องค์ประกอบทางเคมีของน้ำมันระเหยง่ายและลายพิมพ์ดีเอ็นเอชนิดอาร์เอพีดีของพืชสกุล *Curcuma* และ *Kaempferia* ในประเทศไทย

นางสาวอรวรรณ เฑียรฆ์พงษ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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CHEMICAL CONSTITUENTS OF ESSENTIAL OILS AND RAPD FINGERPRINTS OF *CURCUMA* AND *KAEMPFERIA* PLANTS IN THAILAND

Miss Orawan Theanphong

A Dissertation Submitted in Partial Fulfillment of the Requirements
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Thesis Title	CHEMICAL CONSTITUENTS OF ESSENTIAL OILS AND RAPD FINGERPRINTS OF *CURCUMA* AND *KAEMPFERIA* PLANTS IN THAILAND
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อรวรรณ เฑียรฆ์พงษ์ : องค์ประกอบทางเคมีของน้ำมันระเหยง่ายและลายพิมพ์ดีเอ็นเอชนิดอาร์เอพีดีของพืชสกุล *Curcuma* และ *Kaempferia* ในประเทศไทย. (CHEMICAL CONSTITUENTS OF ESSENTIAL OILS AND RAPD FINGERPRINTS OF *CURCUMA* AND *KAEMPFERIA* PLANTS IN THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร.วิชชุดา ธนกิจเจริญพัฒน์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: อ. ดร.ชนิดา พลานุเวช, อ. ดร.กาญจนา รังษีหิรัญรัตน์, 398 หน้า.

พืชสกุล *Curcuma* จำนวน 22 ชนิด และ *Kaempferia* จำนวน 5 ชนิดในระเทศไทย ถูกนำมาศึกษาองค์ประกอบทางเคมีของน้ำมันระเหยง่ายในส่วนเหง้าโดยวิธี Gas Chromatography - Mass Spectroscopy (GC-MS) และศึกษาเครื่องหมายพันธุกรรมโดยอาศัยลายพิมพ์ดีเอ็นเอชนิดอาร์เอพีดี ข้อมูลที่ได้ถูกนำมาใช้ในการศึกษาความสัมพันธ์ทางวงศ์วานวิวัฒนาการระหว่างพืชในแต่ละสกุล จากการศึกษาพบว่าการจำแนกกลุ่มพืชบนพื้นฐานข้อมูลขององค์ประกอบทางเคมีของน้ำมันระเหยง่ายมีความสอดคล้องกับการจำแนกกลุ่มพืชบนพื้นฐานข้อมูลของลายพิมพ์ดีเอ็นเอชนิดอาร์เอพีดี และพบว่าการจำแนกกลุ่มพืชทั้งสองแบบมีความสัมพันธ์กับลักษณะทางพฤกษศาสตร์ของพืช การศึกษานี้ให้ข้อมูลของเครื่องหมายทางเคมีและเครื่องหมายพันธุกรรมที่อาจนำไปใช้ประโยชน์ในการจำแนกกลุ่มพืชหรือการระบุชนิดของพืชในสกุล *Curcuma* และ *Kaempferia* นอกจากนี้ยังทำให้ทราบถึงความสัมพันธ์ทางวงศ์วานวิวัฒนาการระหว่างพืชในสกุล *Curcuma* ที่ยังไม่ได้ระบุชนิดกับพืชที่ระบุชนิดแล้วซึ่งสามารถใช้เป็นข้อมูลเพิ่มเติมสำหรับการพิสูจน์เอกลักษณ์ของพืชที่ยังไม่ได้ระบุชนิดต่อไป

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ORAWAN THEANPHONG: CHEMICAL CONSTITUENTS OF ESSENTIAL OILS AND RAPD FINGERPRINTS OF *CURCUMA* AND *KAEMPFERIA* PLANTS IN THAILAND. ADVISOR: ASST. PROF. WITCHUDA THANAKIJCHAROEENPATH, Ph.D., CO-ADVISOR: CHANIDA PALANUVEJ, Ph.D., KANCHANA RUNGSIHIRUNRAT, Ph.D., 398 pp.

Twenty-two *Curcuma* species and five *Kaempferia* species in Thailand were investigated for essential oil constituents in the rhizomes by Gas Chromatography - Mass Spectroscopy (GC-MS) analysis and for genetic markers by RAPD fingerprinting. The obtained data were used in studying phylogenetic relationships among species belonging to each of the two genera. The classification of the plants based on essential oil constituents was found to be in agreement with that based on RAPD profiles. Furthermore, both of the classifications were found to relate with morphological characters of the plants. This study gave some information on chemical and RAPD markers which might be useful for classification or identification of *Curcuma* and *Kaempferia* plants. In addition, the phylogenetic relationships of some unidentified *Curcuma* species with the identified species have been revealed, providing additional information for further identification of the unidentified species.

Department:	Pharmacognosy and Pharmaceutical Botany	Student's Signature	....
		Advisor's Signature	....
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CONTENTS

Page

List of Table

List of Figure

LIST OF ABBREVIATIONS

5.8s rDNA	=	5.8s ribosomal DNA
18s rDNA	=	18s ribosomal DNA
26s rDNA	=	26s ribosomal DNA
A, T, C, G	=	nucleotide containing the base adenine, thymine, cytosine, and guanine, respectively
bp	=	base pair
°C	=	degree Celsius
cm	=	centimeter
DNA	=	deoxyribonucleic acid
dNTP	=	deoxyribonucleotide triphosphates (dATP, dTTP, dGTP, dCTP)
EDTA	=	ethylenediaminetetraacetic acid
e.g.	=	exempli gratia (for example)
etc.	=	et cetera (and other things)
EtOH	=	ethanol
GC/MS	=	Gas chromatography/mass spectrometry
g	=	Gram
h	=	hour
i.e.	=	id est (that is)
ITS	=	internal transcribed spacer
kb	=	kilobase
L	=	liter
M	=	molar

$Mgcl_2$	=	magnesium chloride
Min	=	minute
m/z	=	Mass-to-charge ratio
mg	=	Milligram
ml	=	Milliliter
nm	=	Nanometer
ppm	=	part per million
pH	=	the negative logarithm of the concentration of hydrogen ions
RAPD	=	random amplified polymorphic DNA
SCARs	=	sequence characterized amplified regions
sp./spp.	=	species
TBE buffer	=	tris-boric and EDTA buffer
U	=	unit
UV	=	Ultraviolet
UPGMG	=	Unweighted pair group method with arithmetic average
µl	=	Microliter
µg	=	Microgram
µM	=	Micromolar
v/v	=	Volume by volume

CHAPTER I

INTRODUCTION

Zingiberaceae or the ginger family, consisting of 53 genera and over 1200 species, is the largest family of the order Zingiberales (Kress, Prince, & Williams, 2002). The distribution of the members of the family is mainly in the tropics and subtropics, especially in Southeast Asia (Sirirugsa, 1999). Thailand is one of the rich sources of Zingiberaceous plants in the world. About 20 genera and 200 species can be found in the country (Larsen & Larsen, 2006). Plants in this family are important sources of food, spices, medicines, dyes, perfumes and cosmetics. Many of them are also cultivated for their economic uses or as ornamental plants. Several species have been used ethnomedically in various countries, including members of the two genera, *Curcuma* and *Kaempferia* (Chuakul & Boonpleng, 2003; Silja, Varma, & Mohanan, 2008)

Curcuma is one of the well-known genera of the family Zingiberaceae. Several *Curcuma* plants have long been known for their uses as food, spices and medicinal plants. However, the botanical identity of many species is confusing owing to their similar appearance and, probably, their natural hybridization (Skornickova, 2006). In addition, a comprehensive taxonomic revision of the whole genus has not yet been accomplished as there are some major problems in the taxonomic studies such as lack of type specimens and illustrations of old species, lack of protologues with finer details in the earlier literature, absence of important floral parts in the herbarium specimens, incomplete description of the rhizome features in the herbarium sheets, fleshy and perishable aerial portions, etc. (Sasikumar, 2005).

Similar to *Curcuma* plants, members of the genus *Kaempferia*, some of which have been used in food and ethnomedicine, are difficult for taxonomic differentiation. The difficultly in distinguishing the identity of these plants results from the morphological similarity of vegetative parts among species of the genus and other closely related genera such as *Boesenbergia, Scaphochlamys* and *Caulokaempferia*

(Holttum, 1950; Picheansoonthon & Koonterm, 2008; Techaprasan, Klinbunga, Ngamriabsakul, & Jenjittikul, 2010).

As the taxonomic identification of plants in the genera *Curcuma* and *Kaempferia* cannot be accomplished effectively through the classical method based on plant morphology, more information on other characters of the plants is required. Chemical characters, used in chemotaxonomic study, and genetic characters, usually represented by DNA sequences to be analyzed for genetic variation, have been proved to be helpful in taxonomic classification and identification of some plant taxa (A. Sharma, Namdeo, & Mahadik, 2008).

The chemical characters of plants are applied for taxonomic approach through the study called "chemotaxonomy". The study provides the classification of plants based on differences and similarities in their chemical constituents. Its advantages include the obvious information used for the differentiation among the groups and the convenience in providing specimen for the study. Furthermore, there are less variations in chemical characters than in botanical characters in an individual plant species (Ankanna, Suhrulatha, & Savithramma, 2012; Bhargava, Patel, & Desai, 2013; Mannheimer, 1998-1999). Chemical constituents of essential oils are a group of compounds generally used in chemotaxonomic study, especially for aromatic plants. Examples of plants which were investigated on their essential oil components for chemotaxonomic purpose, include those of the genera *Ferula* of the Apiaceae (Kanani *et al.*, 2011), *Teucrium* (Radulovic, Dekic, Joksovic, & Vukicevic, 2012; Sonboli *et al*., 2013) and *Ocimum* of the Lamiaceae (Pirmoradi, Moghaddam, & Farhadi, 2013), *Amomum* of the Zingiberaceae (Setyawan, 2002) and *Juniperus* of the Cupressaceae (Rajcevic, Janackovic, Bojovic, Tesevic, & Marin, 2013).

The genetic variation among plants groups, deduced from the DNA sequence, provides useful information for taxonomic study. There are several DNA based molecular technique which are reliable and powerful tools for identification of taxa at various infrageneric levels as they provide consistent results irrespective of age, tissue origin, physiological conditions, environmental factors, harvest, storage, and processing of samples (Heubl, 2010). The random amplified polymorphic DNA (RAPD) technique (Williams, Kubelik, Livak, Rafalski, & Tingey, 1990) is popularly used in genetic studies. RAPD marker is a rapid, inexpensive and effective tool for studying genetic relationships in various plants due to their advantages i.e. no need of prior knowledge of the DNA sequence, the small amount of DNA used in the study and the ability to assay for many loci simultaneously (Semagn, Bjornstad, & Ndjiondjop, 2006; Zou *et al*., 2011). The RAPD technique has been reported of its application in the differentiation of several plants in Zingiberaceae such as those of the genera *Boesenbergia* (Vanijajiva, Sirirugsa, & Suvachittanont, 2005), *Kaempferia* (Pojanagaroon, Praphet, Kaewrak, & Yotdi, 2004; Vanijajiva *et al*., 2005) and *Curcuma* (Kitamura *et al*., 2007; Sasikumar, 2005; Syamkumar & Sasikumar, 2007; Zou *et al*., 2011).

The present study aims to investigate essential oil components of the rhizomes of some *Curcuma* and *Kaempferia* species found in Thailand, and to determine RAPD fingerprints of these plants, in order to obtain the data for studying phylogenetic relationships among the species belonging to each of the two genera. The results might provide some useful information for taxonomic study of *Curcuma* and *Kaempferia* and for better understanding on the taxonomic positions of the unidentified species used in this study.

CHAPTER II
LITERATURE REVIEW

2.1 The genera *Curcuma* and *Kaempferia*

2.1.1 The genus *Curcuma*

The genus *Curcuma,* comprising about 110 species, belongs to the family Zingiberaceae. Plants in the genus are widely distributed in tropical Asia and the Asia-Pacific region. The greatest diversity occurs in India, Myanmar and Thailand and the distribution extends to Korea, China, Australia and the South Pacific (Ravindran, Babu, & Shiva, 2007). The morphological descriptions of plants in the genus *Curcuma* are as follows.

