Bridging Traditional Knowledge & Natural Products Innovations Towards Wellness and Shared Prosperity

Editors

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• Mazura Md. Pisar • Firdaus Kamarulzaman

INSTITUT PENYELIDIKAN PERHUTANAN MALAYSIA
FRIM

Ministry of Energy and Natural Resources

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Ministry of Energy and
Natural Resources

https://www.frim.gov.my/publication/maps_tk
2021

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Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Bridging Traditional Knowledge & Natural Products Innovations Towards Wellness and Shared Prosperity / Editors: Mary Khoo Gaik Hong, Chee Beng Jin, Getha Krishnasamy, Mazura Md. Pisar & Firdaus Kamarulzaman
Mode of access: Internet
eISBN 978-967-2810-05-6
1. Ethnoscience.
2. Traditional medicine.
3. Alternative medicine.
4. Traditional ecological knowledge.
5. Government publication—Malaysia.
6. Electronic books.
I. Khoo, Mary Gaik Hong. II. Chee, Beng Jin.
III. Getha Krishnasamy. IV. Mazura Md. Pisar.
V. Firdaus Kamarulzaman.
306.42

MS ISO 9001:2015

Content

Foreword

Assalamualaikum WBT and greetings!

The effort to combine traditional knowledge with modern scientific studies is a good endeavour that will empower and promote the importance of traditional knowledge. This effort will also ensure a fair and equitable sharing of resources with resource owners under the Access to Biological Resources and Benefit Sharing (ABS) Act 2017.

As a country with rich biological diversity, efforts to strengthen natural resource management are critical as a form of mitigation to climate change and natural disasters. Various measures have been taken by the Ministry of Energy and Natural Resources (KeTSA) including working towards realising the establishment of the Malaysian Biodiversity Centre, which serves as a biodiversity research and conservation centre as well as the National Competent Authority to enforce the ABS Act. Through the enactment and enforcement of this act, Malaysia can perform its obligations under the Convention on Biological Diversity (CBD).

The richness in natural resources including medicinal plants is a blessing to Malaysia. Meanwhile, our local wisdom of previous generations using plants in traditional treatment is a treasure warrants to be preserved. In recent times, health and cosmetic products of natural origin are increasingly in demand due to the high awareness of environmental protection as well as the risk of harmful chemicals to consumers. This is a good prospect for researchers to produce high value and safe research output to meet the present trends.

In addition, the recent world situation in facing the unexpected COVID-19 pandemic has also opened the eyes of many that research on infectious diseases and public health should take precedence. In this aspect, the Natural Products Division at FRIM can be a key pillar that plays an imperative role in upholding the knowledge of local traditions through its strengths in scientific research, development and commercialisation.

It is the aspirations and policies of the Malaysian government to increase efforts as well as the use of local natural resources to produce high value products and innovations for the prosperity of the country. I hope that researchers and the policy makers will always work together to shoulder the responsibility of preserving and conserving the country's natural resources as well as biodiversity to ensure the sustainability of our present-day society and the future generations.

This book is a collection of short scientific papers on traditional knowledge and natural product research as well as innovations from researchers in Malaysia. The basis of this publication stemmed from the passion for knowledge-sharing and as a better preservation method of research findings. I hope that this book is able to reach its goal in sharing the work conducted by these scientists to be reviewed as reference by others.

Dr. Khali Aziz Hamzah
Director General of FRIM

Preface

Malaysian culture demonstrates a rich and unique potpourri of knowledge and practices originated from its multiracial and diverse cultural society. The traditional knowledge practiced by the Malay, Chinese, Indian and the orang asli continues to sustain and maintain their community livelihood from the olden days to the present age. Their dependence on the forests is vital which serves as their sustainable green pharmacies. Apparently, the maintenance of good wellbeing and prevention of illness are much accentuated on food and usage of natural remedies from the surroundings, especially from plants and other natural resources. In the current fast-paced modern society, traditional knowledge which encompasses traditional remedies and folk cures gradually faced extinction and very soon to be long forgotten.

The Natural Products Division at the Forest Research Institute Malaysia (FRIM) had come a long way in pioneering research and discoveries of medicinal and aromatic plants along with local traditional knowledge after receiving its mandate from the Government of Malaysia in 1995. The institute had forged collaborations with renowned local and international academics, research institutions and herbal industries in technology transfer, training, sharing of expertise and product development.

