Chemical Composition of Essential Oil from *Alpinia zerumbet* Fruits

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Abstract:
Alpinia zerumbet, commonly known as shell ginger, is a perennial plant that belongs to the *Zingiberaceae* family. Its various parts, including fruits and seeds, are used in traditional medicines, each of which exhibits a different therapeutic efficacy. In this study, we employed gas chromatography/mass spectrometry to investigate the chemical composition of essential oils extracted from shell ginger fruits, seeds, and pericarps. Fifty-four metabolites, including monoterpenoids, sesquiterpenoids, diterpenoids, and aromatic compounds in the essential oils were either annotated or identified. Among the metabolites, oxygenated sesquiterpenes were identified as the major constituents of the essential oils extracted from the fruits, seeds, and pericarps. The diterpenoids and oxygenated monoterpenes in the fruit oil were derived from the seeds and pericarps, respectively. The predominant constituent of fruit and seed oils was *α*-cadinol. In the pericarp oil, humulene epoxide II was predominant. Furthermore, quantitative analysis of the *n*-hexane extracts revealed that the (*E*)-labda-8(17), 12-diene-15,16-dial and 7,8-dihydro-5,6-dehydrokawain in the fruits are derived from the seeds and pericarps, respectively. These results demonstrate the difference between the chemical compositions of the seeds and the pericarps of shell ginger and reveal that fruits contain phytochemicals derived from the seeds and pericarps, providing understanding of the differences in the medicinal properties of *A. zerumbet* fruits and seeds.

Keywords: *Alpinia zerumbet*, *shell ginger*, *fruits*, *essential oil*, *GC/MS*

1. Introduction

Alpinia zerumbet (Pers.) B.L.Burtt & R.M.Sm., commonly known as shell ginger, is a perennial plant of the *Zingiberaceae* family that is widely distributed in South America, Asia, and Oceania

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(Paulino et al. 2019). Its parts have been used in traditional medicines owing to their therapeutic efficacy (Wei et al. 2020). In Brazil, the plant is called *Colônia* (Victório 2011), and tea made from the leaves have been used as an anti-hypertensive and diuretic medicine (da Cruz et al. 2020; Mpalantinos et al. 1998). In Japan, where it is known as *Gettou* (Okazaki et al. 2023), the seeds were used as aromatic stomachics (Itokawa et al. 1980). In China, the rhizomes and mature fruits of *A. zerumbet* (*Yàn shān jiāng* in Chinese) have been used in medicines (Hsu et al. 1994; Xiao et al. 2024). The Miao people of Guizhou Province have used the mature fruits of the plant to treat cardiovascular diseases (Ji et al. 2019).

Essential oil is a key bioactive ingredient of *A. zerumbet* fruits and has pharmacological properties, including endothelial protective, anti-inflammatory, analgesic, anti-atherosclerotic, antimicrobial, and neuroprotective activities (Ji et al. 2019; Nishidono and Tanaka 2024). Previous studies have revealed the chemical composition of essential oils extracted from shell ginger fruits (Feng et al. 2021; Hou et al. 2023; Tao et al. 2013). Tao et al. (2013) identified 58 metabolites in the essential oil extracted from shell ginger fruits collected from Zhenfeng County, Guizhou Province, China, among which *β*-phellandrene (16.4%), *β*-pinene (15.1%), 1,8-cineole (11.0%), and camphene (10.1%) were predominant. Feng et al. (2021) identified 38 metabolites in the essential oil extracted from shell ginger fruits collected from Guizhou Province, China, and revealed that 1,8-cineole (8.8%) is the major constituent. Hou et al. (2023) identified 26 sesquiterpenoids (sesquiterpenes and oxygenated sesquiterpenes) and 27 monoterpenoids (monoterpenes and oxygenated monoterpenes) in the essential oil prepared from shell ginger fruits purchased from Yulin, Guangxi Province, China, and reported that *β*-pinene (15.1%) is the major volatile constituent. Furthermore, the ethyl acetate extract of *A. zerumbet* fruits, which is rich in 7,8-dihydro-5,6-dehydrokawain, has an anti-hypertensive effect (Xiao et al. 2024), and the petroleum ether extract contains a high proportion of phenolic compounds and exhibits antimicrobial activities (Hou et al. 2023).

Previous studies have revealed the chemical composition of shell ginger fruits; however, the distribution and concentration of phytochemicals in different parts of the fruits, including the seeds and pericarps, remain unclear. Investigating these aspects could contribute to the scientific validation of the traditional understanding that *A. zerumbet* fruits and seeds possess different medicinal properties. Therefore, herein, we prepared essential oils and *n*-hexane extracts from shell ginger fruits, seeds, and pericarps and investigated their chemical compositions using gas chromatography/mass spectrometry (GC/MS).

2. Experimental

(1) General Experimental Procedures

Nuclear magnetic resonance (NMR) spectra were recorded using a JNM-ECZ500R spectrometer (JEOL Ltd., Tokyo, Japan) with tetramethylsilane as the internal standard. GC/MS was performed using a GCMS-QP2010 equipped with an AOC-20i auto-injector (Shimadzu Corporation, Kyoto, Japan). Medium-pressure liquid chromatography (MPLC) was performed using a Yamazen pump 540 (Yamazen Corporation, Osaka, Japan), and thin-layer chromatography was performed using precoated silica gel 60 F_{254} or RP-18 F_{254} plates (Merck, Darmstadt, Germany).