Perennial rhizomatous herbs, rhizomes branched, fleshy, aromatic, often with tuber-bearing roots. Leaves basal; leaf blade broadly lanceolate or oblong, rarely narrowly linear. Inflorescence a terminal spike on pseudostems or on separate shoots arising from rhizomes, sometimes appearing before leaves; peduncle erect; bracts connate for ca. 1/2 their length and forming pouches, spreading at free ends, each subtending a cincinnus of 2–7 flowers, apical bracts often differently colored, large, sterile, forming a coma; bracteoles free to base. Calyx usually shortly tubular, split on 1 side, apex 2- or 3-lobed or -toothed. Corolla funnelform; lobes ovate or oblong, subequal or central lobe longer, apex mucronate. Lateral staminodes petaloid, basally adnate to filament and labellum. Labellum with a thickened, central portion and thinner, lateral lobes overlapping with lateral staminodes. Filament short, broad; anther versatile, base usually spurred; connective appendage absent. Ovary 3-loculed. Capsule ellipsoid, 3-valved, dehiscent (Delin & Larsen, 2000).

According to Burtt and Smith (1972), the family Zingiberaceae was classified, based on morphological features, into 4 tribes and *Curcuma* was placed in the tribe Hedychieae. In the year 2002, Kress *et al.* (2002) classified the family Zingiberaceae, based on DNA sequences of the nuclear internal transcribed spacer

(ITS) and plastid *mat*K regions, into 4 subfamilies and 6 tribes, and *Curcuma* was placed in the tribe Zingibereae (Kress *et al*., 2002). The classifications of the family Zingiberaceae, according to the two systems, are summarized in Table 1.

Table 1. The classifications of the family ZIngiberaceae

Classification system	Subfamily	Tribe
Burtt and Smith (1972)		Globbeae
		Hedychieae*
		Alpinieae
		Zingibereae
Kress *et al*. (2002)	Siphonochiloideae	Siphonochileae
	Tamijioideae	Tamijieae
	Alpinioideae	Alpinieae
		Riedelieae
	Zingiberoideae	Zingibereae*
		Globbeae

* The tribe to which the genus *Curcuma* belongs

The genus *Curcuma* was divided into subgenera and sections by several systems. Baker (1890) divided the genus *Curcuma* into three sections i.e. Exantha, Mesantha and Hitcheniopsis, based on the flowering period, the position of inflorescences, and the bract characters. Schumann (1904) divided this genus into two subgenera; Eucurcuma and Hitcheniopsis, based on the bract and anther spur characteristics and the subgenus Eucurcuma was subdivided, based on the position of the inflorescence, into two sections; Exantha and Mesentha. Valeton (1918) divided the genus into two subgenera; Eucurcuma and Paracurcuma, on the basis of the leaf shapes and ligule, and the subgenus Eucurcuma was subdivided into two sections, Exantha and Mesantha (Maknoi, 2006; Sirirugsa, Larsen, & Maknoi, 2007). The infrageneric classifications of the genus *Curcuma* are summarized in Table 2.

Table 2. The infrageneric classifications of the genus *Curcuma*

Classification system	Genus	Subgenus	Section
Baker (1890)	*Curcuma*	-	Exantha
			Mesantha
			Hitcheniopsis
Schumann (1904)	*Curcuma*	Eucurcuma	Exantha
			Mesentha
		Hitcheniopsis	
Valeton (1918)	*Curcuma*	Eucurcuma	Exantha
			Mesantha
		Paracurcuma	

There are approximately 40 *Curcuma* species in Thailand (Sirirugsa *et al*., 2007). Of these, 38 species are known of their scientific names and the others are still unidentified (Maknoi, Sirirugsa, & Larsen, 2005, 2011; The Botanical Garden Organization, 2014; จรัล มากน้อย & พวงเพ็ญ ศิริรักษ์, 2555; ณรงค์ศักดิ์ ค้านอธรรม, 2551; เต็ม สมิตตินันท์, 2544). The list of identified *Curcuma* species in Thailand is shown in Table 3.

Table 3. The list of *Curcuma* species in Thailand

No.	Species	Vernacular name
1	*Curcuma aeruginosa* Roxb.	ขมิ้นดำ (เชียงใหม่)
		ว่านมหาเมฆ (กลาง)
		ว่านกงจักรพระอินทร์
		ว่านใจดำ
		ว่านมรกต
2	*C. alismatifolia* Gagnep.	กระเจียวบัว (กลาง)
		ขมิ้นโคก (เลย)
		ปทุมมา
3	*C. amada Roxb.*	ขมิ้นขาวบ่า
4	*C. amarissima* Roscoe	ขมิ้นขม (เหนือ)
5	*C. angustifolia* Roxb.	อาวแดง
6	*C. aromatica* Salisb.	ว่านนางคำ (กลาง)
7	*C. aurantiaca* Zijp	ว่านปด
8	*C. bella* C. Maknoi, P. Sirirugsa & K. Larsen	กระเจียวงาม
9	*C. bicolor* J. Mood & K. Larsen	กระเจียวเหลืองแดง
10	*C. candida* (Wall.) Techaprasan & Skornick	ดอกดินเมืองกาญจน์
11	*C. cochinchinensis* Gagnep.	มหาอุดม
12	*C. comosa* Roxb.	ว่านชักมดลูก (กลาง)
		ว่านการบูรเลือด
		ว่านพระยาหัวศึก
		ว่านทรหด
13	*C. caesia* Roxb.	ขมิ้นม่วง
14	*C. ecomata* Craib	กระเจียวสุเทพ
15	*C. flaviflora* S. Q. Tong	กระเจียวเหลือง
16	*C. glans* K. Larsen & J. Mood	มหาอุดม
17	*C. gracillima* Gagnep.	กระเจียว
18	*C. harmandii* Gagnep.	ช่อมรกต
19	*C. larsenii* C. Maknoi & T. Jenjittikul	กระเจียวราศี
20	*C. latifolia* Rosc.	มหากำลัง

Table 3. The list of *Curcuma* species in Thailand (cont.)

No.	Species	Vernacular name
21	*C. leucorrhiza* Roxb.	ขมิ้นขาว
22	*C. longa* L	ขมิ้น (กลาง, ลำปาง)
		ขมิ้นแกง (เชียงใหม่)
		ขมิ้นชัน (กลาง, ใต้)
		ขมิ้นหยอก (เชียงใหม่)
		ขมิ้นหัว (เชียงใหม่)
		ขี้มิ้น (ตรัง, ใต้)
		ตายอ (กะเหรี่ยง, กำแพงเพชร)
		หมิ้น (ตรัง, ใต้)
		สะยอ (กะเหรี่ยง, แม่ฮ่องสอน)
		Turmeric (Common name)
23	*C. mangga* Valeton & Zijp	ขมิ้นขาว (กลาง)
24	*C. parviflora* Wall.	กระเจียวขาว (นครราชสีมา)
		กระเจียวโคก (เลย)
		กระชายดง (เลย)
		อาวขาว (เชียงใหม่)
		ว่านเทพรำลึก
		ว่านเทพประชุม
		ว่านเทพรำพึง
		ว่านเทพรำเพย
		ว่านขมิ้นขาวเสน่ห์
		ว่านฉิมพลี
		หิ่งห้อย
25	*C. petiolata* Roxb.	บัวชั้น
26	*C. pierreana* Gagnep.	มหาอุดมแดง
27	*C. rhabdota* P. Sirisugsa & M. F. Newman	บัวลาย
28	*C. rhomba* J. Mood & K. Larsen	กระเจียวเหลี่ยม

Table 3. The list of *Curcuma* species in Thailand (cont.)

No.	Species	Vernacular name
29	*C. roscoeana* Wall.	ขมิ้นแดง (ภูเก็ต, แม่ฮ่องสอน)
		บัวสวรรค์ (กทม., พังงา)
		กระเจียวส้ม
30	*C. rubescens* Roxb.	กระเจียวกาบแดง
31	*C. rubrobracteata* Skornickova, Sabu & Prananthk.	ว่านงูเห่า
32	*C. sessilis* Gage	กระเจียว (กลาง)
		กาเตียว (เลย)
		จวด (ชุมพร, สงขลา)
		อาวแดง (เหนือ)
33	*C. singularis* Gagnep.	กระเจียวขาว
34	*C. sparganifolia* Gagnep.	กระเจียวบัว (กลาง)
35	*C. stenochila* Gagnep.	ว่านงูเห่า
36	*C viridiflora* Roxb.	ขมิ้นป่า
37	*C. xanthorrhiza* Roxb.	ว่านชักมดลูก (กลาง)
38	*C. zedoaria* (Berg) Roscoe	ขมิ้นขึ้น (เหนือ)
		ขมิ้นอ้อย (กลาง)
		แฮ้วดำ (เชียงใหม่)
		ว่านเหลือง
		ละเมียด (เขมร)
		สากเบือ (ละว้า)

Based on morphological characters, Sirirugsa *et al.* (2007) divided *Curcuma* species in Thailand into 5 groups i.e. Alismatifolia, Cochinchinensis, Ecomata, Longa and Petiolata. The important morphological characteristics for classification into each group are anther types, the presence or absence and shape of stylodial glands, and the shape of bract apex. Details on morphological characteristics and distribution of members of each group are shown in Table 4.

Table 4. Details on morphological characteristics and distribution of *Curcuma* plants in Thailand as divided in 5 group

Group	Morphological characteristics			Species	Distribution in Thailand
	Anther spur	Stylodial gland	Bract apex		
Alismatifolia	Absent	Absent	Acute to rounded	*C. alismatifolia* *C. gracillima* *C. harmandii* *C. parviflora* *C. rhabdota* *C. sparganiifolia*	Northeastern and eastern
Cochinchinensis	Filamentous	Shortly, cylindrical	Acute	*C. cochinchinensis C. pierreana*	*C. cochinchinensis*: north and southwest, *C. pierreana*: eastern (limited)
Ecomata	Broad and blunt	Long and slender	Acute	*C. bicolor* *C. ecomata* *C. flaviflora* *C. glans* *C. singularis* *C. stenochila*	Northern *C. singularis* and *C. stenochila*: northeastern, eastern and southeastern

Table 4. Details on morphological characteristics and distribution of *Curcuma* plants in Thailand as divided in 5 group

Group	Morphological characteristics			Species	Distribution in Thailand
	Anther spurs	Stylodial gland	Bract apex		
Longa	Acicular, inwardly curved	Cylindrical	Acute	*C. aeruginosa* *C. amada* *C. angustifolia* *C. aromatica* *C. comosa* *C. latifolia* *C. leucorrhiza* *C. longa* *C. mangga* *C. rubescens* *C. viridiflora* *C. zanthorrhiza* *C. zedoaria*	Cultivated, few of them grow wild in the north

Table 4. Details on morphological characteristics and distribution of *Curcuma* plants in Thailand as divided in 5 group

Group	**Morphological characteristics**			**Species**	**Distribution in Thailand**
	Anther spurs	Stylodial gland	Bract apex		
Petiolata	Shortly acicular, straight	Cylindrical	Truncate or rounded	*C. aurantiaca* *C. petiolata* *C. roscoeana* *C. rubrobracteata*	North and western

2.1.2 The genus *Kaempferia*

The genus *Kaempferia* comprises approximately 60 species distributed from tropical Africa to India and throughout Southeast Asia (Sirirugsa, 1992). The morphological descriptions of plants in the genus *Curcuma* are as follows.

