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Research Article

Chemical Composition of Essential Oil from *Etlingera coccinea* (Blume) S. Sakai & Nagam in Kadamaian, Kota Belud, Sabah

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Abstract
Etlingera coccinea (Blume) S. Sakai & Nagam is a member of *Zingiberaceae* family. It is commonly known as 'Tuhau' in Sabah, Malaysia and consumed as a local delicacy and used as a traditional remedy for stomachache, food poisoning, and gastric problems. The plant has been reported to have bioactive properties such as anticancer, antioxidant and antibacterial. Due to the high demand for this bioactive compound in national and international markets, chemical profiling of leaves, stems and rhizomes from *E. coccinea* was carried out. Eight germplasms were collected from Trail 1 (Kg. Gensurai) and Trail 2 (Kg. Melangkap Noriou) and submitted to the hydrodistillation process to obtain the essential oil before analysing with GC-MS. From the result obtained, a total of 85 compounds were found and 26 of these were terpenoid compounds. There are several classes of compound present in different parts of *E. coccinea*, such as, monoterpene, sesquiterpene, alcohol, aldehyde, alkane, alkene, ketones, fatty acids derivatives, esters, amines as well as norterpene. Most of the compounds found in *E. coccinea* are monoterpenes at 18 compounds, followed by alcohols (14 compounds), alkanes and alkenes (12 compounds), sesquiterpenes (8 compounds), aldehydes (7 compounds), ketones, fatty acid derivatives, esters (4 compounds), and lastly, amine and norterpene, one compound each. However, total terpenoids from all plant parts from both sites were less than 50% of total abundance. Only the rhizome part from site 2 showed the highest terpenoid abundance (43.34%). Hence, the identified compounds from the study could be expended for large-scale profiling to obtain higher yields of important constituents.

Keywords: *Etlingera coccinea*, Essential oil, Chemical composition, GC-MS

Introduction
The genus *Etlingera* belongs to the Zingiberaceae family (Tachai et al., 2014) and consists of many edible ginger plants (Daniel-Jambun et al., 2018). One of the most commonly known species of *Etlingera* is *Etlingera coccinea* or commonly known as "Tuhau" according to the KadazanDusun. The leafy shoots with stout rhizome produce a stingy smell when it is crushed (Jualang et al.,

2015). As stated by Naive et al. (2018), it is a terrestrial herb and primarily grows in the secondary forest at bright-lit to deeply shaded locations along streams with moist to wet soil. It also grows at an elevation between 300 to 1400 metres above sea level. *E. coccinea* is native to Java, Sumatra, Thailand, Malay Peninsula and throughout Borneo, it is also discovered in the Philippines (Naive et al., 2018).

In Sabah, Malaysia, *E. coccinea* is used by indigenous ethnic groups especially the KadazanDusun to flavour local dishes (Jualang et al., 2015). According to Naive et al. (2018), the pith of the leafy shoot is used as a condiment in Borneo and Java and is also eaten as a vegetable. The fruits are edible, and the seed oil has a characteristic aroma. It is also consumed as a pickle and utilized as a traditional remedy for stomach ache, food poisoning and gastric problems (Mahdavi et al., 2017). Apart from its ability to treat these ailments and being a source of food, it was also discovered to be used in the skincare industry as a face scrub and is commercialized (Geraldine, 2017).

To date, there are only two studies on the essential oil of *E. coccinea* and these previous reports were only focused on the rhizome part of the ginger. Vairappan et al. (2012) reported they successfully extracted essential oils from five *Etlingera* species namely, *E. pyramidosphaera*, *E. megalocheilos*, *E. Elatior, E. brevilabrum* and *E. coccinea*. The chemical composition of each essential oil was then screened using GC-MS analysis and tested for their cytotoxic and antibacterial activities. From the study, they found that there are 39 volatile compounds in five species of *Etlingera* and only nine of the volatile compounds found in *E. coccinea* which are 3-Thujanone, Borneol, Camphor, Cedr-9-ene, L-Calamenene, Carophyllene oxide, α-Bisabolol, α-Epi-muurolol and Cycloartanyl acetate. The most abundant volatiles in *E. coccinea* is Borneol (25.8%).