This book celebrates Natural Products Division's involvement for a period of more than 25 years of research in the importance of natural resources related to medicinal plants and microbes in Malaysia. The content of the book acknowledged the tireless labour, years of hard work and patience of scientists and researchers in the field of traditional knowledge, conservation, agronomy, natural products discovery, standardisation and processing technology, product development and commercialisation, quality control as well as issues on regulatory and standards.

The title "Bridging Traditional Knowledge & Natural Product Innovations Towards Wellness and Shared Prosperity" signifies the effort and aspiration to combine traditional knowledge with new scientific studies to promote measures tending to the betterment of the society in Malaysia. We sincerely hope that the scientific findings contributed by our fellow colleagues and contributors will complement and strengthen each other's discoveries to produce common solutions to a pressing issue for the benefit of this nation.

The Editorial Team
Natural Products Division @ FRIM

TRADITIONAL KNOWLEDGE, AGRONOMY AND CONSERVATION

GC-MS ANALYSIS OF TERPENOIDS FROM LEAVES OF *Canarium odontophyllum* Miq. (DABAI)

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ABSTRACT

Terpenoids are defined as secondary metabolites with carbon backbone molecular structures consisting of isoprene (2-methylbuta-1, 3-diene) units. They demonstrate important biological activities, such as antibacterial, antiviral, antimalarial, antiinflammatory, anticancer and cholesterol synthesis inhibition activities. *Canarium odontophyllum* Miq. or locally known as "dabai" is an endemic plant in Sarawak, Malaysia. Its leaf compositions were examined by using the GC-MS analysis in order to compare and contrast their volatile terpenoids constituents. The terpenoids content were 36.67% and 14% for hexane and ethanol extracts, respectively. n-Hexadecanoic acid, phytol and octadecanoic acid were the major terpenoids constituents from the leaves of *C. odontophyllum* Miq. n-Hexadecanoic acid (20.22%), phytol (8.74%) and octadecanoic acid (7.54%) were found to be predominant in the hexane extract, while phytol (21.02%) and n-hexadecanoic acid (14.52%) were major constituents in the ethanol extract. The *C. odontophyllum* Miq. leaf constituents are also related to their biological activities and would offer promising therapeutic effects. Further investigation should be conducted to develop it as a potential therapeutic drug.

Keywords: *Canarium odontophyllum*, dabai, GC-MS, biological activities, terpenoids

INTRODUCTION

Terpenoids are classified as secondary metabolites with carbon backbone-containing molecular structures made up of isoprene (2-methylbuta-1,3-diene) units. In growth and development, thousands of terpenoids produced by plants have no discernible role and thus are classified as "secondary" metabolites. Important medicinal activities are shown by the terpenoids group such as antiviral, antibacterial, antimalarial, antiinflammatory, cholesterol synthesis inhibition and anticancer (Mahato & Sen 1997).

It has been shown that plants of the genus Canarium contain different biological activities, such as antioxidant, antibacterial, antifungal, antitumour, antiinflammatory, hepatoprotective, analgesic and antidiabetic (Mogana & Wiart 2011; Basri & Nor 2014). To date, only several biological studies had been conducted to investigate the properties of *C. odontophyllum* Miq. *Canarium odontophyllum* Miq. or locally known as "dabai" is an indigenous fruit to Sarawak, Malaysia and devoured as snack food by the natives (Latiff *et al.* 2000). Dabai fruit comprises of edible skin (5–6%) and flesh (54–60 %), and kernel (35–40 %). However, *C. odontophyllum* Miq. is classified as an underutilised fruit and has not been fully explored due to lack of promotion. Our study investigated and determined the terpenoids from *C. odontophyllum* leaf hexane and ethanol crude extracts.

MATERIALS AND METHODS

Plant Sample

Figure 1: Leaves of *C. odontophyllum* Miq. (dabai).