(2) Plant Materials

Dried mature fruits of *Alpinia zerumbet* (Pers.) B.L.Burtt & R.M.Sm. (*Zingiberaceae*) were

purchased from Gettou farm (Okinawa, Japan). Samples were identified by DNA barcoding of the gene regions, internal transcribed spacer 1 and *trn*H–*psb*A (Nishidono et al. 2023). The fruits were manually shucked and separated into seeds, pericarps, and placentas (Figure 1). Rhizomes of *Zingiber officinale* Roscoe (*Zingiberaceae*) for isolating authentic compound were purchased from Kimura farm (Aichi, Japan). Voucher specimens (RIN:210301 of shell ginger and RIN-170101 of ginger) were deposited at the Museum of Materia Medica, College of Pharmaceutical Sciences, Ritsumeikan University, Shiga, Japan.

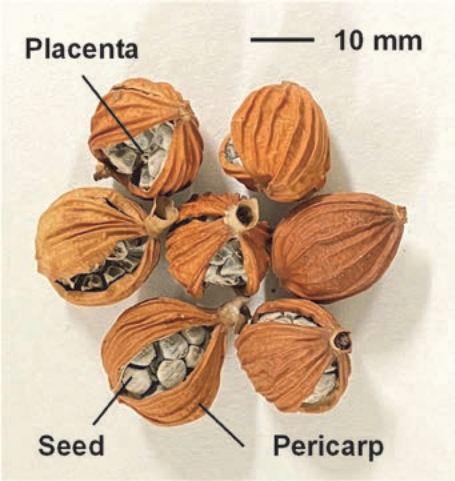

Figure 1. Photo of *Alpinia zerumbet* Fruits

(3) Preparation of Standards

Extraction using acetone was applied to 2 kg of ginger to yield 45.4 g of extract. The extract was suspended in water, and extraction with ethyl acetate was applied to obtain the ethyl-acetate-soluble fraction (14.8 g). Next, 12.0 g of the ethyl-acetate-soluble fraction was subjected to silica gel column chromatography using a solvent gradient elution of *n*-hexane−ethyl acetate mixtures at ratios of 8:2 to 0:1 (v/v) to yield 13 fractions (Nishidono et al. 2020b). Fraction 3 (0.4 g) was further separated by MPLC with an octadecylsilyl column (95% MeOH) to obtain (*E*)-labda-8(17),12-diene-15,16-dial (82.7 mg). The compound was identified by comparing its NMR spectra with the previously reported data (Morita and Itokawa 1988). The isolation of 7,8-dihydro-5,6-dehydrokawain and (*E*)-15,16-dinorlabda-8(17),11-dien-13-one was described in our previous studies (Nishidono et al. 2020a; Saifudin et al. 2013).

(4) Sample Preparation

The fruits, seeds, and pericarps were ground into powder using a Tube Mill 100 control (IKA, Staufen, Germany). Samples (50 g of fruits, 50 g of seeds, and 20 g of pericarps) mixed with distilled water (sample:water ratio = 1:10) were hydrodistilled for 4 h to obtain essential oils. Next, 1 μL of the obtained essential oils was diluted with 1 mL of *n*-hexane, and then, 1 μL of the diluted oil was injected into the GCMS-QP2010 system. Furthermore, extraction was performed on 30 mg of fruits, seeds, and pericarps using *n*-hexane (3 mL) at room temperature for 24 h. The extract was filtered through a 0.45-μm millipore filter (Advantec, Tokyo, Japan), and 1 μL of the filtered extract was injected into the GCMS-QP2010 system.

(5) GC/MS

The GC parameters included an injector temperature of 270°C and a carrier gas (helium) with a flow rate of 1 mL/min. The compounds were separated using a DB-5ms capillary column (30 m × 0.25 mm i.d., film thickness 0.25 μm, Agilent Technologies, Santa Clara, CA, USA). For the essential oil analysis, the initial oven temperature was 50°C, the initial hold time was 3 min, the temperature ramp-up rates were 3°C/min from 50°C to 200°C and 10°C/min from 200°C to 300°C, and the final hold time was 5 min. For the *n*-hexane extract analysis, the initial oven temperature was 50°C, the initial hold time was 3 min, the temperature ramp-up rate was 10°C/min, and the final temperature and hold times were 300°C and 5 min, respectively. For the MS conditions, the ionization mode was electron ionization (EI), the ionization current and voltage were 60 μA and 70 eV, respectively, and the ion source and interface temperature were 270°C.

Eluted metabolites were annotated via library search using the NIST08 and Wiley 9 databases and verified by comparing the retention index (RI) and EI-MS spectrum with those in the literature. Some eluted metabolites were identified using standards. The RI value for each compound was calculated using an alkane mixture (GL Sciences, Tokyo, Japan) as a reference. Metabolite annotation and identification were performed according to the confidence levels of the Metabolomics Standards Initiative (MSI) (Sumner et al. 2007), which include the following four levels: MSI level 1, identified compounds; MSI level 2, putatively annotated compounds; MSI level 3, putatively characterized compound classes; MSI level 4, unknown compounds.

The peaks in the total ion current (TIC) chromatograms were detected (slope = 10,000 min^{-1}; width = 3 s; no smoothing), and their absolute peak areas were obtained using the Shimadzu GCMS Solution software (Shimadzu Corporation). Among them, peaks with absolute peak areas exceeding 1,000,000 were considered the major metabolites.