Perennial rhizomatous herb; rhizome fleshy, usually short, with several roots in a fascicle; roots often bearing tubers. Leaves 1 to few, rising from the rhizome; blades filiform to very broad; petiole usually short; sheath often keeled, broad and short; ligule small, inconspicuous, or none. Inflorescence usually enclosed by the two innermost leaf-sheath, or by bladeless sheaths as in *K. rotunda*. Flower few to many, spirally arranged, forming head-like inflorescence, each solitary accompanied by 2 small bracteoles in the axil of bract. Bracts usually lanceolate or linear. Calyx tubular, divided along one side, the apex unequally 2- to 3- lobed. Corolla-tube long and slender; lobes subequal, usually linear. Staminodes petaloid, often similar to the halves of the labellum, white or lilac. Labellum usually deeply bilobed or emarginated as in *K. parviflora*, the two halves often of similar shape and side to the staminodes, mostly obovate, usually white or purple, sometimes make difference colour. Stamen with very short filament or sessile; anther usually 2-5 mm long, longitudinally dehising; anther-crest usually large, entire or lobed. Ovary trilocular, placentation axile; stylodes mostly filiform (Sirirugsa, 1992).

In Thailand, 21 species of *Kaempferia* are now recognized (Jenjittikul & Larsen, 2000; Picheansoonthon, 2010, 2011; Picheansoonthon & Koonterm, 2008, 2009; Sirirugsa, 1992). The list of *Kaempferia* species in Thailand is shown in Table 5.

Table 5. The list of *Kaempferia* species in Thailand

No.	Species	Vernacular name
1	*Kaempferia angustifolia* Roscoe	เต่าหนังแห้ง (กลาง)
		ปราบสมุทร (กลาง)
		ว่านมหานิยม
2	*K. elegans* (Wall.) Baker	เปราะใหญ่ (กลาง)
		ว่านนกคุ้ม
		เปราะป่า
		ว่านถอนโมกขศักดิ์
		ว่านนกคุ้มตัวเมีย
		ว่านเสือสามทุ่ง
3	*K. fallax* Gagnep.	เปราะลวง (กลาง)
4	*K. filifolia* K.Larsen	เปราะใบแคบ (กลาง)
5	*K. galanga* L.	เปราะหอม (กลาง)
		ว่านตีนดิน (เหนือ)
		ว่านแผ่นดินเย็น (เหนือ)
		ว่านหอม (เชียงใหม่, เหนือ)
		หอมเปราะ (กลาง)
		ว่านเสน่ห์จันทร์หอม
6	*K. grandifolia* Saensouk & Jenjitt.	อีหมูบ
7	*K. glauca* Ridl.	เปราะนวล (กลาง)
		เปราะใต้
8	*K. koratensis* Picheans	-
9	*K. laotica* Gagnep.	เปราะ
10	*K. larsenii* Sirirugsa	เปราะราศี (กลาง)
11	*K. lopburiensis* Picheans.	-
12	*K. marginata* Carey	เปราะเถื่อน (ชุมพร, ประจวบคีรีขันธ์)
		เปราะป่า (กลาง,ใต้)
		ว่านกระแจะจันทร์

Table 5. The list of *Kaempferia* species in Thailand (cont.)

No.	Species	Vernacular name
13	*K. parviflora* Wall. ex Baker	กระชายดำ (กลาง, มหาสารคาม)
		ว่านกำบังภัย
		ว่านจังงัง
		ว่านพญานกยูง
14	*K. pulchra* (Ridl.) Ridl.	เปราะป่า (กลาง, ใต้)
15	*K. roscoeana* Wall.	เปราะป่า (กลาง, ใต้)
		ว่านเปราะดอกขาว
16	*K. rotunda* L.	ว่านดอกดิน (เลย, สุราษฎร์ธานี)
		ว่านตูบหมู (เลย)
		ว่านนอนหลับ (เชียงใหม่)
		ว่านส้ม (ขอนแก่น)
		ว่านหาวนอน (ราชบุรี)
		เอื้องดิน (กทม., เหนือ)
		ว่านทิพยเนตร
		ว่านกำแพงขาว
		ว่านกำแพงเจ็ดชั้น
		ว่านไก่ดำ
		ว่านไม้ดีด
17	*K. siamensis* Sirirugsa	กระชายไทย (กลาง)
18	*K. saraburiensis* Picheans.	-
19	*K. sisaketensis* Picheans. & Koonterm	เปราะหูกระต่าย
20	*K. speciosa* (J. Koenig) Thunb.	ว่านหางนกยูง (กทม., ปัตตานี)
21	*K. spoliata* Sirirugsa	ว่านสมประสงค์ (กลาง)

2.2 Ethnomedical uses of *Curcuma* and *Kaempferia* plants

Plants in the genera *Curcuma* and *Kaempferia* are used in ethnomedicine in many countries such as India (Mohanta, Rout, & Sahu, 2006), Nepal (A. Singh, Kumar, & Tewari, 2012), Bangladesh (Partha & Hossain, 2007), Malaysia (Samuel *et al*., 2010) and Thailand (Chuakul & Boonpleng, 2003, 2004). For example, *Curcuma* and *Kaempferia* plants are used in the treatment of pneumonia, bronchial complaints, abdominal illness, dysentery, diarrhoea, leukorrhea, wound and insect bites (Chuakul & Boonpleng, 2003, 2004; Tushar, Basaka, Sarma, & Rangan, 2010). The ethnomedical uses of *Curcuma* and *Kaempferia* plants are summarized in Tables 6 and 7, respectively.