Fresh leaves of *C. odontophyllum* Miq. (Figure 1) were collected from Kuching, Sarawak, Malaysia in December 2019. The permit for export, and the permit for research and development were obtained from Sarawak Biodiversity Centre with permit number SBC-2020-EP-58-MWH and SBC-2019-RDP-20-MWH, respectively. The leaf was deposited in Universiti Kebangsaan Malaysia (UKM) Herbarium with voucher number ID028/2020.

Preparation of *C. odontophyllum* Miq. Leaf Extracts

The plant leaves were air dried for about 3 days at room temperature. A commercial grinder was used to grind the dried leaves. In order to obtain different extracts, extraction was done using solvents of different polarities, specifically n-hexane and ethanol. Then, the extracts were evaporated using Rotavapor (Buchi) to dryness (Basri *et al.* 2014).

GC-MS Determination of Terpenoids

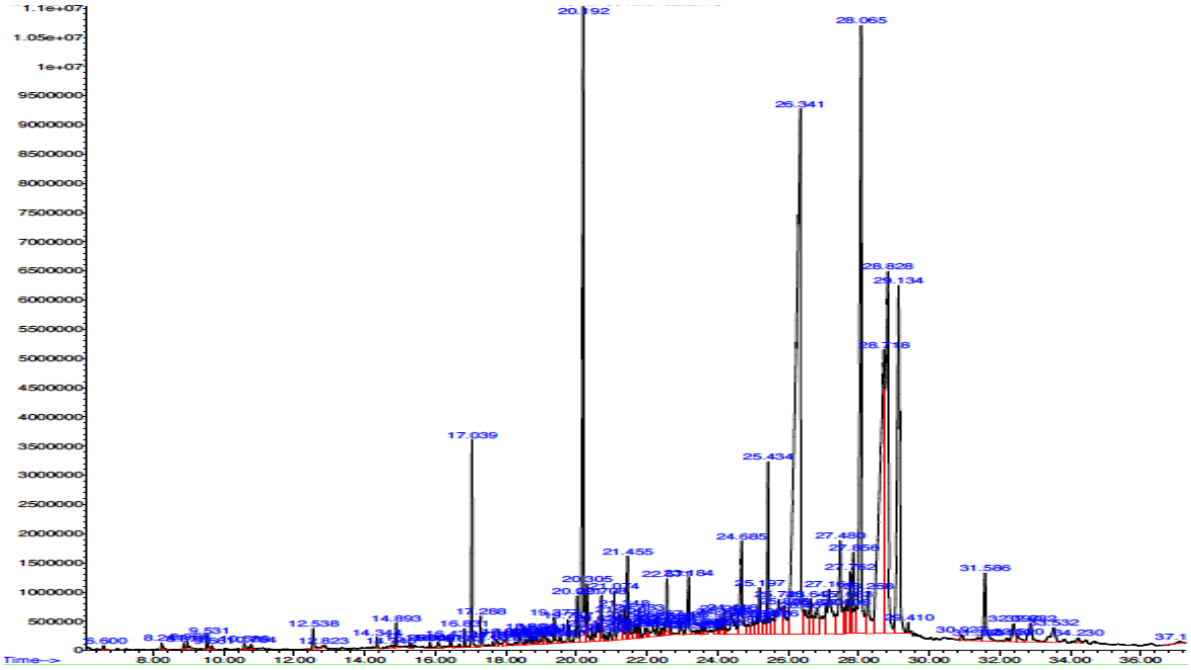
The Marina *et al.* (2013) method was used. Analyses were performed on an Agilent 7890 series Gas Chromatograph coupled to an Agilent 5975 N MSD quadrupole mass spectrometer (Agilent Technologies). Compounds extracted from various extracts were identified based on the GC retention time on the HP-5MS column and the matching of the spectra with standard computer software data (Replib and Mainlab GC-MS systems data) and cross-matched with the massfinder terpenoids library (Dr Hochmuch scientific consulting).

RESULTS AND DISCUSSION

Various crude extracts from *C. odontophyllum* Miq. leaves have unique physical features. The ethanol extract was green to dark green with a sweetened, strong scent. Extraction using n-hexane yielded 0.624% while ethanol yielded 9.9%.

Figure 2 shows the chromatograms for both *C. odontophyllum* Miq. leaf hexane and ethanol extracts after GC-MS analysis.