Meanwhile, a study was conducted by Nagappan et al. (2017) on the essential oils from the rhizomes of *Etlingera* spp. including *E. coccinea*, the barks of *Cinnamomum* spp. and culms of *Schizostachyum* spp. which were extracted by hydrodistillation using Clevenger-type apparatus. The aim of this study was to investigate the diversity of volatile compounds in these extracted plants and test them for their antibacterial activity. From the result obtained, they divided the volatile compounds into two groups which are major and minor groups. They found that Borneol (28.2%) is the most abundant volatile compound in *E. coccinea* followed by Aromadendrene oxide (10.9%), Elemicin (9.7%), Lauryl aldehyde (5.9%), 1-dodecanol (3%) and 2 compounds in the minor group; Camphor (2.8%) and 5-Decen-1-ol (1.3%).

As estimated by the World Health Organisation (WHO), 65 – 80% of the primary health care needs of the world population are only achieved through plant-based traditional medicine. According to Saxena et al. (2007), "Natural and therefore safe and effective", is the cause why there is phenomenal growth in the plant-based medicinal sector. People trust plant-based medicines over synthetic ones. Despite the toxicology of natural and synthetic chemicals being quite similar as mentioned by Ames et al. (1990), there are trade-offs between natural and synthetic chemicals effects on living organisms.

Due to the fact that synthetic chemicals give a lot of negative effects towards the environment and living organisms, it raises awareness regarding the extensive use of synthetic chemicals to inhibit any illness and disease spread in humans, animals as well as plants that can cause carcinogens, clastogens (agents that break chromosomes), teratogens and mutations. It has led researchers to further study the natural chemical constituents and continue exploring the potential bioactive compound that can be useful to mankind. Since *E. coccinea* plays an important role in the plant species community, it is very crucial for the species to be fully explored in terms of its chemical content in hope to find new or existing bioactive compounds. Therefore, the purpose of this study was to investigate the chemical composition of essential oil from different plant tissues of *E. coccinea* by using Gas Chromatography-Mass Spectrometry (GC-MS) analysis.

Methodology

Sampling and Study Area

The plant samples were collected from Trail 1 (Kg. Gensurai) and Trail 2 (Kg. Melangkap Noriou), Kota Belud, Sabah (Figure 1) on 15th to 19th October, 2019 (5 days). The whole part of *Etlingera coccinea* was collected, starting from the rhizome, stem and leaves. Only disease-free and fresh samples were collected.

Figure 2 shows the habit, rhizome, leaves, detail of ligule, inflorescence and infructescence of *E. coccinea* (Naive et al., 2018). This species can be identified from the leaves, which are narrowly obovate lamina, sessile, ciliate margin and acuminate apex (Naive et al., 2018). *E. coccinea* also has a unique, distinct pungent smell that can be easily identified by crushing the leaves by hand.

Fresh plant samples were collected and put in plastic bags with GPS coordinate labels and the date of collection. Ropes were used to secure the plants, which were then transported to Universiti Malaysia Sabah (UMS) for preparation of plant samples.

