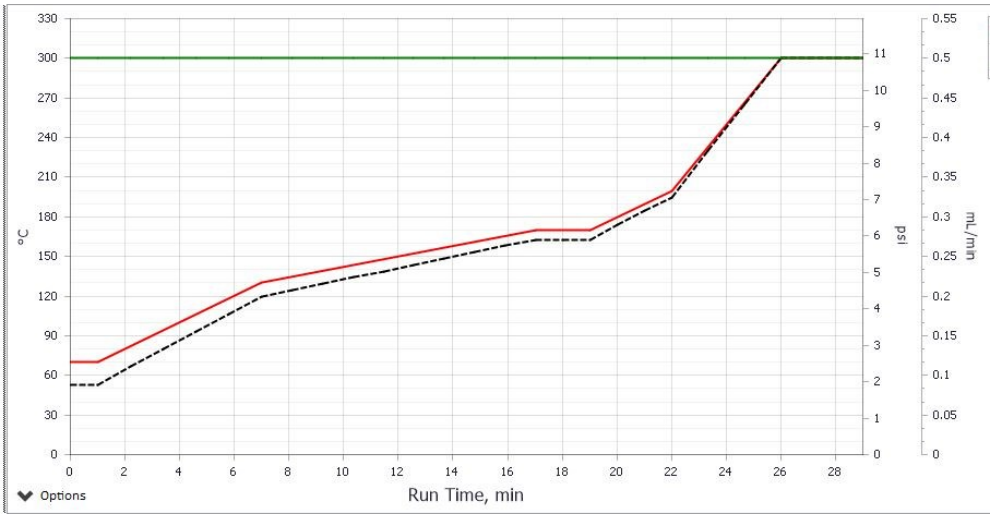

Figure 7 Temperature Program for GC-MS set-up

Supplementary Chapter B: Total Ion Chromatogram of the standard mixture, blank and sample

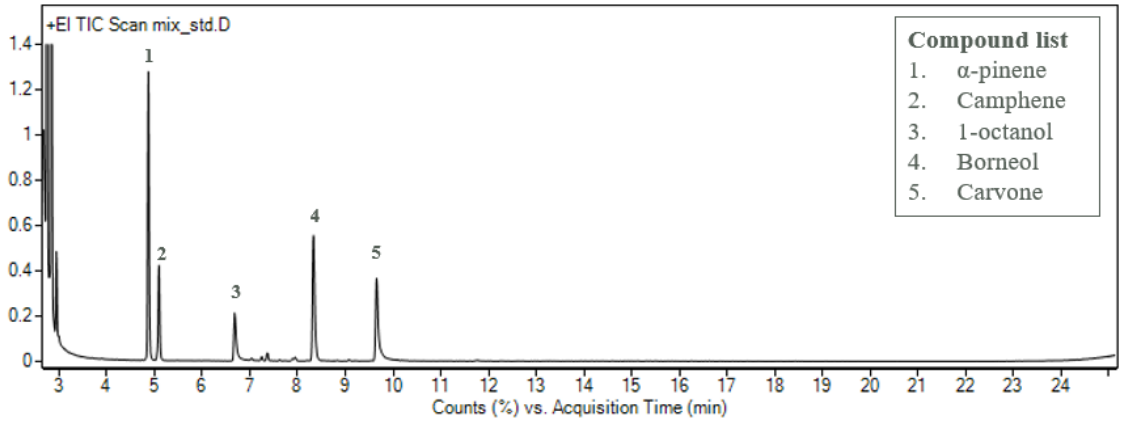

Figure 8 Total Ion Chromatogram of the standard mixture.