Table 6. Ethnomedical uses of *Curcuma* plants

Species	Part use	Ethnomedical use	Reference
C. amada	Rhizome	Antiarthritic	(A. Singh *et al*., 2012)
		Antiasthmatic	(Daimei & Kumar, 2014)
		Antibacterial	(Tushar *et al*., 2010)
		Antidote	(Choudhary, Singh, & Pillai, 2008)
		Antidiarrheal	(Buragohain, 2011)
		Anti-impotence	(Buragohain, 2011)
		Anti-inflammatory	(Jatoi, Kikuchi, Gilani, & Watanabe, 2007; A. Singh *et al*., 2012; Tushar *et al*., 2010)
		Antipruritic	(Jatoi *et al*., 2007)
		Antitussive	(Daimei & Kumar, 2014; Jatoi *et al*., 2007)
		Relief of muscle pain	(Upadhyay, Parveen, Dhaker, & Kumar, 2010)
		Treatment for bronchiolitis	(Tushar *et al*., 2010)
		Treatment for cold	(Jatoi *et al*., 2007)
		Antiulcer	(Sonowal & Barua, 2011)
		Treatment for skin diseases	(Jatoi *et al*., 2007)
		Carminative	(Jatoi *et al*., 2007; Tushar *et al*., 2010)
		Digestive	(A. Singh *et al*., 2012)
		Wound healing	(Jatoi *et al*., 2007)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
	Root	Anti-impotence	(Partha & Hossain, 2007)
	Whole plant	Antihemorrhoidal	(Rout & Thatoi, 2009)
C. angustifolia	Inflorescence and rhizome	Anticancer	(Daimei & Kumar, 2014)
		Anti-inflammatory	(Daimei & Kumar, 2014)
		Antituberculosis	(Daimei & Kumar, 2014)
		Treatment for bone fractures	(Daimei & Kumar, 2014)
	Rhizome	Antiasthmatic	(Padal & Sandhyasri, 2013)
		Treatment for bruises	(Kunwar, Shrestha, & Bussmann, 2010)
		Antidysentery	(Ray, Sheikh, & Mishra, 2011)
		Antifungal	(Tushar *et al*., 2010)
		Antipyretic	(Ray *et al*., 2011; Tushar *et al*., 2010)
		Anagesic	(Kunwar *et al*., 2010)
		Treatment for jaundice	(Abhyankar & Upadhyay, 2011)
		Treatment for stomatitis	(Tushar *et al*., 2010)
		Aid in blood coagulation	(Tushar *et al*., 2010)
		Demulcent	(Tushar *et al*., 2010)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Galactagogue	(Padal & Chandrasekhar, 2013; Padal & Sandhyasri, 2013)
		Muscle relaxant	(Nuammee, Seraypheap, Yannawat, & Seelanan, 2012)
	Root	Antidysentery	(Mohanta *et al*., 2006)
		Antitussive	(Rokaya, Munzbergova, & Timsina, 2010)
		Treatment for bone fractures	(Rokaya *et al*., 2010)
		Treatment for cold	(Rokaya *et al*., 2010)
		Relief of stomachache	(Rokaya *et al*., 2010)
	Tuber	Antiparasitic	(Kunwar *et al*., 2010)
		Treatment for skin diseases	(Kunwar *et al*., 2010)
		Treatment for urinary ailments	(Kunwar *et al*., 2010)
C. aromatica	Rhizome	Treatment for bruises	(Tushar *et al*., 2010)
		Anticancer	(Tushar *et al*., 2010)
		Anthelmintic	(Daimei & Kumar, 2014; Tushar *et al*., 2010)
		Treatment for impetigo	(Kingston *et al*., 2009)
		Treatment for leucoderma	(Daimei & Kumar, 2014)
		Anti-inflammatory	(Buragohain, 2011; Tushar *et al*., 2010)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Antipruritic	(Majumdar & Datta, 2007)
		Antipyretic	(Majumdar & Datta, 2007)
		Antidote to snake bites	(Tushar *et al*., 2010)
		Astringent	(Tushar *et al*., 2010)
		Analgesic	(Padal & Sandhyasri, 2013)
		Antiemetic	(Pradhan & Badola, 2008)
		Relief of stomachache	(Pradhan & Badola, 2008)
		Treatment for chicken pox	(Padal & Chandrasekhar, 2013; Padal, Sandhyasri, & Chandrasekhar, 2013)
		Carminative	(Pradhan & Badola, 2008; Tushar *et al*., 2010)
		Laxative	(A. Das, Dutta, & Sharma, 2008)
	Tuber	Anthelmintic	(Jain, Katewa, Galav, & Sharma, 2005)
		Antipyretic	(Jain *et al*., 2005)
		Antiarthritic	(Jain *et al*., 2005)
		Digestive	(Jain *et al*., 2005)
	Whole plant	Blood purifier	(Kala, 2005)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
C. aurantiaca	Rhizome	Hemostatic	(Chuakul & Boonpleng, 2003)
C. caesia	Leaf	Treatment for skin diseases	(Padal *et al*., 2013)
	Rhizome	Antiasthmatic	(Kala, 2005; Tushar *et al*., 2010)
		Treatment for bruises	(Buragohain, 2011; B. Saikia, 2006)
		Antidiarrheal	(Kagyung, Gajurel, Rethy, & ingh, 2010)
		Antidysentery	(Tushar *et al*., 2010)
		Antifungal	(Tushar *et al*., 2010)
		Anti-inflammatory	(Buragohain, 2011; B. Saikia, 2006; Tushar *et al*., 2010)
		Anti-inflammatory caused by insects and snake bites	(Tushar *et al*., 2010)
		Antimicrobial	(Tushar *et al*., 2010)
		Antipyretic	(Pfoze, Kumar, & Myrboh, 2012)
		Antitussive	(Kala, 2005)
		Antidote	(Partha & Hossain, 2007)
		Antidote to snake and scorpion bites	(Tag, Das, & Loyi, 2007)
		Relief of liver pain	(Partha & Hossain, 2007)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Relief of stomachache	(Pfoze *et al*., 2012)
		Treatment for jaundice	(Padal & Chandrasekhar, 2013)
		Treatment for gout	(Nath & Deka, 2011; B. Saikia, 2006)
		Carminative	(Pradhan & Badola, 2008)
		Wound healing	(Tushar *et al*., 2010)
	Root	Antitussive	(Idrisi, Badola, & Singh, 2010)
		Antiasthmatic	(Idrisi *et al*., 2010)
		Treatment for gastritis	(Idrisi *et al*., 2010)
C. comosa	Rhizome	Treatment for inguinal hernia	(Chuakul & Boonpleng, 2003)
		Aid in uterine involution	(Chuakul & Boonpleng, 2003)
C. decipiens	Rhizome	Treatment for skin diseases	(Abhyankar & Upadhyay, 2011)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
C. longa	Rhizome	Antiallergic	(Padal & Sandhyasri, 2013)
		Antiarthritic	(Anilkumar, 2010; Nath & Deka, 2011; Sirirugsa, 1999)
		Antiblemish	(McClatchey, 1996)
		Treatment for bruises	(Anis, Sharma, & Iqbal, 2000; Silja *et al*., 2008)
		Antibacterial	(Tushar *et al*., 2010)
		Anticancer	(Tushar *et al*., 2010)
		Antidiabetic	(Kadir, Sayeed, Shams, & Mia, 2012)
		Antidiarrheal	(Sirirugsa, 1999)
		Antifungal	(Tushar *et al*., 2010)
		Antihemorrhoidal	(Rout, Panda, & Mishra, 2009)
		Anthelmintic	(A. Singh *et al*., 2012)
		Anti-inflammatory	(Anilkumar, 2010; Kulkarni, Patki, Jog, Gandage, & Patwardhan, 1991; Tangjang, Namsa, Arana, & Litin, 2011; Tushar *et al*., 2010)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Antimalarial	(Adebayo & Krettli, 2011; Odugbemi, Akinsulire, Aibinu, & Fabeku, 2007; Velayudhan, Dikshit, & Nizar, 2012)
		Antipyretic	(Adebayo & Krettli, 2011; Chuakul, 2005; Chuakul & Boonpleng, 2003; Odugbemi *et al*., 2007; Padal & Sandhyasri, 2013; Velayudhan *et al*., 2012)
		Antipruritic	(Padal & Sandhyasri, 2013)
		Treatment for scabies	(Rajakumar & Shivanna, 2009; Tushar *et al*., 2010; Velayudhan *et al*., 2012)
		Antituberculosis	(Sirirugsa, 1999)
		Antitussive	(Anilkumar, 2010; Sirirugsa, 1999)
		Antiviral	(Tushar *et al*., 2010)
		Antidote	(Silja *et al*., 2008)
		Antidote for insect poisons and snake bites	(Rahmatullah *et al*., 2009; Velayudhan *et al*., 2012)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Relief of body discomfort	(Chuakul, Saralamp, & Boonpleng, 2002)
		Relief of breast pain	(Velayudhan *et al*., 2012)
		Relief of muscular pain	(Upadhyay *et al*., 2010)
		Analgesic	(A. Das *et al*., 2008)
		Relief of stomachache	(Sirirugsa, 1999)
		Relief of swelling	(Anis *et al*., 2000)
		Treatment for abscesses	(Hariyadi & Ticktin, 2012)
		Treatment for anorexia	(Anilkumar, 2010)
		Treatment for biliary disorders	(Anilkumar, 2010)
		Treatment for blood disorders	(Khisha, Karim, Chowdhury, & Banoo, 2012)
		Treatment for bone fractures	(Bantawa & Rai, 2009)
		Treatment for cold	(Anilkumar, 2010)
		Treatment for diabetic wounds	(Anilkumar, 2010)
		Treatment for hepatic disorders	(Anilkumar, 2010)
		Treatment for jaundice	(Padal *et al*., 2013; A. Singh *et al*., 2012; Tushar *et al*., 2010)
		Treatment for liver disorders	(A. Singh *et al*., 2012)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Treatment for mumps	(Silja *et al*., 2008)
		Treatment for paralysis	(Chamratpan & Homchuen, 2005)
		Treatment for sinusitis	(Anilkumar, 2010)
		Treatment for skin diseases	(Silja *et al*., 2008)
		Blood purifier	(A. Singh *et al*., 2012)
		Carminative	(Kagyung *et al*., 2010; Sajem & Gosai, 2006; Sirirugsa, 1999; Tushar *et al*., 2010)
		Digestive	(Kagyung *et al*., 2010)
		Hemostatic	(Pfoze *et al*., 2012; A. Singh *et al*., 2012)
		Insect repellant	(McClatchey, 1996)
		Laxative	(McClatchey, 1996)
		Muscle relaxant	(A. Singh *et al*., 2012)
		Tonic	(A. Singh *et al*., 2012; Sirirugsa, 1999)
		Vasodilator	(Tushar *et al*., 2010)
		Wound healing	(Bhat, Hegde, & Hegde, 2012; A. Singh *et al.*, 2012; Upadhyay *et al.*, 2010)
	Rhizome and leaf	Anticancer	(Daimei & Kumar, 2014)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Anthelmintic	(Daimei & Kumar, 2014)
		Antiseptic	(Daimei & Kumar, 2014)
		Blood purifier	(Daimei & Kumar, 2014)
	Root	Antipyretic	(Pradhan & Badola, 2008)
		Antitussive	(Pradhan & Badola, 2008)
		Relief of throat pain	(Pradhan & Badola, 2008)
		Treatment for cold	(Pradhan & Badola, 2008)
		Treatment for skin diseases	(A. Saikia, Ryakala, Sharma, Goswami, & Bora, 2006)
C. oligantha	Rhizome	Tonic	(Chuakul & Boonpleng, 2003)
C. parviflora	Rhizome	Relief of body discomfort	(Chuakul & Boonpleng, 2003)
		Wound healing	(Sirirugsa, 1999)
C. petiolata	Rhizome	Relief of stomachache	(Samuel *et al*., 2010)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
C. pseudomontana	Tuber	Blood purifier	(Bhosle, Ghule, undhe, & agtap, 2009; Jagtap, Deokule, & Bhosle, 2006)
C. sessilis	Rhizome	Tonic	(Chuakul & Boonpleng, 2003)
C. sparganifolia	Rhizome	Antiasthmatic	(Chuakul & Boonpleng, 2003, 2004)
C. xanthorrhiza	Rhizome	Antiasthmatic	(Daimei & Kumar, 2014)
		Antidysentery	(Sirirugsa, 1999)
		Anthelmintic	(Daimei & Kumar, 2014)
		Antihemorrhoidal	(Sirirugsa, 1999)
		Antimicrobial	(Sirirugsa, 1999)
		Antipyretic	(Sirirugsa, 1999)
		Relief of stomachache	(Daimei & Kumar, 2014)
		Treatment for bloody diarrhea	(Sirirugsa, 1999)
		Treatment for skin eruptions	(Sirirugsa, 1999)
		Treatment for stomach disorders	(Sirirugsa, 1999)
		Carminative	(Daimei & Kumar, 2014)
		Tonic	(Daimei & Kumar, 2014)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
C. zedoaria	Leaf	Anticancer	(Lobo, Prabhu, Shirwaikar, & Shirwaikar, 2009)
		Treatment for dropsy	(Lobo *et al*., 2009)
		Treatment for furunculosis	(Lobo *et al*., 2009)
	Rhizome	Antiallergic	(Lobo *et al*., 2009)
		Antidiarrheal	(Pradhan & Badola, 2008)
		Treatment for leucoderma	(Tushar *et al*., 2010)
		Treatment for scabies	(Majumdar & Datta, 2007)
		Antiseptic	(Tushar *et al*., 2010)
		Antituberculosis	(Tushar *et al*., 2010)
		Antitussive	(Kala, 2005; Tushar *et al*., 2010)
		Antidote for food poisoning	(Bantawa & Rai, 2009)
		Relief of stomachache	(Sirirugsa, 1999)
		Relief of toothache	(Tushar *et al*., 2010)
		Relief of weakness	(Buragohain, 2011)
		Treatment for cold	(Kala, 2005)
		Treatment for colic	(Pradhan & Badola, 2008)
		Treatment for paralysis	(Chamratpan & Homchuen, 2005)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Treatment for skin diseases	(Pradhan & Badola, 2008)
		Blood purifier	(Tushar *et al*., 2010)
		Carminative	(Sirirugsa, 1999)
		Digestive	(Pradhan & Badola, 2008; Tushar *et al*., 2010)
		Emmenagogic	(Tushar *et al*., 2010)
		Wound healing	(Tushar *et al*., 2010)
	Rhizome oil	Relief of stomachache	(Lobo *et al*., 2009)
		Antiemetic	(Lobo *et al*., 2009)
		Emmenagogic	(Lobo *et al*., 2009)
	Root	Treatment for leukorrhea	(Lobo *et al*., 2009)
	Tuber	Antimicrobial	Wilson *et al*., 2005
		Treatment for cold	(Wilson *et al*., 2005)
		Anthelmintic	(Lobo *et al*., 2009)
		Carminative	Wilson *et al*., 2005
		Digestive	Wilson *et al*., 2005
		Tonic	(Wilson *et al*., 2005)

Table 6. Ethnomedical uses of *Curcuma* plants (cont.)

Species	Part use	Ethnomedical use	Reference
Curcuma sp. (ว่านเลือด)	Rhizome	Antidiarrheal	(Chuakul & Boonpleng, 2003)
Curcuma sp. (กระเจียวขาว)	Rhizome	Tonic	(Chuakul & Boonpleng, 2003)
Curcuma sp. (ขมิ้นจืด)	Rhizome	Treatment for food poisoning	(Chuakul & Boonpleng, 2003)

Table 7. Ethnomedical uses of *Kaempferia* plants

Species	Part use	Ethnomedical use	Reference
K. elegans	Rhizome	Antipyretic	(Chuakul & Boonpleng, 2003)
		Carminative	(Chuakul & Boonpleng, 2003)
K. filifolia	Rhizome	Treatment for leukorrhea	(Chuakul & Boonpleng, 2004)
K. galanga	Rhizome	Antiarthritic	(Hariyadi & Ticktin, 2012)
		Anti-inflammatory	(Daimei & Kumar, 2014)
		Antipyretic	(Chuakul, 2005; Hariyadi & Ticktin, 2012; Nuammee *et al*., 2012; Rahmatullah *et al*., 2009; Sudeesh, 2012)
		Anti-impotence	(Rahmatullah *et al*., 2009)
		Antitussive	(Buragohain, 2011; Ghosh & Sarkhel, 2013; Rahmatullah *et al*., 2009; Samuel *et al*., 2010)
		Relief of abdominal pain	(S. Das, Choudhury, Mandal, & Talukdar, 2012)
		Analgesic	(S. Das *et al*., 2012; Silja *et al*., 2008)

Table 7. Ethnomedical uses of *Kaempferia* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Relief of mouth sores	(Hynniewta & Kumar, 2008)
		Relief of pectoral pain	(S. Das *et al*., 2012)
		Relief of stomachache	(Samuel *et al*., 2010)
		Relief of toothache	(S. Das *et al*., 2012; Ghosh & Sarkhel, 2013)
		Treatment for biliary disorders	(Rahmatullah *et al*., 2009)
		Treatment for blood vomiting	(Hynniewta & Kumar, 2008)
		Treatment for cold	(Buragohain, 2011; S. Das *et al*., 2012)
		Treatment for gastritis	(Sudeesh, 2012)
		Treatment for leprosy	(Rahmatullah *et al*., 2009)
		Treatment for skin diseases	(Sudeesh, 2012)
		Treatment for tongue blisters	(Hynniewta & Kumar, 2008)
		Abortifacient	(Daimei & Kumar, 2014)
		Blood purifier	(Rahmatullah *et al*., 2009)
		Carminative	(Nuammee *et al*., 2012; Rahmatullah *et al*., 2009)
		Antidote for poisonous plants	(Chuakul & Boonpleng, 2003)

Table 7. Ethnomedical uses of *Kaempferia* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Digestive	(S. Das *et al*., 2012; Ghosh & Sarkhel, 2013)
		Wound healing	(Sudeesh, 2012)
	Rhizome and leaf	Antidiarrheal	(Tushar *et al*., 2010)
		Antidandruff	(Tushar *et al*., 2010)
		Antidote	(Tushar *et al*., 2010)
		Relief of abdominal pain	(Tushar *et al*., 2010)
		Analgesic	(Tushar *et al*., 2010)
		Relief of menstrual pain	(Tushar *et al*., 2010)
		Relief of pectoral pain	(Tushar *et al*., 2010)
		Relief of toothache	(Tushar *et al*., 2010)
		Treatment for cold	(Tushar *et al*., 2010)
		Carminative	(Tushar *et al*., 2010)
		Digestive	(Tushar *et al*., 2010)
		Insecticidal	(Tushar *et al*., 2010)
	Rhizome and tuber	Antiarthritic	(Sirirugsa, 1999)
		Relief of abdominal pain	(Sirirugsa, 1999)
		Relief of stomachache	(Sirirugsa, 1999)
		Relief of swelling	(Sirirugsa, 1999)
		Relief of toothache	(Sirirugsa, 1999)
		Antidandruff	(Sirirugsa, 1999)

Table 7. Ethnomedical uses of *Kaempferia* plants (cont.)