3. Results and Discussion

(1) Chemical Composition of the Essential Oils

The dried mature fruits were manually shucked and separated into seeds, pericarps, and placentas. Because the fruits were mainly composed of seeds (76.7%, w/w) and pericarps (22.5%, w/w), with the placentas constituting only 0.8% (w/w), the placentas were not considered in further studies. Essential oils were prepared from the fruits, seeds, and pericarps by hydrodistillation and analyzed by GC/MS. The yield of essential oils from the fruits, seeds, and pericarps was less than 0.2%, 0.2%, and 0.5% (v/w), respectively. Figure 2 shows the GC/MS TIC chromatograms of the samples. Table 1 lists the major metabolites annotated or identified in the essential oils and their contents (%), and Figure 3 shows their chemical structures. These metabolites represent 90.1%, 94.0%, and 94.5% of the essential oils prepared from the shell ginger fruits, seeds, and pericarps, respectively. The annotations of peaks 1–32, 34–37, and 39–46 were obtained from library searches (NIST and Wiley Mass Spectral libraries) and were verified by comparing their RI values and EI-MS spectra with those given in the Adams database (Adams 2007). Peaks 49 and 52 were annotated as *γ*-bicyclohomofarnesal and (*E*)-15,16-dinorlabda-8(17),12-dien-14-al, respectively, based on previous studies (Urbanova et al. 2024; Weyerstahl et al. 1995). Peaks 51, 53, and 54 were identified as (*E*)-15,16-dinorlabda-8(17),11-dien-13-one, tricosane, and (*E*)-labda-8(17),12-diene-15,16-dial, respectively, based on the authentic compound. Peaks 33, 38, 47, 48, and 50 could not be identified (Figure 4). Peaks 33, 38, and 48 were tentatively annotated as oxygenated sesquiterpenes based on the peak at 220 (*m*/*z*), and peak 47 was

tentatively annotated as an oxygenated sesquiterpene based on the peak at 218 (*m*/*z*). Peak 50 was tentatively annotated as norlabdane diterpene based on the peak at 246 (*m*/*z*) and previous report (Weyerstahl et al. 1995). Based on these results, peaks 51, 53, and 54 were identified at MSI level 1, peaks 1–32, 34–37, 39–46, 49, and 52 were annotated at MSI level 2, and peaks 33, 38, 47, 48, and 50 were tentatively annotated at MSI level 3.