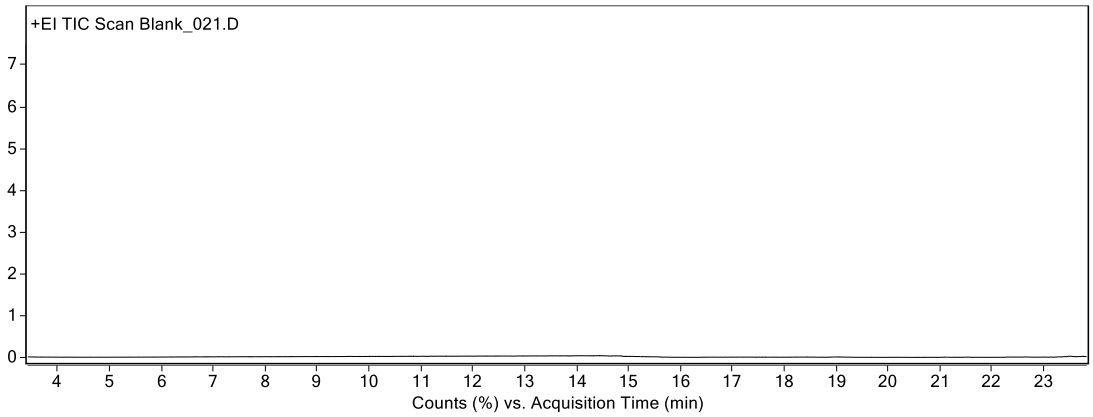

Figure 9 Total Ion Chromatogram of the blank solution

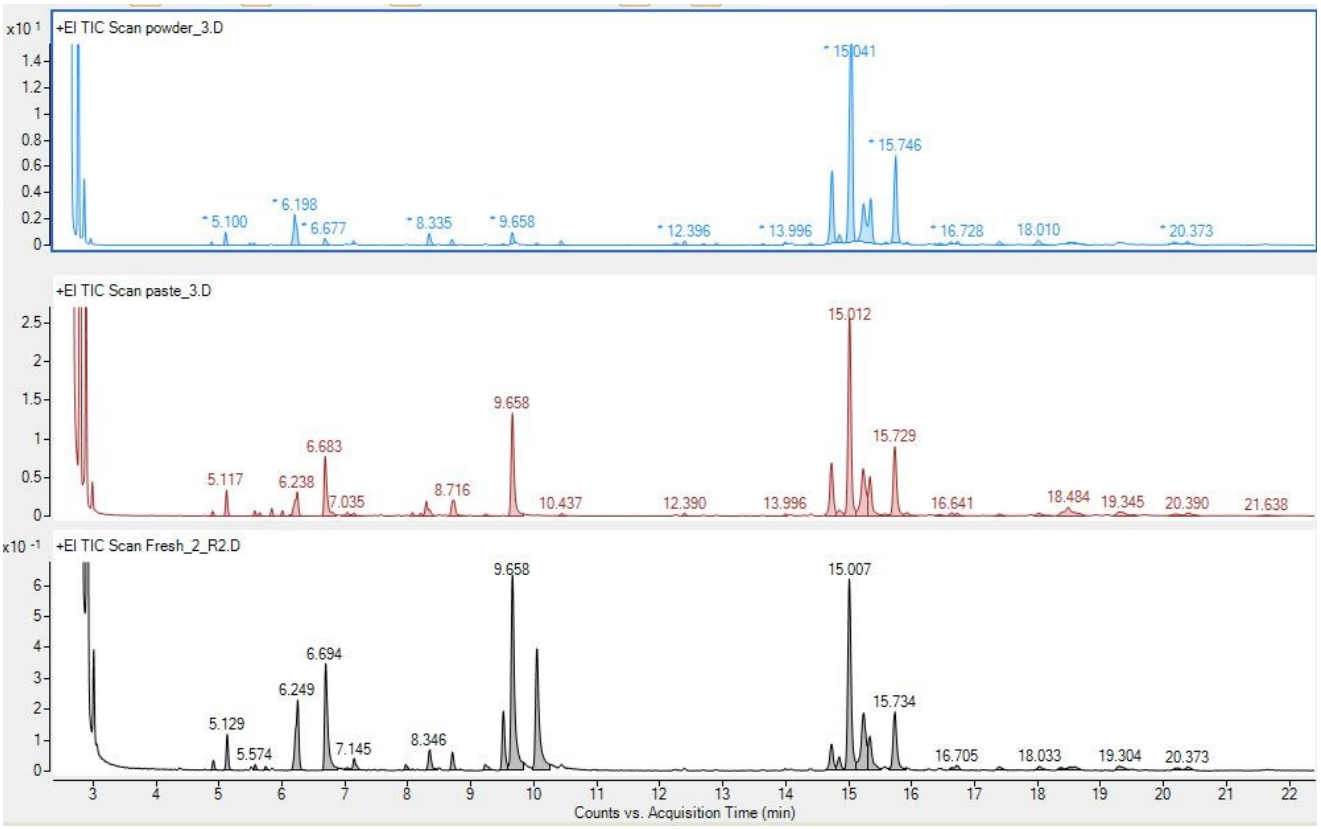

Figure 10 *Total Ion Chromatogram of the powdered ginger (blue), paste ginger (red), and Fresh ginger (black). The difference in compound profile was observed.*

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Supplementary Chapter C: Compound identification and profiling

Table 7 *Identified compounds in powder, paste, and fresh ginger sample and their respective area*

Peak	RT (min)	Compounds	Area %		
			Powder	Paste	Fresh
1	4.9	α-Pinene	0.32%	0.49%	0.76%
2	5.1	Camphene	1.36%	2.74%	2.86%
3	5.6	β-Myrcene	0.21%	0.55%	0.41%
4	5.8	α-Phellandrene		0.78%	
5	6.2	Eucalyptol	5.38%	4.98%	8.93%
6	7.1	Linalool	0.31%	0.54%	1.52%
7	8.0	Citronellal			0.62%
8	8.3	Endo-Borneol	1.85%	0.40%	2.48%
9	8.7	α-Terpineol	0.81%	3.59%	1.97%
10	9.2	Citronellol		0.38%	
11	9.5	Neral	0.23%		6.30%
12	10.0	α-Citral	0.28%		18.52%
13	10.4	2-Undecanone	0.63%	0.46%	
14	12.4	α-Copaene	0.63%	0.46%	
15	12.9	Zingiberene	0.30%		
16	14.0	β-Famesene	0.36%	0.36%	