(a)



(b)

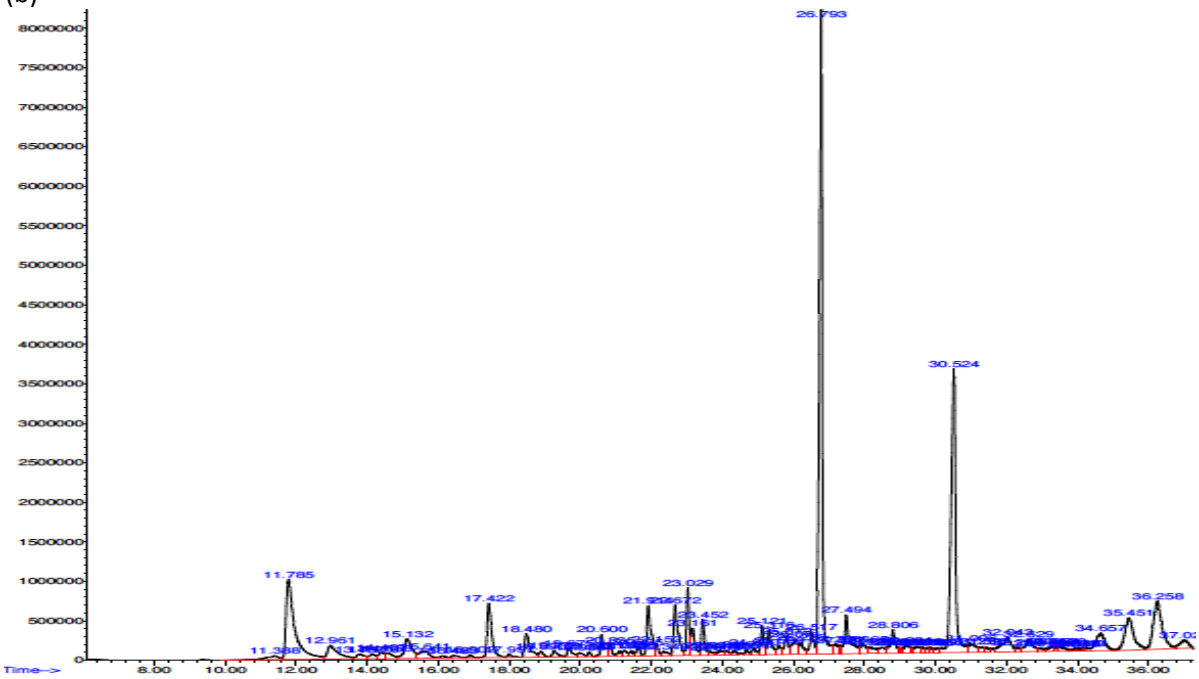


Figure 2: GC-MS chromatogram of (a) hexane extract and (b) ethanol extract *of C. odontophyllum* Miq. leaf.

Based on the GS-MS analysis, the terpenoids content were 36.67% and 14% for hexane and ethanol extracts, respectively. The terpenoids detected are listed in Table 1. It was shown that hexane extract contains richer amount and number of terpenoids compared to the ethanol extract. Hence, for any study regarding plant terpenoids, hexane extract will be the best choice to study properties of terpenoids as major constituent.

Table 1: Terpenoids content in *C. odontophyllum* Miq. leaf (a) hexane and (b) ethanol extracts

	***C. odontophyllum* Hexane Extract**	***C. odontophyllum* Ethanol Extract**
Terpenoids	alpha-cadinol, alpha-pinene, beta-bisabolene, beta-humulene, gamma-himachalene, gamme-muurolene, 1-nonadecene, 2-methyltetracosane, 6,10,14-trimethyl 2-pentadecanone, alloaromadendrene, dehydro-aromadendrene, caryophyllene, copaene, D-limonene, decane, dodecane, humulene, methyl stearate, n-hexadecanoic acid, nonadecane, nonanal, nonanoic acid, 3-ethyl-5-(2-ethylbutyl)-octadecane & octadecanoic acid.	beta-bisabolene, aromandendrene, camphene, caryophyllene, n-hexadecanoic acid, octadecanoic acid, pentadecanoic acid, phytol & tetradecanoic acid.

n-Hexadecanoic acid, phytol and octadecanoic acid were the major terpenoids constituents of *C. odontophyllum* Miq. leaf (Table 2). n-Hexadecanoic acid (20.22%), phytol (8.74%) and octadecanoic acid (7.54%) were predominant in hexane extract, while phytol (21.02%) and n-hexadecanoic acid (14.52%) were major in ethanol extract.