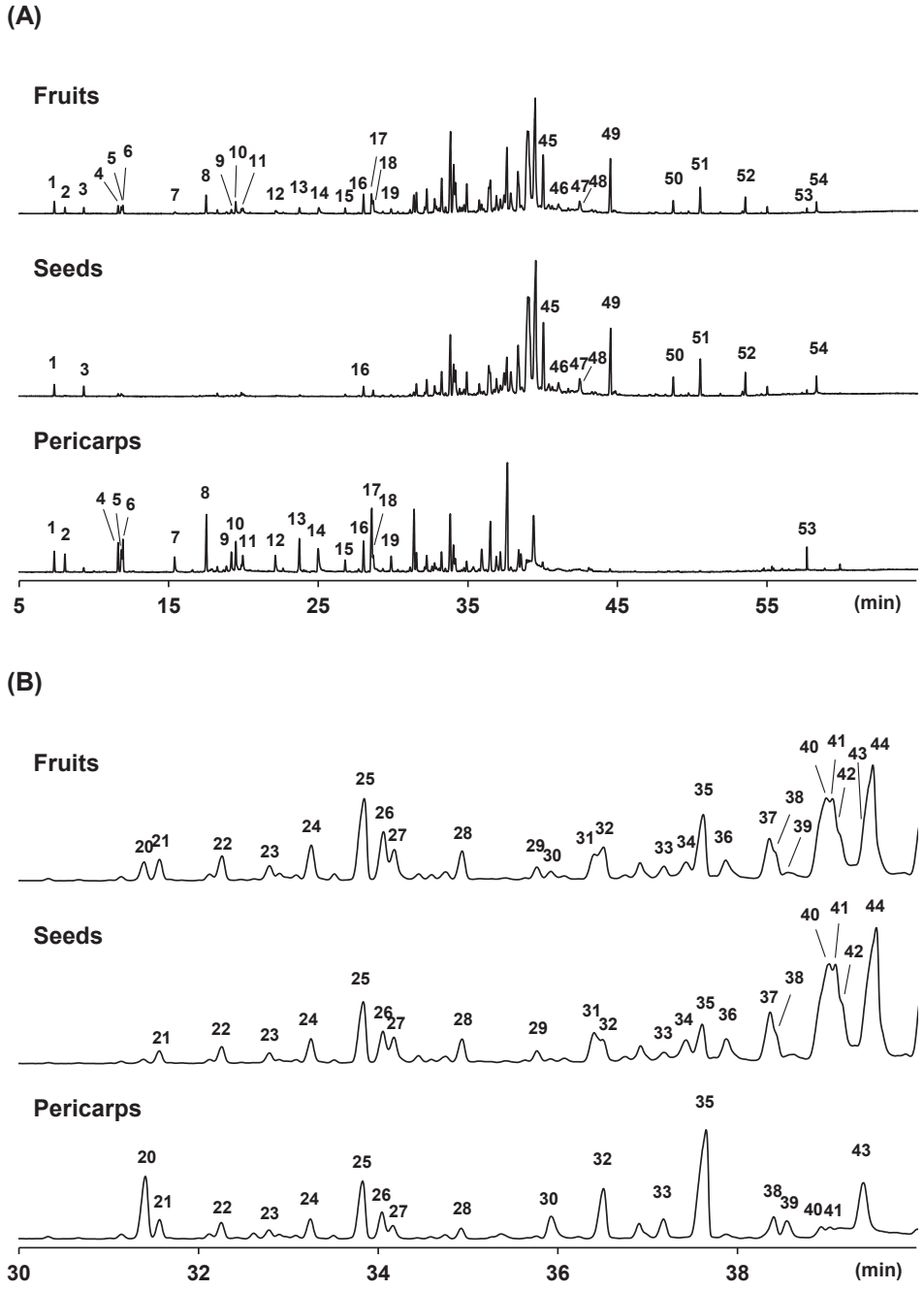

Figure 2. Gas Chromatography/Mass Spectrometry Total Ion Current (TIC) Chromatograms
(A) TIC chromatograms of essential oils extracted from the fruits, seeds, and pericarps of shell ginger. (B) Enlarged TIC chromatograms (retention times from 30 to 40 min). The numbers in the figure indicate the compounds in Table 1 and Figure 3.

Table 1. Composition of Essential Oils of the Fruits, Seeds, and Pericarps of *A. zerumbet*

Peak No.	RT (min)	RI	Compounds	Relative contents (%)		
				Fruits	Seeds	Pericarps
1	7.36	936	*α*-Pinene	0.6	0.6	1.3
2	8.07	952	Camphene			1.1
3	9.33	978	*β*-Pinene		0.5	
4	11.62	1025	*p*-Cymene			2.1
5	11.82	1030	Limonene			1.8
6	11.94	1032	1,8-Cineol			2.3
7	15.40	1100	Linalool			1.2
8	17.50	1146	Camphor	1.0		4.3
9	19.19	1180	Terpinen-4-ol			1.7
10	19.48	1185	Cryptone	0.7		2.7
11	19.96	1194	*α*-Terpineol			1.4
12	22.13	1242	Cuminaldehyde			1.5
13	23.74	1276	*p*-Menth-1-en-7-al			2.8
14	25.04	1303	Carvacrol	0.6		3.0
15	26.80	1344	*α*-Cubebene			0.9
16	28.03	1372	*α*-Copaene	1.2	0.6	2.5
17	28.56	1383	(*E*)-Cinnamic acid methyl ester	1.3		6.0
18	28.67	1386	*β*-Elemene	0.8		1.1
19	29.87	1413	*β*-Caryophyllene			1.3
20	31.39	1450	*α*-Humulene	1.2		5.5
21	31.56	1455	*allo*-Aromadendrene	1.4	0.8	1.4
22	32.26	1471	*γ*-Muurolene	1.6	1.1	1.3
23	32.79	1483	*β*-Selinene	1.0	0.7	0.8
24	33.25	1494	*α*-Muurolene	2.6	1.7	1.7
25	33.84	1508	*γ*-Cadinene	6.4	4.6	5.2
26	34.06	1514	*δ*-Cadinene	3.7	2.4	2.3
27	34.18	1517	*cis*-Calamenene	2.2	1.8	1.1
28	34.93	1537	*α*-Calacorene	1.9	1.6	0.8
29	35.77	1558	*β*-Calacorene	0.9	0.8	
30	35.92	1562	(*E*)-Nerolidol	0.6		2.4
31	36.41	1574	Spathulenol	1.8	2.8	
32	36.51	1576	Caryophyllene oxide	2.6	1.3	4.9
33	37.18	1592	Oxygenated sesquiterpene	1.1	0.9	1.9
34	37.43	1598	Ledol	1.7	2.3	
35	37.62	1603	Humulene epoxide II	5.3	3.0	12.7
36	37.87	1610	1,10-Di-*epi*-Cubenol	2.1	2.4	
37	38.35	1624	1-*epi*-Cubenol	3.2	4.0	
38	38.40	1625	Oxygenated sesquiterpene	0.9	1.0	2.1
39	38.55	1629	*γ*-Eudesmol			1.7
40	38.93	1639	*epi*-*α*-Cadinol	9.0	12.7	0.9
41	39.03	1642	*epi*-*α*-Muurolol	5.1	5.7	0.9
42	39.16	1645	*δ*-Cadinol	2.5	3.4	
43	39.40	1652	*β*-Eudesmol			6.9
44	39.51	1654	*α*-Cadinol	12.2	18.0	
45	40.04	1668	Cadalene	4.1	6.0	
46	41.06	1695	4-Isopropyl-6-methyl-1-tetralone	0.5	0.7	
47	42.47	1735	Oxygenated sesquiterpene	0.6	1.1	
48	42.53	1736	Oxygenated sesquiterpene		0.7	
49	44.53	1791	*γ*-Bicyclohomofarnesal	4.0	5.3	
50	48.73	1915	Norlabdane diterpene	0.7	1.1	
51	50.54	1970	(*E*)-15,16-Dinorlabda-8(17),11-dien-13-one	1.7	2.5	
52	53.56	2071	(*E*)-15,16-Dinorlabda-8(17),12-dien-14-al	0.9	1.3	
53	57.68	2300	Tricosane			0.9
54	58.31	2351	(*E*)-Labda-8(17),12-diene-15,16-dial	0.5	0.8	