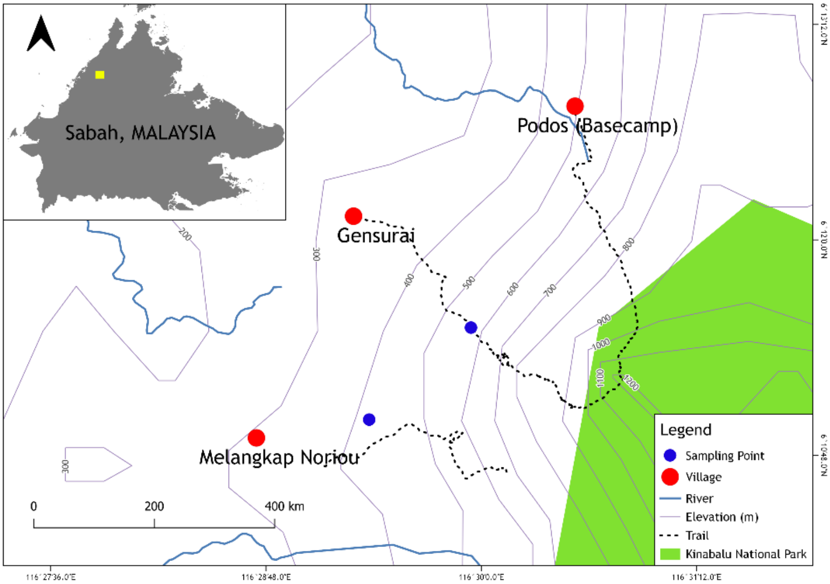

Figure 1. Sampling points during Borneo Geographic Expedition in Kadamaian, Kota Belud. Inset: Yellow box shows Kadamaian area in the north of Sabah.

Figure 2. *Etlingera coccinea* : A. Habit B. Rhizome C. Leaves D. Detail of ligule *E. Inflorescence F. Infructescence* (Naive et al., 2018)

Plant Sample Preparation
The samples were divided into leaves, stems and rhizomes. Each sample was cut into smaller pieces and stored immediately in -80℃ before further analysis.

Extraction of Essential Oil from Plant
The extraction of the essential oil from *E. coccinea* was conducted following Mahdavi et al. (2017) with slight modification. 250g-300g of leaves were chopped into smaller pieces and ground together with distilled water using a blender to increase the surface area before being subjected to hydrodistillation. One litre of distilled water that mixed well with the leaves was then added and placed into a 2L round bottom flask. The 2mL of 99% (v/v) n-pentane (BHD, Germany) was added to trap the condensed oil, through the top of the condenser into the round bottom flask containing samples. The extraction was carried out at 100℃ for 7 to 8 hours. The light-yellow coloured mixture of pentane, water and essential oil then dried over anhydrous sodium sulfate (Na_2SO_4) overnight, and then filtered. Finally, the essential oil was concentrated by blowing the pentane using nitrogen gas, leaving only the essential oil kept in airtight vials at 4℃, and dark conditioned before further analysis.

Identification of Volatile Compound of Essential Oil
The GC-MS analysis was based on previous experiments by Vairappan et al. (2012) with several changes. The analysis of the essential oils was performed using a Shimadzu QP-2010 gas chromatograph attached to a Shimadzu GCMSQP-2010 plus detector (Shimadzu Corp., Japan) with a SGE BPX-5 (30.0 m X 0.25 µm i.d., film thickness 0.25 µm) fused silica capillary column. High purity helium was used as the carrier gas at a constant flow rate of 1.0 mL min-1. One µL of sample was injected in splitless mode into the GCMS using an AOC5000 auto-injector. The initial temperature was set at 40°C, then heated at a rate of 2°C min-1 to 280°C and held isothermally for 5 minutes. The ion source temperature was set at 200°C and the interface temperature at 280°C. The mass spectrometer was set to operate in EI mode with ionizing energy of 70 eV and an acquisition mass range from 35 a.m.u. to 550 a.m.u. at 0.25 scan s-1. Solvent delay was set for 5 minutes.

Results and Discussion

Sampling and study sites
Five samples of *Etlingera coccinea* were collected along Trail 2 in three different GPS points and elevation (N 06°10’58.9”, E 116°29’29.5” at 514m elevation, N 06°10’59.9”, E 116°29.22.5” at 509m elevation and N 06°11’02.2”, E

116°29'27.2" at 520m elevation) and three samples were collected from Trail 1 (N 06°19'18.5", E 116°49'90.4") at elevation 558m.

GC-MS Chromatograms

The GC-MS chromatograms of the leaves, stems and rhizomes essential oil showed the presence of a total of 85 compounds. The compounds were identified through comparison of the fragmentation patterns in the resulting mass spectra with those published in literature and using NIST mass spectral database. So far, there have been no reports on the chemical profiling of the essential oil of *E. coccinea* leaves and stems, only rhizome. The GC-MS analysis on the rhizome of *E. coccinea* have been used in the past by Vairappan et al. (2012) and Nagappan et al. (2017). Therefore, these are the preliminary data for the chemical compositions of leaves, stems and rhizomes of *E. coccinea*.