Table 2: Major terpenoids in hexane and ethanol extracts of *Canarium odontophyllum* Miq. leaf with claimed biological activities

Retention Time (RT)	**Library/ID Terpenoids**	**Qual**	**Biological Activities Claimed**
30.527 (Hex) 26.344 (EtOH)	n-Hexadecanoic acid ($C_{16}H_{32}O_2$)	99 99	Antioxidant, antitumor (nasopharynx), tumor necrosis production inhibitor factor. (U.S. Department of Agriculture, Agricultural Research Service 2019)
26.792 (Hex) 28.066 (EtOH)	Phytol ($C_{20}H_{40}O$)	91 96	Antimicrobial, antiinflammatory, diuretic, anticancer. (U.S. Department of Agriculture, Agricultural Research Service 2019)
29.132 (Hex)	Octadecanoic acid ($C_{18}H_{36}O_2$)	91	Antifungal, antitumor activity, antibacterial. (Hsouna *et al.* 2011; Geha *et al.* 2009)

The *C. odontophyllum* Miq. leaf would offer promising therapeutic effects based on the content of terpenoids found in it. Our study could also help to predict the terpenoids structure and formula of biomolecules. In addition, further research may lead to the isolation and purification of terpenoids from bioactive compounds and their structural elucidation by screening for their biological activities will be beneficial for further drug development.

CONCLUSION

Canarium odontophyllum Miq. leaf hexane extract contains higher amount of terpenoids than the ethanol extract and will be beneficial for further research and drug development. Nevertheless, the isolation and biological activity of individual terpenoids will certainly yield rewarding findings, thus will open up new areas of research into particular compounds and their pharmacological potential.

ACKNOWLEDGEMENTS

We would like to acknowledge the financial support from Universiti Kebangsaan Malaysia via Dana Impak Perdana (DIP-2018-034).

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VOLATILE CONSTITUENTS, ANTIINFLAMMATORY AND ANTICOLLAGENASE EFFECT OF ESSENTIAL OILS FROM FOUR *CYMBOPOGON* SPECIES

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ABSTRACT

The genus of *Cymbopogon* is a member of the Poaceae (Gaminae) family, popularly known for their high content of essential oil. In this study, leaves of *C. winterianus*, *C. martini*, *C. nardus* and *C. citratus* were extracted to produce the essential oil through lab-scale hydrodistillation technique. GC and GC/MS analyses revealed the presence of monoterpene and sesquiterpene compounds in each of the essential oils. Geranyl acetate (57.6%), linalool (3.6%), citronellal (3.2%) and citronellol (0.3%) were identified as major compounds in *C. winterianus* oil. The main compounds for *C. martini* oil were geraniol (15.6%), methyl eugenol (10.2%), (*E*)-methyl isoeugenol (10.1%), borneol (4.4%), citronellal (4.2%) and citronellol (3.4%). *Cymbopogon nardus* oil contained geraniol (40.8%), citronellal (15.7%), (*E*)-citral (9.4%), citronellol (8.8%) and (*Z*)-citral (5.7%) as major compounds. Meanwhile, *C. citratus* oil was rich in (*Z*)-citral (30.7%) and (*E*)-citral (37.9%), followed by geranial (5.1%) and myrcene (3.0%). These oils were screened for antiinflammatory activity by *in vitro* assays, namely antihyaluronidase, antixanthine oxidase, antilipoxygenase and antiprotein denaturation assays, as well as anticollagenase assay for antiaging effect. *Cymbopogon citratus* oil showed the highest percentage of inhibition against lipoxygenase activity (84.45 ± 2.85%), followed by *C. martini* which exhibited moderate inhibition effect (41.08 ± 2.70%). All essential oils showed low activity for inhibition of xanthine oxidase and hyaluronidase. No inhibition of protein denaturation was observed for *C. winterianus* and *C. citratus*, while *C. martini* and *C. nardus* demonstrated negligible activity. All essential oils exhibited profound anticollagenase activity (57–74%) except *C. nardus* oil (21%). These findings provided evidence that the *Cymbopogon* oils could be used as an active ingredient in product formulation for antiinflammatory and antiaging effects.