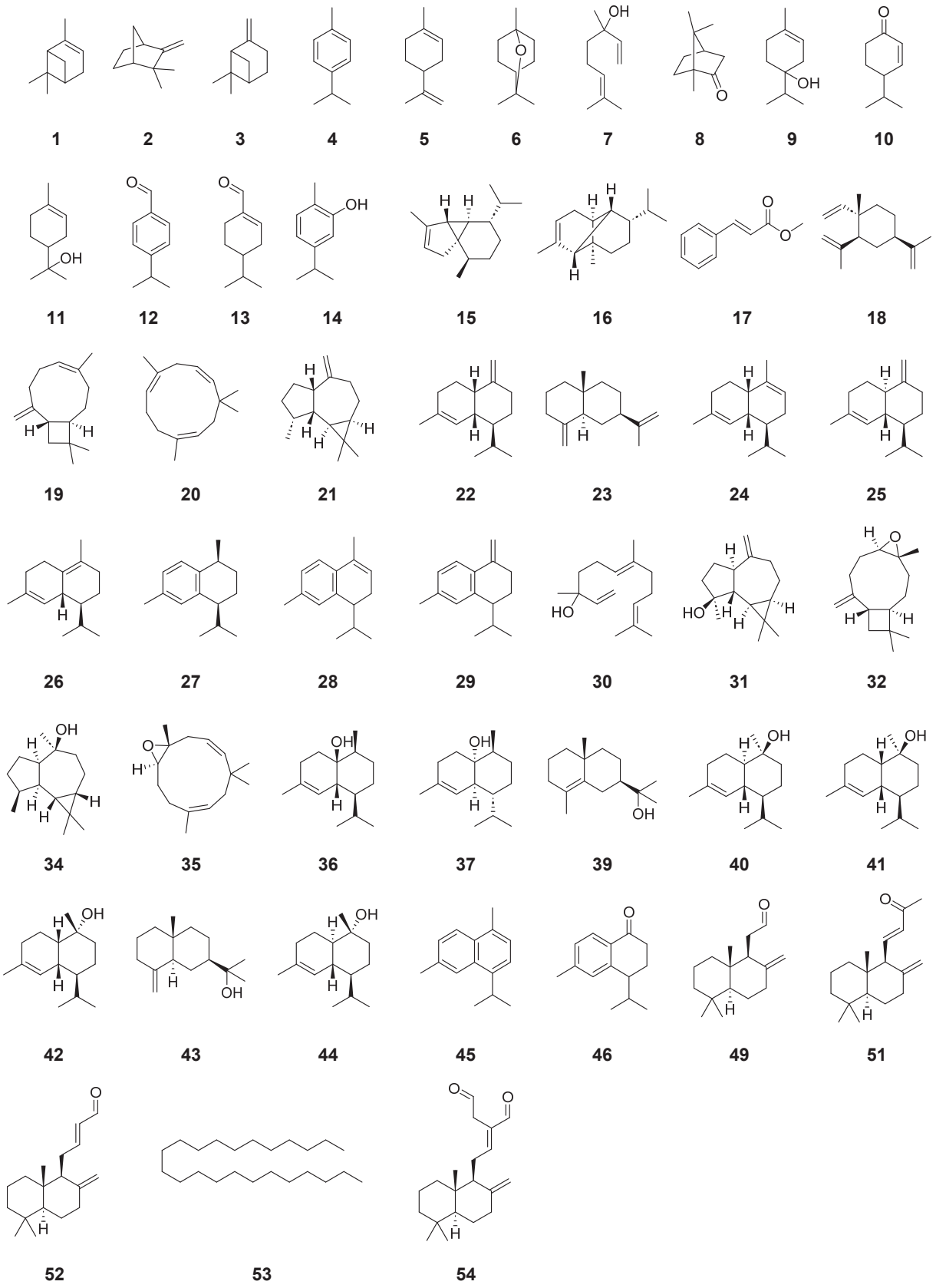

Figure 3. Chemical Structures of the Annotated or Identified Metabolites

The absolute chemistry of each compound remains to be clarified.