Species	Part use	Ethnomedical use	Reference
		Carminative	(Sirirugsa, 1999)
	Tuber	Anthelmintic	(Francis, Arun, & Freeda, 2012)
		Antipyretic	(Francis *et al*., 2012)
		Relief of stomachache	(Francis *et al*., 2012)
		Treatment for lung diseases	(Francis *et al*., 2012)
K. larsenii	Rhizome	Treatment for insect bites	(Chuakul & Boonpleng, 2004)
		Antidote	(Chuakul & Boonpleng, 2003)
K. marginata	Rhizome	Relief of edema	(Chuakul & Boonpleng, 2003)
		Relief of stomachache	(Daimei & Kumar, 2014)
		Abortifacient	(Daimei & Kumar, 2014)
	Whole plant	Antipyretic	(Chuakul *et al*., 2002)
K. parviflora	Rhizome	Antidiarrheal	(Nuammee *et al*., 2012)
		Anti-impotence	(Daimei & Kumar, 2014)
		Anti-inflammatory	(Daimei & Kumar, 2014)
		Blood purifier	(Nuammee *et al*., 2012)
		Tonic	(Nuammee *et al*., 2012)
	Tuber	Treatment for bronchial ailments	(Partha & Hossain, 2007)
		Treatment for pheumonia	(Partha & Hossain, 2007)

Table 7. Ethnomedical uses of *Kaempferia* plants (cont.)

Species	Part use	Ethnomedical use	Reference
K. pulchra	Rhizome, leaf and pseudo stem	Treatment for bronchial ailments	(Tushar *et al*., 2010)
		Treatment for pheumonia	(Tushar *et al*., 2010)
		Wound healing	(Tushar *et al*., 2010)
K. roscoeana	Rhizome	Antidote	(Chuakul & Boonpleng, 2003)
K. rotunda	Leaf and root	Treatment for gastritis	(Daimei & Kumar, 2014)
	Rhizome	Treatment for bone fractures	(Bantawa & Rai, 2009)
		Treatment for joint dislocation	(Bantawa & Rai, 2009)
		Antiulcer	(Rout & Thatoi, 2009)
		Carminative	(Nuammee *et al*., 2012)
		Insect repellant	(S. Das *et al*., 2012)
		Antidote	(Chuakul & Boonpleng, 2003)
	Rhizome and leaf	Anti-inflammatory	(Tushar *et al*., 2010)
		Relief of stomachache	(Tushar *et al*., 2010)
	Stem bark	Treatment for migraine	(Padal *et al*., 2013)

Table 7. Ethnomedical uses of *Kaempferia* plants (cont.)

Species	Part use	Ethnomedical use	Reference
	Tuber	Anticancer	(U. Sharma & Pegu, 2011; A. Singh & Hamal, 2013)
		Anti-inflammatory	(A. Singh & Hamal, 2013)
		Relief of pus	(A. Singh & Hamal, 2013)
		Relief of stomachache	(Sirirugsa, 1999)
		Treatment for abdominal ailments	(Sirirugsa, 1999)
		Treatment for gastric complaints	(Sirirugsa, 1999)
		Treatment for gastroenteritis	(U. Sharma & Pegu, 2011)
		Antiulcer	(U. Sharma & Pegu, 2011)
		Wound healing	(U. Sharma & Pegu, 2011)
K. sikkimensis	Leaf	Treatment for bone fractures	(Idrisi *et al*., 2010)
	Rhizome	Treatment for bone fractures	(Idrisi *et al*., 2010; Pradhan & Badola, 2008)
		Wound healing	(Pradhan & Badola, 2008)

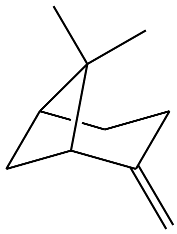
2.3 Chemical constituents of *Curcuma* and *Kaempferia* plants

Previous phytochemical investigations on several *Curcuma* species revealed the presence of various types of secondary metabolites such as monoterpenoids (Jantan, Ahmad, Ali, Ahmad, & Ibrahim, 1999; G. Singh, Singh, & Maurya, 2002), sesquiterpenoids (Jantan *et al*., 1999; R. Sharma *et al*., 1997; Srivastava, Srivastava, & Syamsundar, 2006), diterpenoids (Srivastava *et al*., 2006) and diarylheptanoids (Jayaprakasha, Jagan, & Sakariah, 2005; Jurgens *et al*., 1994; Li *et al*., 2011; Masuda, Isobe, Jitoe, & Nakataw, 1992; Wang, Zhang, Zhang, & Wang, 2008; Winuthayanon *et al*., 2009).

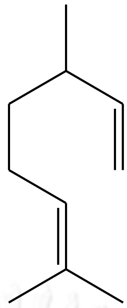
Plants in the genus *Kaempferia* are found to contain a wide range of chemical constituents such as momoterpenoids (Helen, Anil, Nizzy, Jayasree, & Lekshimi, 2011; Sirat, Jamil, & Siew, 2005; Tewtrakul, Yuenyongsawad, Kummee, & Atsawajaruwan, 2005), sesquiterpenoids (Jantan *et al*., 1999; Sirat *et al*., 2005; Woerdenbag, Windono, Bos, Riswan, & Quax, 2004), diterpenoids (Tang, Sukari, Rahmani, Lajis, & Al, 2011; Thongnest, Mahidol, Sutthivaiyakit, & Ruchirawat, 2005) and flavonoids (Tewtrakul, Subhadhirasakul, & Kummee, 2008; Yenjai, Prasanphen, Daodee, Wongpanich, & Kittakoop, 2004).

The rhizomes of *Curcuma* and *Kaempferia* plants are rich sources of essential oils which are responsible for their pleasant aroma and medicinal value. Examples of compound found in essential oil of *Curcuma* rhizomes include β-pinene, 1,8-cineol and camphor of the monoterpenoid group, α-zingiberene, *ar*-turmerone and germacrone of the sesquiterpenoid group while those found in *Kaempferia* essential oils include myrcene and borneol of the monoterpenoid group, germacrene B and caryophyllene oxide of the sesquiterpenoid group and *E*-ethyl cinnamate of the phenylpropanoid group. The structures of those examples are shown in Figure 1. Chemical constituents of the oil of *Curcuma* and *Kaempferia* plants are summarized in Tables 8 and 9, respectively.

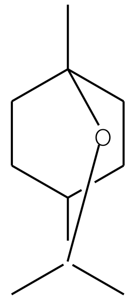
Monoterpenoids



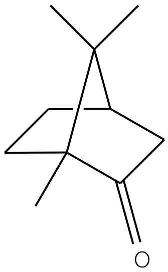
β-Pinene



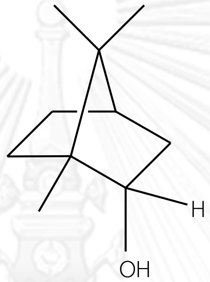
Myrcene



1,8-Cineol

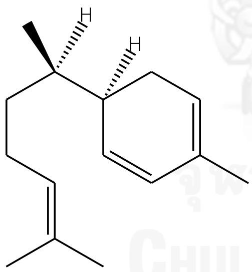


Camphor

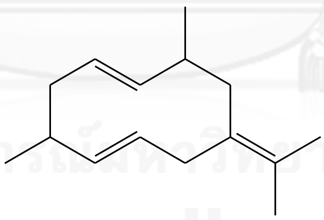


Borneol

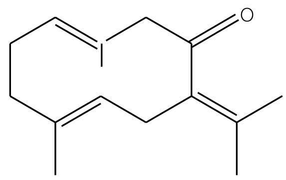
Sesquiterpenoids



α-Zingiberene

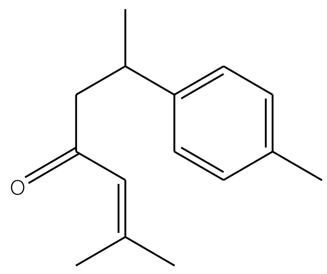


Germacrene B

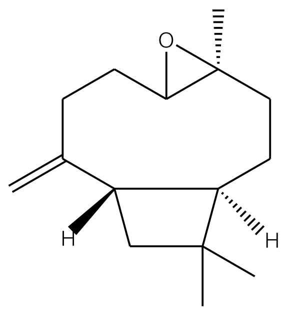


Germacrone

Figure 1. Examples of compounds found in essential oil of *Curcuma* and *Kaempferia* rhizome

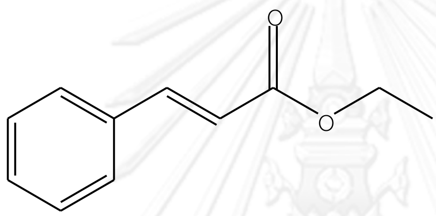


ar-Turmerone



Caryophyllene oxide

Phenylpropanoid derivatives



E-Ethyl cinnamate

Figure 1. Examples of compounds found in essential oil of *Curcuma* and *Kaempferia* rhizome (cont.)

Table 8. Chemical constituents of essential oil of *Curcuma* plants

No.	Chemical constituents	Sources	References
Terpenoids*			
Monoterpenoids			
1	(*Z*,*Z*)-Alloocimene (MH)	*C. mangga*	(Wong, Chong, & Chee, 1999)
2	iso-Artemisia ketone (OM)	*C. longa*	(Usman *et al*., 2009)
3	Borneol (OM)	*C. aeruginosa*	(Jantan *et al*., 1999) (Sirat, Jamil, & Hussain, 1998)
		C. amada	(Srivastava, Srivastava, & Shah, 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi, Sperkova, & Leclercq, 1999)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng, Truong, Ky, & Leclercq, 1997)
		C. kwangsiensis	(Zeng, Xu, & Chen, 2009)
		C. leucorhiza	(Devi, Rana, Devi, Verdeguer, & Blázquez, 2012)
		C. longa	(Jantan *et al*., 1999; R. Sharma *et al*., 1997; Usman *et al*., 2009)

* Letters in the parentheses after the name of terpenoid compounds represent their types according to the presence or absence of O-atom in the molecule; MH= monoterpene hydrocarbon, OM= oxygenated monoterpene, SH= sesquiterpene hydrocarbon, OS= oxygenated sesquiterpene