In previous studies by Vairappan et al. (2012) and Nagappan et al. (2017), the rhizome part of *E. coccinea* were extracted using hydrodistillation and essential oil obtained on GC-MS. There were nine volatile compounds detected in *E. coccinea* rhizome which are 3-Thujanone, Borneol, Camphor, Cedr-9-ene, L-Calamenene, Carophyllene oxide, α-Bisabolol, α-Epi-muurolol and Cycloartanyl acetate (Vairappan et al., 2012). Another seven compounds found in the rhizome of *E. coccinea* by Nagappan et al. (2017) are Borneol, Aromadendrene oxide, Elemicin, Lauryl aldehyde, 1-dodecanol, Camphor and 5-Decen-1-ol. Borneol and Camphor were the only compounds found in both papers. However, in this report, Cyclododecane and Geranyl formate are the most abundant in the rhizome part of both trails and no compound in these two previous reports were found in this paper. The same happened in the case of *Etlingera brevilabrum*, no similar chemical compound of rhizome essential oil was found in both papers reported by Vairappan et al. (2012) and Mahdavi et al. (2016), even the major chemical compositions are different. According to Boaro et al. (2019), this difference in chemical composition can be influenced by abiotic factors (mineral nutrition, water, light, temperature, and soil types), and biotic factors, such as attacks of pathogens, pests, and herbivores.

Table 1 shows the volatile profiling of leaves, stems and rhizomes essential oil from *E. coccinea* by hydro-distillation technique analysed using GC-MS from both trails in Kadamaian, Kota Belud. There are several classes of compound present in different parts of *E. coccinea*, such as, monoterpene, sesquiterpene, alcohol, aldehyde, alkane, alkene, ketones, fatty acids derivatives, esters, amines and norterpene.

Table 1. Volatile profiling of leaves, stems and rhizomes essential oil from *Etlingera coccinea* by hydro-distillation technique analysed using Gas Chromatography-Mass Spectrometry (GC-MS)

No.	Molecular formula	Compound name	*Etlingera coccinea* (%)					
			Trail 1 (Kg. Gensurai)			Trail 2 (Kg. Melangkap Noriou)		
			Leaves	Stems	Rhizomes	Leaves	Stems	Rhizomes
	Sesquiterpenes		**-**	**-**	**7.01**	**-**	**-**	**-**
1	$C_{15}H_{24}O$	10-epi-italicene ether	-	-	3.23	-	-	-
2	$C_{15}H_{24}O$	Caryophyllane 4, 8-α-epoxy	-	-	0.59	-	-	-
3	$C_{15}H_{22}O$	Dehydrofukinone	-	-	1.21	-	-	-
4	$C_{15}H_{26}O$	neo-Intermedeol	-	-	0.43	-	-	-
5	$C_{17}H_{28}O_2$	Nerolidyl acetate	-	-	0.44	-	-	-
6	$C_{16}H_{26}O_2$	Trans-Nerolidyl formate	-	-	0.36	-	-	-
7	$C_{15}H_{24}$	ß-Guaiene	-	-	0.41	-	-	-
8	$C_{15}H_{24}$	ß-Patchoulene	-	-	0.34	-	-	-
	Norterpene							
9	$C_{19}H_{40}$	Pristane	**2.11**	**-**	**-**	**0.83**	**0.89**	**-**
	Monoterpenes		**19.34**	**9.93**	**30.48**	**23.75**	**6.61**	**43.34**
10	$C_{10}H_{18}O$	Isothujol	-	-	-	0.05	-	-
11	$C_{10}H_{16}$	ß-Pinene	0.14	-	-	4.03	-	-
12	$C_{10}H_{16}$	3-Carene	9.86	-	0.58	-	-	-
13	$C_{10}H_{18}O$	4-Terpineol	-	-	-	0.06	-	-
14	$C_{10}H_{16}O$	cis-Limonene oxide	-	-	-	-	0.04	-
15	$C_{10}H_{16}O$	cis-Pinocamphone	-	-	-	0.34	-	-
16	$C_{10}H_{16}$	D-Limonene	0.25	-	-	0.60	-	-
17	$C_{10}H_{18}O$	Eucalyptol	-	-	-	0.08	-	-
18	$C_{11}H_{18}O_2$	Geranyl Formate	-	9.93	29.90	-	-	41.24
19	$C_{10}H_{18}O$	Isocineole	0.36	-	-	-	0.19	-
20	$C_{10}H_{18}O$	Pinocampheol	-	-	-	0.10	0.09	-
21	$C_{10}H_{16}$	Sabinene	-	-	-	0.15	-	-
22	$C_{10}H_{16}$	α-Phellandrene	-	-	-	0.08	-	-