Keywords: *Cymbopogon* spp., essential oil, volatile compounds, antiinflammatory, antiaging

INTRODUCTION

Cymbopogon spp. belong to the family Poaceae (Graminae). They comprised of nearly 140 species reported to be found in Africa, India, Australia, America, Europe and South Asia *(Nakahara et al. 2013; Wany et al. 2013). They are known worldwide for their high content of essential oil.* In different countries, traditional use of *Cymbopogon* spp. showed a range of applications including as insect repellent, insecticide, common tea, flu control and medicinal supplement (Shah *et al.* 2011; Wany *et al.* 2013; Avoseh *et al*. 2015). Pharmacological activities such as antiamoebic, antibacterial, antidiarrhoeal, antiinflammatory, antiobesity, antinociceptive, antimalarial, antifungal, antianxiety and antioxidant have been reported in *Cymbopogon* spp. (Wannissorn *et al.* 2005; Shah *et al.* 2012; Nishijima *et al.* 2014; Kusmardiyani *et al.* 2016; Miral *et al.* 2016). Essential oils from *Cymbopogon* spp. are commonly used in the formulation of skincare products. The discovery of new natural inhibitors of pro-inflammatory and pro-aging enzymes could be interesting for the formulation of active and safe cosmetic ingredients for skin protection. In this

study, the essential oils from selected *Cymbopogon* species, namely *C. winterianus*, *C. nardus*, *C. martinii* and *C. citratus* were screened for volatile compounds and *in vitro* antiinflammatory as well as antiaging activities. The results obtained will be useful to justify the use of these plants as antiinflammatory and antiaging agents for further studies in product development.

MATERIALS AND METHODS

Collection and Preparation of Sample

The fresh leaf samples of *C. winterianus, C. nardus* and *C. martinii* were collected from MARDI Linggi, Melaka. While *C. citratus* leaf samples were collected from Branang, Negeri Sembilan. The samples were air-dried for 2 days until the moisture content of samples reached 30–40%. Then, they were cut into small pieces before being weighed and subjected to water distillation technique for 6 hours using *Clavenger*-type apparatus. The oils were collected and isolated from their hydrosol using anhydrous sodium sulphate. The pure oils were kept in a fridge prior to further analysis.

GC and GC/MS Analysis

Analysis of the oils was conducted by Gas Chromatography (GC) using Shimadzu GC-2010 Plus capillary chromatograph which was equipped with a flame ionisation detector (FID) and the split/splitless mode injection technique was used under the following conditions: carrier gas helium; similar temperature for injector and detector at 250^{o}C. A non-polar capillary column BP-5 (30 m by 0.25 mm, film thickness 0.25 μm) was used and the operating conditions were as follows: initial oven temperature, 60^{o}C for 10 min, up to 230^{o}C at 3^{o}C/min and then 230^{o}C for 10 min. Gas Chromatography/Mass Spectrometry (GC/MS) analysis was conducted on Agilent Technologies GCMS 7890A/5975C Series MSD under similar conditions as described in GC programs using HP-5MS column (30 m by 0.25 mm, film thickness 0.25 μm). The chemical constituents were identified by comparison of retention times and calculated Kovats indices with reference and matching their mass spectra with database library (HPCH2205.L; Wiley7Nist05.L; NIST05a.L).

Bioactivity Tests

In vitro Antiinflammatory Activity

The antiinflammatory activity of essential oils of *Cymbopogon* spp. were evaluated using 4 *in vitro* assays, namely lipoxygenase inhibition, xanthine oxidase inhibition, hyaluronidase inhibition and protein denaturation inhibition assays according to methods of Azhar *et al.* (2004), Noro *et al.* (1983), Ling *et al.* (2003) and Williams *et al.* (2008), respectively, with minor modifications. The results were expressed as mean of the percentage inhibition ± standard error of mean (SEM) of at least 3 separate independent experiments measured in triplicate.