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. mangga	(Wahab *et al*., 2011; (Wong *et al*., 1999)
		C. ochrorhiza	(Sirat, Jamil, & Rahman, 1997)
		C. wenyujin	(J. Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha, Nath, & Klink, 2006)
4	*endo*-Borneol (OM)	*C. sichuanensis*	(Zhou *et al*., 2007)
5	Isoborneol (OM)	*C. aeruginosa*	(Kamazeri, Samah, Taher, Susanti, & Qaralleh, 2012; Sirat *et al*., 1998)
		C. amada	(Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Raina, Srivastava, & Syamsundar, 2005)
		C. mangga	(Wahab, Blagojevic, Radulovic, & Boylan, 2011)
		C. ochrorhiza	(Sirat *et al*., 1997)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(J. Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006)
6	Bornyl acetate (OM)	*C. caesia*	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. leucorhiza	(Devi *et al*., 2012)
		C. sichuanensis	(Zhou *et al*., 2007)
7	Isobornyl acetate (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
8	Camphene (MH)	*C. aeruginosa*	(Jantan *et al*., 1999; Sirat *et al*., 1998)
		C. amada	(Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
		C. mangga	(Jantan *et al*., 1999) (Wahab *et al*., 2011)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(J. Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(G. Singh *et al*., 2002)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
9	Camphene hydrate (MH)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006)
10	α-Campholenal (OM)	*C. mangga*	(Wahab *et al*., 2011)
11	Camphor (OM)	*C. aeruginosa*	(Kamazeri *et al*., 2012; Sirat *et al*., 1998)
		C. amada	(Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Jantan *et al*., 1999); (Raina *et al*., 2002; Raina *et al*., 2005)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. ochrorhiza	(Sirat *et al*., 1997)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(J. Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
12	*m*-Camphorene (MH)	*C. mangga*	(Wahab *et al*., 2011)
13	*ρ*-Camphorene (MH)	*C. mangga*	(Wahab *et al*., 2011)
14	δ-2-Carene (MH)	*C. longa*	(Gounder & Lingamallu, 2012); (Usman *et al*., 2009)
		C. wenyujin	(J. Cao *et al*., 2006)
15	δ-3-Carene (MH)	*C. amada*	(Rao, Rajanikanth, & Seshadri, 1989)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. longa	(Chane-Ming, Vera, Chalchat, & Cabassu, 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela, Tava, Shafi, John, & Chempakam, 2002; Raina *et al*., 2002; Raina *et al*., 2005; R. Sharma *et al*., 1997; G. Singh *et al*., 2010)
		C. wenyujin	(J. Cao *et al*., 2006)
		C. zedoaria	(G. Singh *et al*., 2002)
16	(1*S*, 3*R*, 6*R*)-(-)- 4-Carene (MH)	*C. wenyujin*	(J. Cao *et al*., 2006)
17	Carvacrol (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
18	Carvomenthene (MH)	*C. amada*	(Rao *et al*., 1989)
19	*cis*-Carvotanacetol (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
20	*cis*-Carveol (OM)	*C. haritha*	(Raj *et al*., 2008)
21	*trans*-Carveol (OM)	*C. mangga*	(Wahab *et al*., 2011)
22	Carvone (OM)	*C. aeruginosa*	(Sirat *et al*., 1998)
		C. longa	(Leela *et al.,* 2002)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
23	*trans*-Chrysanthenyl acetate (OM)	*C. mangga*	(Kamazeri *et al*., 2012)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. longa	(Jantan *et al*., 1999)
			(Raina *et al*., 2002; Raina *et al*., 2005)
		C. xanthorrhiza	(Jantan *et al*., 1999)
24	1,8-Cineole (OM)	*C. aeruginosa*	(Kamazeri *et al*., 2012; Sirat *et al*., 1998)
		C. amada	(Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Raina *et al*., 2005; R. Sharma *et al*., 1997; G. Singh *et al*., 2010; Tsai *et al*., 2011; Usman *et al*., 2009)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. sichuanensis	(Tsai *et al*., 2011)
		C. wenyujin	(J. Cao *et al*., 2006)
		C. zedoaria	(G. Singh *et al*., 2002)
25	Citronellal (OM)	*C. amada*	(Rao *et al*., 1989)
26	Citronellol (OM)	*C. zedoaria*	(G. Singh *et al*., 2002)
27	*m*-Cymene (MH)	*C. wenyujin*	(J. Cao *et al*., 2006)
28	*ρ*-Cymene (MH)	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999) (Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Raina *et al*., 2005; R. Sharma *et al*., 1997; G. Singh *et al*., 2010)
		C. mangga	(Wahab *et al*., 2011) (Wong *et al*., 1999)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. zedoaria	(G. Singh et al., 2002)
29	Dehydro-*ρ*-cymene (MH)	*C. longa*	(R. Sharma et al., 1997)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
30	*ρ*-Cymene-8-ol (OM)	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. longa	(Leela et al., 2002; Raina et al., 2005; G. Singh et al., 2010)
		C. mangga	(Wahab *et al*., 2011)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. zedoaria	(G. Singh et al., 2002)
31	*ρ*-Cymenene (MH)	*C. longa*	(Chane-Ming *et al*., 2002; Jantan *et al*., 1999)
32	Estragole (OM)	*C. caesia*	(Pandey & Chowdhury, 2003)
33	*endo*-Fenchol (OM)	*C. caesia*	(Pandey & Chowdhury, 2003)
34	*exo*-Fenchol (OM)	*C. mangga*	(Wahab *et al*., 2011)
35	α-Fenchol (OM)	*C. mangga*	(Wong et al., 1999)
36	*endo*-Fenchyl acetate (OM)	*C. caesia*	(Pandey & Chowdhury, 2003)
		C. longa	(Raina et al., 2002; Raina et al., 2005)
37	Geranial (OM)	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. longa	(Usman *et al*., 2009)
		C. mangga	(Wahab et al., 2011)
38	Geraniol (OM)	*C. longa*	(Raina et al., 2002; Raina et al., 2005)
		C. mangga	(Wong et al., 1999)
39	Geranyl formate (OM)	*C. mangga*	(Wong et al., 1999)
40	Geranyl butyrate (OM)	*C. longa*	(Raina et al., 2002; Raina et al., 2005)
41	Geranyl hexanoate (OM)	*C. longa*	(Raina *et al*., 2002; Raina *et al*., 2005)

42	2-Isopropylidene-3-methylhexa-3,5-dienal	*C. mangga*	(Kamazeri *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
43	5-Isopropylidene-3,8-dimethyl-1(5H)-azulenone	*C. zedoaria*	(Mau *et al*., 2003)
44	Isopulegol (OM)	*C. comosa*	(Palanuvej & Ruangrungsi, 2007)
45	Lavandulol (OM)	*C. amada*	(Rao *et al*., 1989)
46	Limonene (MH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Srivastava et al., 2001)
		C. aromatica	(Bordoloi et al., 1999; Tsai et al., 2011)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Gounder & Lingamallu, 2012; Jantan et al., 1999; Raina et al., 2005; R. Sharma et al., 1997; G. Singh et al., 2010; Tsai et al., 2011; Usman et al., 2009)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. sichuanensis	(Zhou et al., 2007)
		C. wenyujin	(J. Cao et al., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
47	Linalool (OM)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Srivastava et al., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Jantan *et al.,* 1999; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Tsai *et al*., 2011)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. sichuanensis	(Tsai *et al*., 2011)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Singh *et al*., 2002)
48	*cis*-Linalool oxide (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. aromatica	(Tsai *et al*., 2011)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Tsai *et al*., 2011)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. sichuanensis	(Tsai *et al*., 2011)

		C. zedoaria	(Singh *et al*., 2002)
49	*trans*-Linalooloxide (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. leucorhiza	(Devi *et al*., 2012)
50	Linalyl acetate (OM)	*C. longa*	(Raina *et al*., 2002)
		C. mangga	(Jantan *et al*., 1999)
51	*ρ*-menth-1,8-dien-9-ol (OM)	*C. amada*	(Rao *et al*., 1989)
52	*ρ*-Menth-1-en-9-ol (OM)	*C. amada*	(Rao *et al*., 1989)
53	5-Hydroxy-*ρ*-menth-6-en-2-one (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
54	*trans*-ρ-Menth-2-en-1-ol (MH)	*C. longa*	(Raina *et al*., 2002; Raina *et al*., 2005)
55	*trans*-*ρ*-Mentha-1(7),8-dien-2-ol (OM)	*C. mangga*	(Wahab *et al*., 2011)
56	*ρ*-Menthatriene (MH)	*C. mangga*	(Kamazeri *et al*., 2012)
57	1,3,8-*ρ*-Menthatriene (MH)	*C. wenyujin*	(Cao *et al*., 2006)
58	Menthone (OM)	*C. caesia*	(Pandey & Chowdhury, 2003)
59	Isomenthone (OM)	*C. caesia*	(Pandey & Chowdhury, 2003)
60	2-methyl-6-methylene-1,7-octadien-3-one	*C. mangga*	(Wong *et al*., 1999)
61	2-methyl-6-methylene-3,7-octadien-2-ol	*C. mangga*	(Wong *et al*., 1999)
62	3-Methyl-2-methylene-3-butenyl-2-methylacrylate	*C. mangga*	(Kamazeri *et al*., 2012)
63	*ρ*-Methylacetophenone (OM)	*C. longa*	(Jantan *et al*., 1999)
		C. longa	(Leela *et al*., 2002)
64	Morbornyl acetate (OM)	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
65	Myrcene (MH)	*C. aeruginosa*	(Jantan *et al*., 1999)

		C. aeruginosa	(Sirat *et al*., 1998)
		C. amada	(Mustafa, Ali, & Khan, 2005; Rao *et al*., 1989; Srivastava *et al*., 2001)
		C. amada	(Singh *et al*., 2002)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Sharma *et al*., 1997; Singh *et al*., 2010; Usman *et al*., 2009)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006; Singh *et al*., 2002)
66	6,7-Epoxymyrcene (OM)	*C. mangga*	(Wahab *et al*., 2011)
67	Myrcenol (OM)	*C. mangga*	(Wahab *et al*., 2011; Wong *et al*., 1999)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
68	Dihydromyrcenol (OM)	*C. amada*	(Rao *et al*., 1989)

69	Myrtenal (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2005)
		C. mangga	(Wong *et al*., 1999)
70	Myrtenol (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. harmandii	(Dũng *et al*., 1997)
		C. longa	(Jantan *et al*., 1999; Raina *et al*., 2002)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. sichuanensis	(Zhou *et al*., 2007)
71	*trans*-Myrtanol (OM)	*C. mangga*	(Wahab *et al*., 2011)
72	Myrtenyl acetate (OM)	*C. mangga*	(Wahab *et al*., 2011)
73	Neral (OM)	*C. longa*	(Raina *et al*., 2005; Usman *et al*., 2009)
		C. mangga	(Rao *et al*., 1989; Wahab *et al*., 2011; Wong *et al*., 1999)
74	Nerol (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. mangga	(Wahab *et al*., 2011; Wong *et al*., 1999)
		C. zedoaria	(Singh *et al*., 2002)
75	[1*R*-(1α, 3α-β, 4α, 7β)]-1,2,3,3α,4,5,6,7-Octahydro-1,4-dimethyl-7-(1-methyl ethenyl)- azulene (MH)	*C. wenyujin*	(Cao *et al*., 2006)
76	(*Z*)-β-Ocimene (MH)	*C. amada*	(Rao *et al*., 1989; Singh *et al*., 2002)
		C. caesia	(Pandey & Chowdhury, 2003)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. comosa	(Palanuvej & Ruangrungsi,

			2007)
		C. longa	(Raina *et al*., 2002; Usman *et al*., 2009)
		C. mangga	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006; Singh *et al*., 2002)
77	*cis*-dihydroocimene (MH)	*C. amada*	(Rao *et al*., 1989)
78	(*E*)- β-Ocimene (MH)	*C. amada*	(Rao *et al*., 1989; Singh *et al*., 2002)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005; Usman *et al*., 2009)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006; Singh *et al*., 2002)
79	*trans*-Dihydroocimene (MH)	*C. amada*	(Rao *et al*., 1989)
80	(*E*)-Epoxyocimene (OM)	*C. mangga*	(Wahab *et al*., 2011)
81	α-Phellandrene (MH)	*C. amada*	(Rao *et al*., 1989)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. mangga	(Jantan *et al*., 1999)

		C. zedoaria	(Singh *et al*., 2002)
82	β-Phellandrene (MH)	*C. amada*	(Rao *et al*., 1989)
		C. longa	(Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Usman *et al*., 2009)
		C. mangga	(Wahab *et al*., 2011)
		C. zedoaria	(Singh *et al*., 2002)
83	α-Pinene (MH)	*C. aeruginosa*	(Jantan *et al*., 1999; Sirat *et al*., 1998)
		C. amada	(Singh *et al*., 2002; Srivastava, Srivastava, & Shah, 2001)
		C. angustifolia	(Srivastava, Srivastava, & Syamsundar, 2006)
		C. aromatica	(Bordoloi, Sperkova, & Leclercq, 1999)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng, Truong, Ky, & Leclercq, 1997)
		C. kwangsiensis	(Zeng, Xu, & Chen, 2009)
		C. leucorhiza	(Devi *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Chane-Ming, Vera, Chalchat,

			& Cabassu, 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela, Tava, Shafi, John, & Chempakam, 2002; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010; Tsai *et al*., 2011; Usman *et al*., 2009)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong, Chong, & Chee, 1999)
		C. sichuanensis	(Tsai *et al*., 2011; Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006; Singh *et al*., 2002)
84	Perilla alcohol (OM)	*C. mangga*	(Wahab *et al*., 2011)
85	Perilla ketone (OM)	*C. longa*	(Raina *et al*., 2002)
86	Perillyl alcohol (OM)	*C. mangga*	(Wong *et al*., 1999)
87	Perillene (OM)	*C. amada*	(Singh *et al*., 2002)
		C. mangga	(Wahab *et al*., 2011; Wong *et al*., 1999)
88	*cis*-Pinocamphone (OM)	*C. mangga*	(Wahab *et al*., 2011; Wong *et al*., 1999)
89	Pinocarvone (OM)	*C. mangga*	(Wahab *et al*., 2011)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
90	*cis*-Pinocarveol (OM)	*C. mangga*	(Wahab *et al*., 2011)