(Continued on next page)

Table 1. (continued)

23	$C_{10}H_{16}$	α-Thujene	8.43	-	-	2.92	-	-
24	$C_{10}H_{16}$	ß-Myrcene	0.30	-	-	14.83	5.73	1.87
25	$C_{10}H_{16}$	ß-Phellandrene	-	-	-	0.07	-	-
26	$C_{10}H_{16}O$	ß-Thujone	-	-	-	0.45	-	-
27	$C_{10}H_{16}$	δ-Carene	-	-	-	-	0.56	0.22
	Ketones		**24.50**	**0.26**	**1.52**	**21.44**	**42.90**	**0.08**
28	$C_6H_{12}O$	2-Hexanone	-	-	-	-	-	0.08
29	$C_{10}H_{16}O_2$	cis-piperitone epoxide	24.50	0.26	0.39	20.42	42.90	-
30	$C_{13}H_{24}O$	Citronellyl acetone	-	-	-	0.12	-	-
31	$C_9H_{14}O$	Nopinone	-	-	1.13	0.90	-	-
	Fatty acids derivatives		**-**	**5.19**	**1.85**	**-**	**0.44**	**-**
32	$C_{10}H_{20}O_2$	4-Methylnonanoic acid	-	3.22	0.52	-	0.12	-
33	$C_{12}H_{22}O_2$	Ethyl trans-2-decenoate	-	-	-	-	0.32	-
34	$C_9H_{18}O_2$	Nonanoic acid / Pelargonic acid	-	0.30	-	-	-	-
35	$C_8H_{16}O_2$	Octanoic acid	-	1.67	1.33	-	-	-
	Esters		**0.48**	**1.37**	**2.31**	**0.82**	**0.33**	**0.10**
36	$C_{12}H_{22}O_2$	(E)-2-Decenyl acetate	-	0.27	-	-	-	-
37	$C_8H_{12}N_2O_2$	N-tert-Butoxycarbonylimidazole	-	0.86	1.94	-	-	0.10
38	$C_{19}H_{31}F_7O_2$	Pentadecyl heptafluorobutyrate	0.48	-	-	0.82	0.33	-
39	$C_6H_{10}O_2$	Vinyl butyrate	-	0.24	0.37	-	-	-
	Amines							
40	$C_6H_{14}N_2$	1-Aminohomopiperidine	**0.41**	**0.30**	**0.39**	**0.24**	**-**	**0.03**
	Alkenes		**2.55**	**2.09**	**1.60**	**5.85**	**2.12**	**1.61**
41	$C_{13}H_{26}$	(2Z)-4,5-Dimethyl-2-undecene	-	0.67	1.21	-	-	0.41
42	$C_{16}H_{32}$	(Z)-7-Hexadecene	-	0.24	-	-	-	-
43	$C_{12}H_{24}$	1-Dodecene	0.91	-	-	0.53	-	-
44	$C_{15}H_{30}$	1-Pentadecene	-	0.20	0.19	-	-	-
45	$C_{13}H_{26}$	1-Tridecene	-	0.16	-	-	-	-
46	$C_{13}H_{26}$	1-Tridecene	-	0.30	0.20	-	-	-

(Continued on next page)