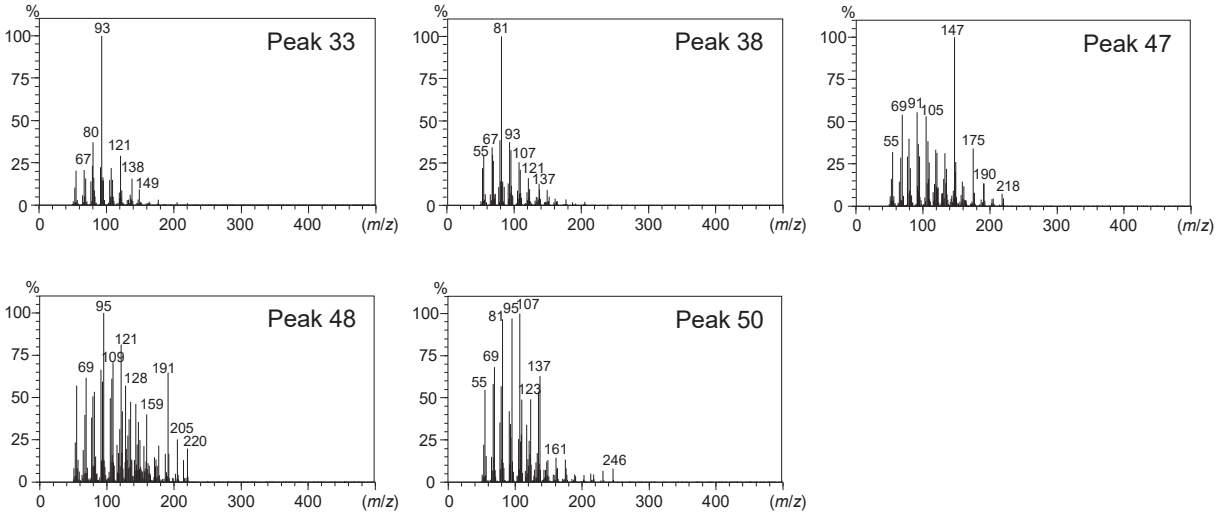

Figure 4. Electron Ionization Mass Spectrometry Spectra of Unidentified Peaks

The essential oil extracted from the shell ginger fruits mainly contained sesquiterpenoids, including *α*-cadinol (12.2%), *epi*-*α*-cadinol (9.0%), *γ*-cadinene (6.4%), humulene epoxide II (5.3%), and *epi*-*α*-muurolol (5.1%) (Table 1). Among them, *α*-cadinol, *epi*-*α*-cadinol, and *epi*-*α*-muurolol were mainly derived from the seeds, and humulene epoxide II was mainly from pericarps. *γ*-Cadinene was derived from both the seeds and pericarps. These results differ from those reported for shell ginger fruits collected in China, in which monoterpenoids are predominant (Feng et al. 2021; Hou et al. 2023; Tao et al. 2013). In the seed oil, *α*-cadinol (18.0%), *epi*-*α*-cadinol (12.7%), cadalene (6.0%), *epi*-*α*-muurolol (5.7%), and *γ*-bicyclohomofarnesal (5.3%) were the major constituents (Table 1). This is consistent with a previous report (Elzaawely et al. 2007) in which *α*-cadinol (oxygenated sesquiterpene) was identified as the most abundant volatile constituent (13.5%) of the seed oil extracted from shell ginger cultivated in Japan. However, several studies have shown that monoterpenoids are the major volatile constituents of seed oils extracted from shell ginger from Taiwan (Ho 2010; Lin et al. 2008). Therefore, the chemical composition of essential oils from the shell ginger fruits and seeds may depend on the location where the plant is grown. To date, only a few studies have analyzed the essential oils extracted from the seeds and fruits of shell ginger (Elzaawely et al. 2007; Feng et al. 2021; Ho 2010; Hou et al. 2023; Lin et al. 2008; Tao et al. 2013). Therefore, there is a need for further research to confirm the compositions of the essential oils and determine their variations with plant locations.

The essential oil from the pericarps was dominated by humulene epoxide II (12.7%), followed by *β*-eudesmol (6.9%), (*E*)-cinnamic acid methyl ester (6.0%), *α*-humulene (5.5%), and *γ*-cadinene (5.2%) (Table 1). To the best of our knowledge, this is the first report that describes the chemical composition of essential oils of *A. zerumbet* pericarps.

Figure 5 shows the chemical classes of the volatiles and their relative contents in the essential oils. The essential oil from the fruits mainly contains monoterpenoids, sesquiterpenoids, diterpenoids, and aromatic compounds. Among them, oxygenated sesquiterpenes were predominant, and diterpenoids and oxygenated monoterpenes were derived from the seeds and pericarps, respectively. A previous study revealed that most essential oils prepared from shell ginger leaves, rhizomes, and flowers are rich in oxygenated monoterpenes (1,8-cineole and terpinen-4-ol) (Nishidono and Tanaka

2024). The chemical composition of essential oils prepared from the fruits and seeds mainly contains oxygenated sesquiterpenes, which differ from those extracted from the leaves, rhizomes, and flowers.

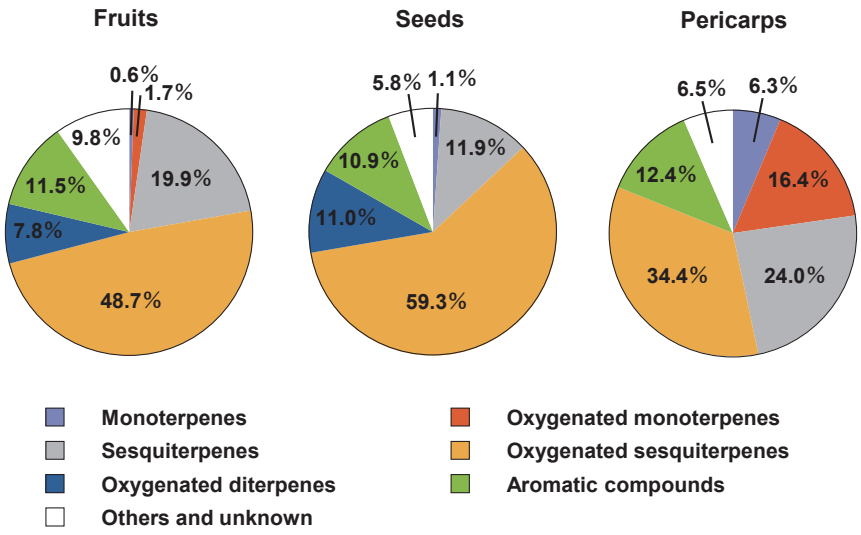

Figure 5. Chemical Classes of the Volatiles and their Relative Contents (%) in the Essential Oils from the Fruits, Seeds, and Pericarps of Shell Ginger

The bioactivities of essential oils prepared from shell ginger fruits and seeds are shown in Table 2. The pericarps are included in the fruits but not in the seeds. Therefore, the difference in clinical efficacy between the whole fruits, including the seeds and pericarps, and the seeds alone of shell ginger may be because of the phytochemicals in the pericarps.