		C. sichuanensis	(Zhou *et al*., 2007)
91	*trans*-Pinocarveol (OM)	*C. mangga*	(Wahab *et al*., 2011; Wong *et al*., 1999)
92	*trans*-Pinocarvyl formate (OM)	*C. mangga*	(Wahab *et al*., 2011)
93	Piperitone (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
94	Rosefuran (OM)	*C. mangga*	(Wahab *et al*., 2011)
95	Sabinene (MH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Singh *et al*., 2002)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010; Tsai *et al*., 2011; Usman *et al*., 2009)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. sichuanensis	(Tsai *et al*., 2011)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006; Singh *et al*., 2002)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
96	*cis*-Sabinene hydrate (MH)	*C. zedoaria*	(Singh *et al*., 2002)

97	*trans*-Sabinene hydrate (MH)	*C. mangga*	(Wahab *et al*., 2011; Wong *et al*., 1999)
98	*trans*-Sesquisabinene hydrate (MH)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
99	Sabinyl acetate	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
100	*cis*-Sabinol (OM)	*C. longa*	(Raina *et al*., 2005)
101	Sylvestrene (MH)	*C. comosa*	(Palanuvej & Ruangrungsi, 2007)
102	α-Teripinene (MH)	*C. amada*	(Mustafa *et al*., 2005; Rao *et al*., 1989)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010)
		C. mangga	(Wahab *et al*., 2011; Wong *et al*., 1999)
		C. zedoaria	(Singh *et al*., 2002)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
103	γ-Terpinene (MH)	*C. aeruginosa*	(Jantan *et al*., 1999)

		C. amada	(Mustafa *et al*., 2005; Rao *et al*., 1989)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Usman *et al*., 2009)
		C. mangga	(Wahab *et al*., 2011; Wong *et al*., 1999)
		C. zedoaria	(Singh *et al*., 2002)
104	Terpinen-4-ol (OM)	*C. aeruginosa*	(Jantan *et al*., 1999)
			(Sirat *et al*., 1998)
		C. amada	(Mustafa *et al*., 2005; Singh *et al*., 2002; Srivastava *et al*., 2001)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Chane-Ming *et al*., 2002;

			Jantan *et al*., 1999; Raina *et al*., 2002; Sharma *et al*., 1997; Tsai *et al*., 2011)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006; Singh *et al*., 2002)
105	α-Terpineol acetate (OM)	*C. mangga*	(Kamazeri *et al*., 2012)
106	α-Terpinyl acetate (OM)	*C. amada*	(Rao *et al*., 1989)
107	α-Terpineol (OM)	*C. aeruginosa*	(Jantan *et al*., 1999)
			(Sirat *et al*., 1998)
		C. amada	(Rao *et al*., 1989; Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Gounder & Lingamallu,

			2012; Jantan *et al.*, 1999; Leela *et al.*, 2002; Raina *et al.*, 2002; Tsai *et al.*, 2011; Usman *et al.*, 2009)
		C. mangga	(Jantan *et al.*, 1999; Wahab *et al.*, 2011; Wong *et al.*, 1999)
		C. sichuanensis	(Tsai *et al.*, 2011; Zhou *et al.*, 2007)
		C. xanthorrhiza	(Jantan *et al.*, 1999)
		C. zedoaria	(Mau *et al.*, 2003; Purkayastha *et al.*, 2006)
108	β-Terpineol (OM)	*C. amada*	(Rao *et al.*, 1989)
109	Terpinolene (MH)	*C. aeruginosa*	(Jantan *et al.*, 1999)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. harmandii	(Dũng *et al.*, 1997)
		C. longa	(Chane-Ming *et al.*, 2002; Gounder & Lingamallu, 2012; Leela *et al.*, 2002; Raina *et al.*, 2002; Raina *et al.*, 2005; Sharma *et al.*, 1997; Singh *et al.*, 2010)
		C. mangga	(Jantan *et al.*, 1999; Wahab *et al.*, 2011; Wong *et al.*, 1999)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. ochrorhiza	(Sirat, Jamil, & Rahman,

			1997)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. zedoaria	(Singh *et al*., 2002)
110	α-Thujene (MH)	*C. aeruginosa*	(Jantan, Ahmad, Ali, Ahmad, & Ibrahim, 1999)
		C. haritha	(Raj *et al*., 2008)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Raina, Srivastava, & Syamsundar, 2005; Usman *et al*., 2009)
		C. mangga	(Jantan *et al*., 1999; Wahab, Blagojevic, Radulovic, & Boylan, 2011)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Singh, Singh, & Maurya, 2002)
111	β-Thujone (OM)	*C. harmandii*	(Dũng *et al*., 1997)
112	Thymol (OM)	*C. amada*	(Mustafa *et al*., 2005)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. longa	(Gounder & Lingamallu, 2012; Raina *et al*., 2002 ;Usman *et al*., 2009)
113	Thymol acetate (OM)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2002)
114	Tricyclene (MH)	*C. haritha*	(Raj *et al*., 2008)
		C. leucorhiza	(Devi, Rana, Devi, Verdeguer, & Blázquez, 2012)
115	*trans*-Verbenol (OM)	*C. mangga*	(Wahab *et al*., 2011)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
	Sesquiterpenoids		

1	Albicanol (OS)	*C. mangga*	(Wahab *et al*., 2011)
2	Isoalbicanal (OS)	*C. mangga*	(Wahab *et al*., 2011)
3	Aromadendrene (SH)	*C. haritha*	(Raj *et al*., 2008)
		C. sichuanensis	(Zhou *et al*., 2007)
4	*allo*-Aromadendrene (SH)	*C. haritha*	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
5	Aromadendrene oxide (OS)	*C. aeruginosa*	(Kamazeri *et al*., 2012)
6	Alloaromadendrene oxide (OS)	*C. mangga*	(Kamazeri *et al*., 2012)
		C. aeruginosa	(Kamazeri *et al*., 2012)
7	Isoaromadendrene epoxide (OS)	*C. wenyujin*	(Cao *et al*., 2006)
8	(*E*)-α-Atlantone (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Jantan *et al*., 1999; Raina *et al*., 2002; Raina *et al*., 2005; Singh *et al*., 2010; Sharma *et al*., 1997)
9	α-Bergamotene (SH)	*C. amada*	(Srivastava *et al*., 2001)
10	*cis*-α-Bergamotene (SH)	*C. longa*	Chane-Ming *et al*., 2002; Singh *et al*., 2010
11	*trans*-α-Bergamotene (SH)	*C. comosa*	(Palanuvej & Ruangrungsi, 2007)
		C. longa	(Singh *et al*., 2010)
12	*Z*-α-*trans*- Bergamotol (OS)	*C. longa*	(Gounder & Lingamallu, 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
13	6*S*,7*R* Bisabolene (SH)	*C. longa*	(Leela *et al*., 2002)

14	β-Bisabolene (SH)	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. harmandii	(Dũng *et al*., 1997)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Sharma *et al*., 1997; Singh *et al*., 2010; Singh *et al*., 2002; Usman *et al*., 2009)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003)
15	*trans*-γ-Bisabolene (SH)	*C. longa*	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Singh *et al*., 2010)
16	*trans-Z*- α-Bisabolene epoxide (OS)	*C. wenyujin*	(Cao *et al*., 2006)
17	β-Bisabolol (OS)	*C. amada*	(Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Gounder & Lingamallu, 2012; Raina *et al*., 2002;

			Singh *et al.*, 2010)
18	1-Bisabolone (OS)	*C. harmandii*	(Dũng *et al.*, 1997)
		C. longa	(Raina *et al.*, 2002; Sharma *et al.*, 1997)
19	6*R*,7*R*-Bisabolone (OS)	*C. longa*	(Singh *et al.*, 2010)
20	β-Bourbonene (SH)	*C. harmandii*	(Dũng *et al.*, 1997)
		C. sichuanensis	(Zhou *et al.*, 2007)
21	α-Bulnesene (SH)	*C. aeruginosa*	(Kamazeri *et al.*, 2012)
22	But-3-enal, 2-methyl-4-(2,6,6,-trimethyl- 1-cyclohexenyl) (OS)	*C. mangga*	(Kamazeri *et al.*, 2012)
23	α-Cadinene (SH)	*C. angustifolia*	(Srivastava *et al.*, 2006)
24	7-*epi*-α-Cadinene (SH)	*C. wenyujin*	(Cao *et al.*, 2006)
25	δ-Cadinene (SH)	*C. aromatica*	(Tsai *et al.*, 2011)
		C. haritha	(Raj *et al.*, 2008)
		C. harmandii	(Dũng *et al.*, 1997)
		C. longa	(Tsai *et al.*, 2011)
		C. sichuanensis	(Tsai *et al.*, 2011)
		C. wenyujin	(Cao *et al.*, 2006)
26	α-Cadinol (OS)	*C. haritha*	(Raj *et al.*, 2008)
		C. mangga	(Wahab *et al.*, 2011)
		C. wenyujin	(Cao *et al.*, 2006)
		C. zedoaria	(Mau *et al.*, 2003)
27	*epi*-α-Cadinol (OS)	*C. aromatica*	(Bordoloi *et al.*, 1999)
		C. haritha	(Raj *et al.*, 2008)
		C. harmandii	(Dũng *et al.*, 1997)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Raina *et al.*, 2002; Raina *et al.*, 2005)

		C. mangga	(Wahab *et al*., 2011)
		C. zedoaria	(Purkayastha *et al*., 2006)
28	α-Calacorene (SH)	*C. harmandii*	(Dũng *et al*., 1997)
		C. zedoaria	(Mau *et al*., 2003)
29	Calarene (SH)	*C. zedoaria*	(Mau *et al*., 2003)
30	*cis*-Calamenene (SH)	*C. harmandii*	(Dũng *et al*., 1997)
31	*trans*-Calamenene (SH)	*C. sichuanensis*	(Zhou *et al*., 2007)
32	β-Caryophyllene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999; Kamazeri *et al*., 2012; Sirat *et al*., 1998)
		C. amada	(Mustafa *et al*., 2005; Singh *et al*., 2002; Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012;

			Jantan *et al.*, 1999; Raina *et al.*, 2002; Sharma *et al.*, 1997; Singh *et al.*, 2010; Singh *et al.*, 2002; Tsai *et al.*, 2011)
		C. mangga	(Jantan *et al.*, 1999; Wahab *et al.*, 2011; Wong *et al.*, 1999)
		C. wenyujin	(Cao *et al.*, 2006)
		C. xanthorrhiza	(Jantan *et al.*, 1999)
		C. zedoaria	(Purkayastha *et al.*, 2006; Singh *et al.*, 2002)
33	*trans*-caryophyllene (SH)	*C. sichuanensis*	(Zhou *et al.*, 2007)
34	Isocaryophyllene (SH)	*C. wenyujin*	(Cao *et al.*, 2006)
35	Caryophylla-4(12),8(13)-dien-5α-ol (OS)	*C. mangga*	(Wahab *et al.*, 2011)
36	(*E*)-14-Hydroxy-9-epicaryophyllene (OS)	*C. mangga*	(Wahab *et al.*, 2011)
37	Caryophyllene oxide (OS)	*C. amada*	(Srivastava *et al.*, 2001)
		C. angustifolia	(Srivastava *et al.*, 2006)
		C. aromatica	(Bordoloi *et al.*, 1999)
		C. aromatica	(Tsai *et al.*, 2011)
		C. haritha	(Raj *et al.*, 2008)
		C. harmandii	(Dũng *et al.*, 1997)
		C. leucorhiza	(Devi *et al.*, 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Jantan *et al.*, 1999; Raina *et al.*, 2002; Raina *et al.*, 2005;