Collagenase Inhibitory Assay (Antiaging Activity)

The anticollagenase assay was adopted from Thring *et al.* (2009) and was slightly modified. This assay was performed in tricine buffer pH 7.5 (50 mM tricine with 10 mM $CaCl_2$ and 400 mM sodium chloride, pH 7.5 at 25°C). The reaction mixture (150 μL total volume) contained 37 μL tricine buffer and 20 μL of collagenase enzyme (0.1 U/Ml) in a 96 well plate, in triplicates. A 50 μL of essential oil (10 mg/mL) was added into 96 well microtiter plate and pre-incubated for 10 min at 25°C. Then, 60 uL of FALGPA (1 mM) substrate was added into all the wells except blank and the absorbance was measured at 340 nm using a spectrophotometer.

RESULTS AND DISCUSSION

The essential oil from the leaves of *C. winterianus*, *C. martini*, *C. nardus* and C. *citratus* were extracted by hydrodistillation and yielded 3.36, 1.31, 3.27 and 0.87% v/w, respectively (on dry weight basis). The essential oils were subjected to GC and GC/MS analysis. Table 1 shows the major compounds of each essential oil. Geranyl acetate (57.6%), linalool (3.6%), citronellal (3.2%) and citronellol (0.3%) were identified as major compounds in *C. winterianus* oil. The main compounds for *C. martini* oil were geraniol (15.6%), methyl eugenol (10.2%), (*E*)-methyl isoeugenol (10.1%), borneol (4.4%), citronellal (4.2%) and citronellol (3.4%). *Cymbopogon nardus* oil contained geraniol (40.8%), citronellal (15.7%), (*E*)-citral (9.4%), citronellol (8.8%) and (*Z*)-citral (5.7%) as major compounds. Citronellal is responsible for their distinctive lemony scent (Wany *et al.* 2013). Meanwhile, *C. citratus* oil was rich in (*Z*)-citral (30.7%) and (*E*)-citral (37.9%). Citral is one of the widely used raw material in perfumery, confectionery and vitamin A production industries (Khanuja *et al.* 2005).

Table 1: Major chemical constituents of *Cymbopogon* spp. essential oils

No.	Chemical Name	RT	Percentage (%)			
			C. winterianus	*C. martini*	*C. nardus*	*C. citratus*
1	Camphene	946	-	3.28	-	-
2	6-Methyl-5-hepten-2-one	981	0.06	0.04	0.17	1.72
3	Myrcene	988	-	0.31	-	2.97
4	Limonene	1024	1.74	4.21	-	-
5	Linalool	1095	3.61	0.78	1.09	1.48
6	Citronellal	1148	3.29	4.24	15.73	-
7	Borneol	1165	-	4.36	-	-
8	α-Terpineol	1186	0.16	1.06	-	-
9	Citronellol	1223	0.27	3.43	8.81	0.44
10	Neral	1235	1.87	0.76	5.65	30.73
11	Geraniol	1249	2.79	15.6	40.75	5.04
12	Geranial	1264	3.16	1.18	9.93	38.31
13	Citronellyl acetate	1350	3.66	0.88	0.83	-
14	Eugenol	1356	1.20	0.03	1.94	-
15	Geranyl acetate	1379	57.62	2.98	2.39	2.02
16	β-Elemene	1389	-	1.12	0.04	-
17	Methyl eugenol	1403	-	10.18	-	-
18	β-Caryophyllene	1417	4.45	0.21	1.15	0.11
19	α-*cis*-Bergamotene	1432	-	6.43	-	0.73
20	(*E*)-Methyl isoeugenol	1491	-	10.08	0.09	-
21	γ-Cadinene	1513	4.04	-	2.93	-
22	Elemol	1548	7.00	4.19	0.84	-
23	γ-Eudesmol	1630	0.43	1.54	0.09	-
24	α-Eudesmol	1652	0.59	1.41	0.15	-