Table 1. (continued)

47	$C_{14}H_{26}$	2,6,10-Trimethylundeca-1,3-diene	-	-	-	-	-	0.40
48	$C_{10}H_{20}$	3,7-Dimethyl-1-octene	0.14	-	-	0.05	-	-
49	$C_{12}H_{24}$	3-Dodecene	0.56	-	-	0.62	1.02	0.00
50	$C_{18}H_{36}$	5-Octadecene	-	0.52	-	-	-	-
51	$C_{14}H_{28}$	5-Tetradecene	0.94	-	-	1.35	1.10	0.80
52	$C_{10}H_{16}$	Bornylene	-	-	-	3.29	-	-
	Alkanes		**47.88**	**50.80**	**50.84**	**45.18**	**42.86**	**51.83**
53	$C_{19}H_{40}$	2-Methyloctadecane	-	0.28	-	-	-	-
54	$C_{12}H_{24}$	1-Ethyl-2-heptylcyclopropane	-	-	-	-	-	0.29
55	C_9H_{18}	1-Methylpentylcyclopropane	-	0.07	0.14	-	-	-
56	C_9H_{20}	2,3,3-Trimethylhexane	0.19	0.41	0.62	0.13	0.16	0.24
57	$C_{17}H_{36}$	2-Methylhexadecane	-	18.03	10.25	-	-	3.51
58	$C_{15}H_{32}$	2-Methyltetradecane	-	12.75	7.24	-	-	2.44
59	$C_6H_{13}NO_2$	2-Nitrohexane	-	1.05	1.15	-	-	0.25
60	$C_{17}H_{31}F_3O_2$	2-Trifluoroacetoxypentadecane	-	-	0.52	-	-	-
61	$C_{15}H_{32}$	3-Methyltetradecane	2.87	-	-	0.93	0.52	-
62	$C_{10}H_{16}$	5,5-Dimethyl-1-vinylbicyclo[2.1.1]hexane	-	-	-	-	-	0.30
63	$C_{12}H_{24}$	Cyclododecane	44.83	17.46	30.93	44.11	42.18	44.79
64	$C_{13}H_{24}O_2$	Hexyl cyclohexanecarboxylate	-	0.76	-	-	-	-
	Aldehydes		**0.31**	**25.99**	**2.07**	**0.85**	**1.09**	**1.37**
65	$C_{15}H_{30}O$	13-Methyltetradecanal	-	0.54	-	-	-	0.28
66	$C_8H_{14}O$	2-Octenal	0.14	-	0.31	0.13	0.58	0.37
67	$C_{12}H_{24}O$	Dodecanal	-	17.57	1.76	-	-	0.08
68	$C_{11}H_{22}O$	Methyl Octyl Acetaldehyde	-	-	-	-	-	0.15
69	$C_{14}H_{28}O$	Tetradecanal	-	7.88	-	-	-	-
70	$C_9H_{14}O$	Trivertal	0.09	-	-	-	0.19	0.15
71	$C_{11}H_{20}O$	Undec-(8Z)-enal	0.08	-	-	0.72	0.31	0.35
	Alcohols		**2.42**	**4.08**	**1.91**	**1.04**	**2.76**	**1.65**
72	$C_{10}H_{22}O$	1-Decanol	-	-	-	-	0.27	-
73	$C_{12}H_{22}O$	1-Dodecyn-4-ol	-	1.18	-	-	-	-
74	$C_8H_{18}O$	1-Octanol	-	0.23	0.20	-	-	0.03

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Table 1. (continued)