Table 2. Bioactivities of Fruit and Seed Essential Oils of Shell Ginger

Plant parts	Bioactivities	References
Fruits	Analgesic	(Xiao et al. 2018)
	Anti-atherosclerotic	(Wang et al. 2024)
	Anti-inflammatory	(Hou et al. 2023)
		(Xiao et al. 2018)
	Antimicrobial	(Hou et al. 2023)
	Endothelial protective	(Ji et al. 2019)
		(Shen et al. 2012)
		(Xiao et al. 2014)
		(Zhang et al. 2022)
		(Zhang et al. 2020)
	Neuroprotective	(Yang et al. 2020)
	Vasodilator	(Tao et al. 2013)
Seeds	Antimicrobial	(Ho 2010)
	Hypolipidemic	(Chuang et al. 2011)
		(Lin et al. 2008)
	Larvicidal	(Ho 2010)
	Tyrosinase inhibitory	(Ho 2010)

(2) Chemical Composition of the *n*-Hexane Extracts

Extraction was performed on shell ginger fruits, seeds, and pericarps using *n*-hexane, which efficiently extracts bioactive compounds from shell ginger plants (Nishidono and Tanaka 2024). The chemical compositions of the extracts were analyzed by GC/MS, and their TIC chromatograms are

shown in Figure 6A. The chemical compositions of the *n*-hexane extracts differ significantly from those of the essential oils. The TIC chromatograms of the *n*-hexane extract of the fruits show two major peaks (22.26 and 24.33 min), which originate from the pericarps and seeds, respectively. These peaks were identified based on standards. The retention time and EI-MS spectra of 7,8-dihydro-5,6-dehydrokawain and (*E*)-labda-8(17),12-diene-15,16-dial were matched with those of the peaks at 22.26 and 24.33 min, respectively (Figure 6B–D). These results show that 7,8-dihydro-5,6-dehydrokawain and (*E*)-labda-8(17),12-diene-15,16-dial can be extracted more efficiently from shell ginger fruits using *n*-hexane than through hydrodistillation.

Table 3 lists the metabolite contents of the samples. The fruits and pericarps contained 0.24% and 0.59% 7,8-dihydro-5,6-dehydrokawain, respectively. These results are consistent with a previous study, which reported that shell ginger pericarps contain 0.54% 7,8-dihydro-5,6-dehydrokawain (Rao

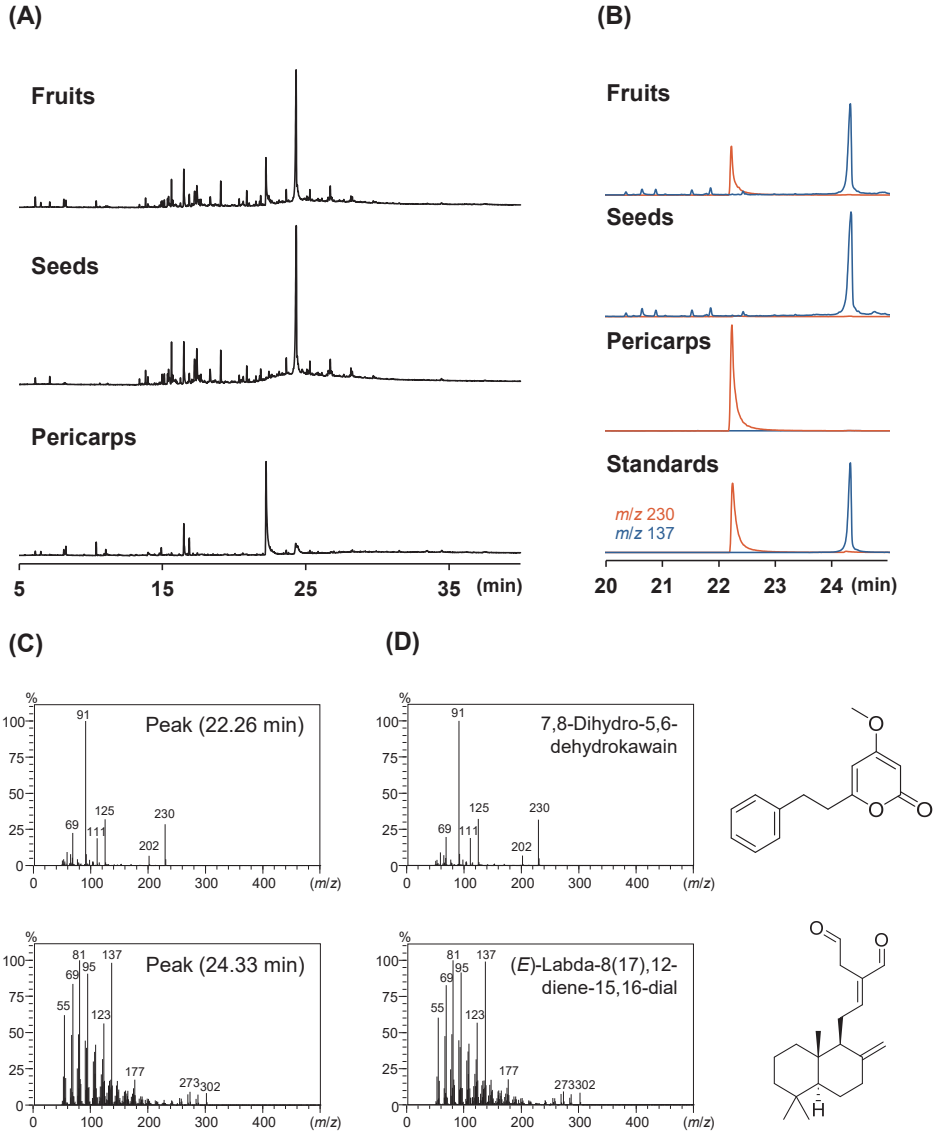

Figure 6. Identification of Two Major Peaks in the Total Ion Current (TIC) Chromatogram of the *n*-Hexane Extract of Shell Ginger Fruits