Table 2 shows the findings for antiinflammatory and antiaging effect of all essential oils. They were screened for antiinflammatory activity by means of *in vitro* assay of antihyaluronidase, antixanthine oxidase, antilipoxygenase and antiprotein denaturation as well as anticollagenase assay for antiaging effect. At the final concentration of 100 µg/mL, *C. citratus* oil elicited the highest inhibition of the enzyme lipoxygenase (84.45 ± 2.85%) while *C. martini* demonstrated moderate inhibition effect (41.08 ± 2.70%). The possible association between the observed inhibition of enzyme lipoxygenase and essential oil composition (Table 1) could be due to 2 main components identified as geranial and neral, representing more than 30% of the total content in *C. citratus*. Liao *et al.* (2015) showed that both neral and geranial demonstrated better efficacy in inhibiting the expression of the proinflammatory mediators. These compounds also elicited significant *in vivo* antiallergic and antiinflammatory effects by supressing an immunoglobulin E (IgE)-induced passive cutaneous anaphylactic reaction in mice and a 12-*O*-tetradecanoylphorbol-13-acetate (TPA)-induced inflammatory mouse ear oedema, respectively (Mitoshi *et al.* 2014). All essential oils showed low activity for inhibition of xanthine oxidase and hyaluronidase enzymes. There was no inhibition of protein denaturation of *C. winterianus* and *C. citratus*. While, *C. martini* and *C. nardus* only inhibited at low percentage. For anticollagenase assay, all essential oils at the final concentration of 2.5 mg/mL had high collagenase inhibiting activity (57–74%) except for *C. nardus* oil (21%). Thus, the essential oils of *Cymbopogon spp.* have potential capabilities to protect the degradation of collagen from collagenase, and slows down aging symptoms.

Table 2: *In vitro* antiinflammatory and antiaging activities

Species	Antiinflammatory				Antiaging
	Lipoxygenase (% ± SEM)[a]	Xanthine Oxidase (% ± SEM)[a]	Hyaluronidase (% ± SEM)[a]	Protein Denaturation (% ± SEM)[a]	Anticollagenase (% ± SEM)[b]
C. winterianus	5.97 ± 3.45	5.04 ± 3.59	2.38 ± 0.23	NA	71.99 ± 6.53
C. nardus	22.51 ± 4.93	8.49 ± 1.76	2.33 ± 0.90	3.64 ± 1.47	21.78 ± 0.20
C. martinii	41.08 ± 2.70	3.33 ± 1.95	1.63 ± 0.33	1.20 ± 0.75	57.14 ± 3.43
C. citratus	84.45 ± 2.85	3.99 ± 2.00	1.80 ± 0.19	NA	74.40 ± 5.23
Positive controls					
NDGA	97.62 ± 1.19	-	-	-	-
Allopurinol	-	99.77 ± 0.22	-	-	-
Apigenin	-	-	82.58 ± 6.04	-	-
Diclofenac sodium	-	-	-	93.18 ± 0.93	-
EGCG	-	-	-	-	> 100.00

Notes: Values are expressed as mean inhibition (%) ± Standard Error Mean (SEM) of triplicate measurements from 3 independent experiments. [a]Final concentration of samples/positive controls in reaction mixture was fixed at 100 µg/mL. [b]Final concentration of samples/positive controls in reaction mixture was fixed at 2.5 mg/mL.

CONCLUSION

The monoterpene composition of essential oils of *Cymbopogon* species markedly varied among the species. Monoterpenes are responsible for the characteristic odours of essential oils and scents of *Cymbopogon* species. The fact that antiinflammatory and antiaging assays used in this study involved different inflammatory mechanisms, led us to suggest a possible mechanism of action for these essential oils. This finding suggests that the mechanism involved in the antiinflammatory effect of essential oil from *C. citratus* may be related to inhibition of enzymes involved in the production of proinflammatory leukotrienes. Neral and geranial which represented major constituents in the plant, are the bioactive components conferring the biological activity.

ACKNOWLEDGEMENT

We thankfully acknowledge the financial support of FRGS grant (FRGS/1/2018/WAB01/NRE/1). We would like to express heartfelt thanks to all staff from MARDI Linggi, Melaka involved in collecting the plant materials and to all staff from Natural Product Division FRIM for their technical assistance and encouragements during the work.

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This book is a collection of short scientific papers on traditional knowledge and natural product research and innovations from researchers in Malaysia. The basis of this publication stemmed from the passion for knowledge-sharing. It is our humble desire to share the work conducted by these scientists to be reviewed as reference by others.

e ISBN 978-967-2810-05-6