75	$C_{10}H_{18}O$	2,4-Pentadien-1-ol,3-pentyl-,(2Z)-	-	-	-	-	-	0.94
76	$C_9H_{20}O$	2-Nonanol	-	-	-	-	-	0.21
77	$C_5H_{12}O_2$	2-Propoxyethanol	-	0.22	-	-	-	-
78	$C_8H_{16}O$	4-Ethylcyclohexanol	0.75	-	-	-	0.10	0.07
79	$C_{14}H_{30}O$	6-Tetradecanol	-	2.03	0.79	-	-	-
80	$C_{10}H_{20}O$	Cyclodecanol	1.11	0.08	0.28	0.64	0.41	0.35
81	$C_{10}H_{20}O$	Decylenic alcohol	0.36	-	-	-	1.38	-
82	$C_8H_{18}O$	Isooctanol	0.19	0.33	0.64	0.11	0.11	0.06
83	$C_9H_{20}O$	Nonanol	-	-	-	-	0.49	-
84	$C_{13}H_{28}O$	n-Tridecanol	-	-	-	0.10	-	-
85	$C_{10}H_{18}O$	trans-ß-Terpineol	-	-	-	0.19	-	-
	Total compound abundance (%)	Total monoterpenes	19.34	9.93	30.48	23.75	6.61	43.34
		Total sesquiterpenes	-	-	7.01	-	-	-
		Total terpenoid	19.34	9.93	37.49	23.75	6.61	43.34
		Total abundance (%)	100.00	100.00	100.00	100.00	100.00	100.00

Most of the compounds found in *E. coccinea* are monoterpenes at 18 compounds, followed by alcohols (fourteen compounds), alkanes and alkenes (twelve compounds), sesquiterpenes (eight compounds), aldehydes (seven compounds), ketones, fatty acid derivatives, esters (four compounds), and lastly, amine and norterpene, one compound each.

Despite the number of compounds present in each class, the relative abundance for each compound differed. Referring to Figure 3, the major compound class are monoterpenes, ketones, aldehydes and alkanes. Alkanes are the most abundant in all parts of *E. coccinea*, ranging from 42.86% to 51.83%. In the previous study by Cui et al. (2008), the alkanes in defoliated leaves were higher compared to fresh leaves. The plant sample collection was completed one week earlier before it could be stored and extracted to get essential oil, a lot of samples were already defoliated, hence, supporting the abundance of alkanes in the result obtained.

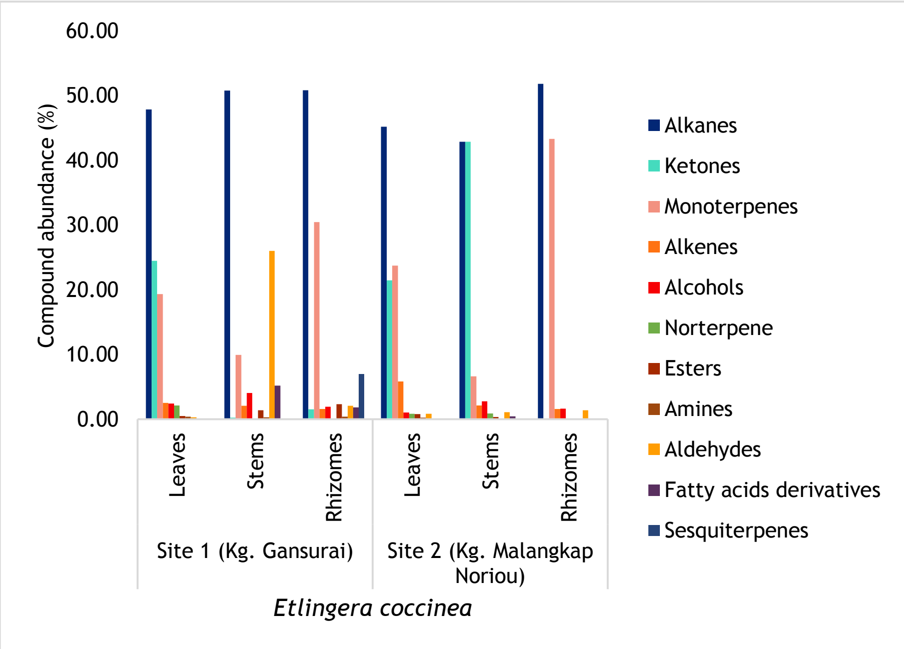

Figure 3. The relative abundance of several classes of the compound found in *Etlingera coccinea* essential oil