(A) TIC chromatograms of the *n*-hexane extracts of the fruits, seeds, and pericarps of shell ginger. (B) Extracted ion current chromatograms of the *n*-hexane extracts of the fruits, seeds, and pericarps of shell ginger and standards. (C) Electron Ionization Mass Spectrometry (EI-MS) Spectra of the two major peaks in the TIC chromatogram of the *n*-hexane extract of the shell ginger fruits. (D) EI-MS Spectra of the Standards.

et al. 2014). The (*E*)-labda-8(17),12-diene-15,16-dial contents in the fruits and seeds were 0.84% and 1.22%, respectively. Chompoo et al. (2011, 2012) also estimated the content of diterpene in shell ginger extracts but not in dried plants. Herein, we determined the content of (*E*)-labda-8(17),12-diene-15,16-dial in different plant parts of shell ginger for the first time. As listed in Table 3, 7,8-dihydro-5,6-dehydrokawain and (*E*)-labda-8(17),12-diene-15,16-dial in the fruit extracts were derived from the pericarps and seeds, respectively.

Table 3. Quantification of the Characterized Compounds (%) in the *n*-Hexane Extracts of Fruits, Seeds, and Pericarps of Shell Ginger

	Fruits	Seeds	Pericarps
7,8-Dihydro-5,6-dehydrokawain	0.24		0.59
(*E*)-Labda-8(17),12-diene-15,16-dial	0.84	1.22	

The bioactivities of these metabolites are listed in Table 4. These results demonstrate that the medicinal properties of (*E*)-labda-8(17),12-diene-15,16-dial are expected in shell ginger fruits and seeds, whereas those of 7,8-dihydro-5,6-dehydrokawain are expected in the fruits but not the seeds.

Table 4. Bioactivities of the Characterized Compounds

Compounds	Bioactivities	References
7,8-Dihydro-5,6-dehydrokawain	Antifungal	(Tawata et al. 1996)
	Antihypertensive	(Xiao et al. 2024)
	Anti-inflammatory	(Nishidono et al. 2020a)
	Anti-obesity	(Tu and Tawata 2014)
	Antiplatelet	(Teng et al. 1990)
	Antiulcer	(Hsu et al. 1994)
	HIV-1 integrase inhibitory	(Upadhyay et al. 2011)
	Neuraminidase inhibitory	(Upadhyay et al. 2011)
	Neuroprotective	(Rao et al. 2014)
(*E*)-Labda-8(17),12-diene-15,16-dial	*α*-Amylase inhibitory	(Ghosh and Rangan 2014)
	Anti-alopecia	(Taira et al. 2017)
	Antibacterial	(Ghosh et al. 2013)
	Anticancer	(Taira et al. 2017)
	Antifungal	(Morita and Itokawa 1988)
	Antiglycation	(Chompoo et al. 2011)
	Anti-hyperlipidemic	(Jalaja et al. 2021)
	Anti-inflammatory	(Chen et al. 2013)
		(Chen et al. 2017)
		(Hsiao et al. 2020)
		(Morikawa et al. 2002)
	Antimicrobial	(Tatsimo et al. 2005)
	Anti-Trypanosoma	(Igoli et al. 2012)
	Anti-tubercular	(Singh et al. 2010)
	Anti-proliferative	(Liu and Nair 2011)
	COX-2 inhibitory	(Liu and Nair 2011)
	Cytotoxicity	(Itokawa et al. 1988)
		(Malek et al. 2011)
		(Morita and Itokawa 1988)
	α-Glucosidase inhibitory	(Ghosh and Rangan 2015)
	β-Glucuronidase inhibitory	(Liew et al. 2020)
	Lipid peroxidation inhibitory	(Liu and Nair 2011)
	5-Lipoxygenase inhibitory	(Abe et al. 2006)
	Neuraminidase inhibitory	(Upadhyay et al. 2011)
	Pancreatic lipase inhibitory	(Jalaja et al. 2018)

4. Conclusion

In this study, we determined the chemical composition of essential oils prepared from the fruits, seeds, and pericarps of shell ginger using GC/MS. Fifty-four metabolites in the essential oils were annotated or identified, and oxygenated sesquiterpenes were identified as the major constituents of the essential oils. The presence of diterpenoids and oxygenated monoterpenes in the essential oil from the fruits is attributed to the seeds and pericarps, respectively. Among the volatile constituents, *α*-cadinol in the fruit and seed oils and humulene epoxide II in the pericarp oil were predominant, which differ from the results reported for the essential oils of shell ginger leaves, rhizomes, and flowers. Furthermore, analysis of the bioactive compounds in the *n*-hexane extracts revealed that 7,8-dihydro-5,6-dehydrokawain and (*E*)-labda-8(17),12-diene-15,16-dial present in the fruits are derived from the pericarps and seeds, respectively. These results demonstrate the differences in the chemical compositions of the seeds and pericarps of shell ginger and reveal that the fruits contain phytochemicals derived from the seeds and pericarps, providing valuable insights into the differences in the medicinal properties of *A. zerumbet* fruits and seeds.

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