17	14.4	Aromandendrene	0.35%		
18	14.7	Curcumene	12.03%	10.41%	3.64%
19	14.9	β-Copaene	1.19%		1.88%
20	15.0	Zingiberene	40.92%	34.78%	24.81%
21	15.2	α-Farnesene		12.60%	11.09%
22	15.3	β-Bisabolene	16.63%	7.99%	5.40%
23	15.6	Germacrene D		0.58%	
24	15.7	β-Sesquiphellandrene	14.07%	13.61%	8.78%
25	16.6	Nerolidol	0.78%	0.64%	
26	16.7	γ-Elemene	0.48%		
27	18.0	Zingiberenol		0.86%	
28	18.5	Zingiberenol	0.24%		
29	19.3	Eudesmol		1.85%	
30	20.4	Cedrenol	0.64%	0.97%	

*Yellow label: Monoterpene, Blue label: Dialkyl ketone and orange label: Sesquiterpene

Table 8 *The ratio of each compound group and related health benefits*

Compounds	Powder	Paste	Fresh	Health benefits
Monoterpene	10.75%	14.45%	44.37%	Analgesic and antinociceptive [11]
				Anti-inflammatory [12]
				Antiviral [13]
				Antibacterial [14]
				Anti-fungal [15]
Sesquiterpene	88.62%	85.11%	55.60%	Antihelminthic[16]
				Antiulcer [17]
				Hepatocurative [18]
				Anti-inflammatory [19]
				Antibacterial [20]
Dialkyl ketone (DAK)	0.63%	0.46%	0.00%	The effects of DAKs on human health remain unclear [21]