As shown in Table 1, the ranks from highest to the lowest abundance of monoterpenes found in different parts of the plant are in the order of rhizomes > leaves > stems. According to Gershenzon et al. (2000), in most plants monoterpenes are easily released to the atmosphere. The biosynthesis and accumulation of monoterpenes are also easily influenced by the external environment and improper cultivation (Zhang et al., 2017). Therefore, further assessment needs to be conducted before stating that the abundance of monoterpenes are only concentrated in some parts of a plant. Ketones, on the other hand, mostly dominate the leaves part of *E. coccinea* and sesquiterpenes were only found in rhizomes of *E. coccinea* that had been collected from Trail 1. Plants have always been known for their ability to produce a natural product that has an essential role in their defence mechanism against herbivores and any pathogens, these natural products or metabolites are synthesized in specific organs, specific stages of development, environmental effect or induced by getting attacked by other organisms (Gershenzon et al., 2000). Therefore, the presence of a chemical compound in each plant part is not necessarily the same or in the same concentration. For example, in a study of sesquiterpenes, researchers found that high emission of sesquiterpenes was detected in maize leaves that were damaged by the herbivores compared to undisturbed maize leaves (Köllner et al., 2013). Another study by Liu et al. (2020), has reported that any intact and uninjured tea plant does not emit any sesquiterpene but those that have been damaged mechanically produce one sesquiterpene ((E, E)-α-farnesene) and insect-damaged ones emit two sesquiterpenes ((E, E)-α-farnesene and (E)-nerolidol). Though our data does not reflect similar observation, this could be one of the reasons why sesquiterpenes were only found in Trail 1. Apart from this, the environmental condition where samples were collected were not really the same, Trail 2 was nearer to urban areas and Trail 1 was in the forest.

Terpenoid content

Terpenoids are terpenes that have different functional groups and are an oxidized methyl group attached or detachedfrom the compound at numerous positions. It is divided into several classes, which are monoterpenes ($C_{10}H_{16}$), sesquiterpenes ($C_{15}H_{24}$), diterpenes ($C_{20}H_{32}$), sesterpenes ($C_{25}H_{40}$), and triterpenes ($C_{30}H_{48}$) varying on its carbon units. The most reliant terpenoids that varied in their formations are biologically active and extensively used all over the world as a source of cure for ailments (Perveen, 2018). From the result obtained in Table 1, the terpenoids found in *E. coccinea* are divided into two, monoterpenes and sesquiterpenes. The terpenoid content in *E. coccinea* was highly abundant in the rhizomes, then followed by leaves and stems parts for both Trail 1 and Trail 2.

There are 26 terpenoids found in *E. coccinea* (Table 1). However, the terpenoids abundance in all plant parts for both trails are less than 50%. The rhizome part collected from Trail 2 recorded the highest terpenoid abundance (43.34%). Terpenoids were known to exhibit various beneficial properties. Based on previous studies, B-Pinene that can be found in the leaves of *E. coccinea* was found to be a good anti-inflammatory (Rivas da Silva et al., 2012) and anti-depressant agent (Guzmán-Gutiérrez et al., 2012). While Pinocampheol compound that can be found both in leaves and stems of *E. coccinea* was reported to have promising insecticidal activity (Kalechits & Kozlov, 2008). Other terpenoid that can be found in the leaves of *E. coccinea* are known as D-limonene, a major compound in citrus peel. It has a major role in breast cancer prevention and treatment according to Miller et al. (2011). Moreover, geranyl formate, a monoterpene compound that can be found mostly in the floral-rosy scent of plants, such as citronella, geranium, rose and verbena. As stated by Jirovetz et al., (2006), geranyl formate showed antimicrobial activity when tested against yeast and gram (+) and gram (-) bacteria.

Conclusion

The result of this study has successfully shown that the composition of chemical compounds from different parts of tissues is very diverse. Potential biological activities such as anti-oxidants and anti-microbial of *E. coccinea* essential oil as reported previously, has increased the value of *E. coccinea* itself on the market. Further studies, such as the environmental factors of *E. coccinea*, need to be continued to determine a unique potential for this species.

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