			Tsai *et al*., 2011)
		C. mangga	(Kamazeri *et al*., 2012; Wahab *et al*., 2011)
		C. sichuanensis	(Tsai *et al*., 2011; Zhou *et al*., 2007)
		C. xanthorrhiza	(Jantan *et al*., 1999)
38	Cedrene (SH)	*C. longa*	(Gounder & Lingamallu, 2012)
39	α-Copaene (SH)	*C. amada*	(Mustafa *et al*., 2005; Singh *et al*., 2002)
		C. mangga	(Wahab *et al*., 2011)
40	β-Copaene (SH)	*C. amada*	(Rao *et al*., 1989)
41	Dihydro-*cis*-α-copaene-8-ol (OS)	*C. wenyujin*	(Cao *et al*., 2006)
42	Dihydrocostunolide (OS)	*C. aeruginosa*	(Kamazeri *et al*., 2012)
43	α-Cubebene (SH)	*C. harmandii*	(Dũng *et al*., 1997)
		C. wenyujin	(Cao *et al*., 2006)
44	β-Cubebene (SH)	*C. aeruginosa*	(Kamazeri *et al*., 2012)
		C. caesia	(Pandey & Chowdhury, 2003)
45	Cubenol (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. haritha	(Raj *et al*., 2008)
		C. mangga	(Wahab *et al*., 2011)
46	1-*epi*-Cubenol (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
47	1,10-di-*epi*-Cubenol (OS)	*C. haritha*	(Raj *et al*., 2008)
		C. mangga	(Wahab *et al*., 2011)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
48	*ar*-Curcumene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Rao *et al*., 1989; Srivastava

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
			et al., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. harmandii	(Dũng *et al*., 1997)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
49	α-Curcumene (SH)	*C. zedoaria*	(Mau *et al*., 2003)
50	β-Curcumene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Rao *et al*., 1989; Srivastava *et al*., 2001)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
		C. xanthorrhiza	(Jantan *et al*., 1999)
51	γ-Curcumene (SH)	*C. caesia*	(Pandey & Chowdhury, 2003)
		C. longa	(Leela *et al*., 2002)
52	Dehydrocurcumene (SH)	*C. longa*	(Leela *et al*., 2002)
53	Curcumenol (OS)	*C. aromatica*	(Bordoloi *et al*., 1999)
		C. aeruginosa	(Sirat *et al*., 1998)
54	*iso*-Curcumenol (OS)	*C. aeruginosa*	(Sirat *et al*., 1998)
55	Curcumol (OS)	*C. aromatica*	(Tsai *et al*., 2011)
		C. haritha	(Raj *et al*., 2008)

		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Tsai *et al*., 2011)
		C. sichuanensis	(Tsai *et al*., 2011; Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Mau *et al*., 2003)
56	Isocurcumenol (OS)	*C. wenyujin*	(Cao *et al*., 2006)
		C. zedoaria	(Mau *et al*., 2003)
57	Curcuphenol (OS)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Chane-Ming *et al*., 2002; Jantan *et al*., 1999; Leela *et al*., 2002; Sharma *et al*., 1997; Singh *et al*., 2010)
58	Curdione (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. harmandii	(Dũng *et al*., 1997)
		C. haritha	(Raj *et al*., 2008)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Sharma *et al*., 1997)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Mau *et al*., 2003)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
59	neo-Curdione (OS)	*C. leucorhiza*	(Devi *et al*., 2012)
		C. harmandii	(Dũng *et al*., 1997)

		C. haritha	(Raj *et al*., 2008)
60	Curlone (OS)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Jantan *et al*., 1999; Leela *et al*., 2002)
		C. xanthorrhiza	(Jantan *et al*., 1999)
61	Curzerene (OS)	*C. aromatica*	(Bordoloi *et al*., 1999)
		C. haritha	(Raj *et al*., 2008)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002)
		C. mangga	(Wong *et al*., 1999)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
62	Curzerenone (OS)	*C. aeruginosa*	(Jantan *et al*., 1999; Sirat *et al*., 1998)
		C. amada	(Rao *et al*., 1989; Singh *et al*., 2002; Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. longa	(Raina *et al*., 2002)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003;

			Purkayastha *et al*., 2006)
63	*epi*-Curzerenone (OS)	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
64	8-Isopropenyl-1,5-dimethyl-cyclode (SH)	*C. wenyujin*	(Cao et *al*., 2006)
65	β-Elemene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999; Kamazeri *et al*., 2012; Sirat *et al*., 1998)
		C. amada	(Mustafa *et al*., 2005; Rao *et al*., 1989; Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011))
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Singh *et al.,* 2010; Tsai *et al*., 2011)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. mangga	(Wong *et al*., 1999)
		C. ochrorhiza	(Sirat *et al*., 1997)

No.	Chemical constituents	Sources	References
		C. sichuanensis	(Tsai *et al*., 2011; Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
66	γ-Elemene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Mustafa *et al*., 2005)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2005)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
67	δ-Elemene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002)
		C. sichuanensis	(Zhou *et al*., 2007)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. wenyujin	(Cao *et al*., 2006)

		C. zedoaria	(Purkayastha *et al*., 2006)
68	*cis*-β-Elemenone (OS)	*C. aromatica*	(Bordoloi *et al*., 1999)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. longa	(Singh *et al*., 2010)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
69	*trans*-β-Elemenone (OS)	*C. leucorhiza*	(Devi *et al*., 2012)
		C. sichuanensis	(Zhou *et al*., 2007)
70	Elemol (OS)	*C. caesia*	(Pandey & Chowdhury, 2003)
		C. zedoaria	(Mau *et al*., 2003)
71	Eudesma-3,7(11)-diene (SH)	*C. wenyujin*	(Cao *et al*., 2006)
72	Eudesma-4(14), 11-diene (SH)	*C. aeruginosa*	(Kamazeri *et al*., 2012)
		C. wenyujin	(Cao *et al*., 2006)
73	β-Eudesmol (OS)	*C. leucorhiza*	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
74	10-*epi*-α-Eudesmol (OS)	*C. wenyujin*	(Cao *et al*., 2006)
75	10-*epi*-γ-Eudesmol (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
		C. zedoaria	(Purkayastha *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
76	(*Z*)-β-Farnesene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999; Sirat *et al*., 1998)

		C. amada	(Mustafa *et al*., 2005)
		C. longa	(Jantan *et al*., 1999; Singh *et al*., 2010)
		C. mangga	(Jantan *et al*., 1999)
		C. xanthorrhiza	(Jantan *et al*., 1999)
77	(*E*)-β-Farnesene (SH)	*C. aromatica*	(Bordoloi *et al*., 1999)
		C. harmandii	(Dũng *et al*., 1997)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2002)
		C. mangga	(Jantan *et al*., 1999; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003)
78	(*E*,*E*)-α-Farnesene (SH)	*C. longa*	(Singh *et al*., 2010)
		C. mangga	(Kamazeri *et al*., 2012; Wahab *et al*., 2011; Wong *et al*., 1999)
79	(*Z*,*Z*)-α-Farnesene (SH)	*C. longa*	(Gounder & Lingamallu, 2012)
80	(*Z*,*E*)-a-Farnesene (SH)	*C. caesia*	(Pandey & Chowdhury, 2003)
		C. longa	(Gounder & Lingamallu, 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
81	Farnesene epoxide (OS)	*C. wenyujin*	(Cao *et al*., 2006)
82	*trans*-Farnesal (OS)	*C. amada*	(Rao *et al*., 1989)

83	Farnesol (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. mangga	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003)
84	*cis*-Farnesol (OS)	*C. amada*	(Rao *et al*., 1989)
		C. mangga	(Kamazeri *et al*., 2012)
85	γ-Bicyclofarnesal (OS)	*C. mangga*	(Wahab *et al*., 2011)
86	γ-Bicyclohomofarnesal (OS)	*C. mangga*	(Wahab *et al*., 2011)
87	(E,E)-Farnesyl acetone (SH)	*C. angustifolia*	(Srivastava *et al*., 2006)
88	Furanodienone (OS)	*C. aeruginosa*	(Sirat *et al*., 1998)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. haritha	(Raj *et al*., 2008)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
89	Isofuranodiene (OS)	*C. ochrorhiza*	(Sirat *et al*., 1997)
90	Furanogermenone (OS)	*C. aeruginosa*	(Sirat *et al*., 1998)
		C. haritha	(Raj *et al*., 2008)
		C. ochrorhiza	(Sirat *et al*., 1997)
		C. wenyujin	(Cao *et al*., 2006)
91	Germacrene A (SH)	*C. haritha*	(Raj *et al*., 2008)
		C. leucorhiza	(Devi *et al*., 2012)
		C. sichuanensis	(Zhou *et al*., 2007)
92	Germacrene B (SH)	*C. aromatica*	(Bordoloi *et al*., 1999)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)

		C. zedoaria	(Mau *et al*., 2003)
		C. zedoaria	(Purkayastha *et al*., 2006)
93	Germacrene D (SH)	*C. amada*	(Mustafa *et al*., 2005)
		C. haritha	(Raj *et al*., 2008)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002;)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. zedoaria	(Purkayastha *et al*., 2006)
94	Germacrone (OS)	*C. aeruginosa*	(Jantan *et al*., 1999; Kamazeri *et al*., 2012; Sirat *et al*., 1998)
		C. amada	(Rao *et al*., 1989; Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005; Singh *et al*., 2010)
		C. mangga	(Kamazeri *et al*., 2012; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. ochrorhiza	(Sirat *et al*., 1997)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Purkayastha *et al*., 2006)

95	Germacra-4(15),5,10(14)-trien-1α-ol (OS)	*C. mangga*	(Wahab *et al*., 2011)
96	(4*S*,5*S*)-Germacrone-4,5-epoxide (OS)	*C. haritha*	(Raj *et al*., 2008)
97	Geranyl butyrate (SH)	*C. longa*	(Raina *et al*., 2002)
98	(-)-Globulol (OS)	*C. wenyujin*	(Cao *et al*., 2006)
99	*epi*-Globulol (OS)	*C. caesia*	(Pandey & Chowdhury, 2003)
100	α-Guaiene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Mustafa *et al*., 2005)
		C. longa	(Raina *et al*., 2002)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
101	Guaia-3,9-diene (SH)	*C. wenyujin*	(Cao *et al*., 2006)
102	Guaia-6,9-diene (SH)	*C. amada*	(Mustafa *et al*., 2005)
103	β-Gurjunene (SH)	*C. amada*	(Singh *et al*., 2002)
		C. longa	(Raina *et al*., 2002)
104	β-Himachalene (SH)	*C. zedoaria*	(Mau *et al*., 2003)
105	α-Humulene (SH)	*C. aeruginosa*	(Kamazeri *et al*., 2012)
		C. amada	(Mustafa *et al*., 2005; Singh *et al*., 2002)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. comosa	(Palanuvej & Ruangrungsi, 2007)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)

		C. longa	(Chane-Ming *et al.*, 2002; Jantan *et al.*, 1999; Raina *et al.*, 2002; Sharma *et al.*, 1997; Singh *et al*., 2010; Tsai *et al.*, 2011)
		C. mangga	(Jantan *et al*., 1999; Kamazeri *et al*., 2012; Wahab *et al*., 2011; Wong *et al*., 1999)
		C. sichuanensis	(Tsai *et al*., 2011; Zhou *et al*., 2007)
		C. wenyujin	(Cao *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
106	Humulene oxide (OS)	*C. aromatica*	(Tsai *et al*., 2011)
		C. longa	(Tsai *et al*., 2011)
		C. sichuanensis	(Tsai *et al*., 2011)
107	Humulene epoxide II (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. haritha	(Raj *et al*., 2008)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2005)
		C. mangga	(Wahab *et al*., 2011)
108	α-Ionone (SH)	*C. amada*	(Rao *et al*., 1989)
109	Kessane (OS)	*C. leucorhiza*	(Devi *et al*., 2012)
110	Ledene oxide-(II) (OS)	*C. wenyujin*	(Cao *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
111	Ledol (OS)	*C. amada*	(Mustafa *et al*., 2005)
		C. wenyujin	(Cao *et al*., 2006)

112	Linalyl-2-methyl butyrate (OS)	*C. longa*	(Jantan *et al*., 1999)
113	α-Longifolene (SH)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2002)
		C. xanthorrhiza	(Jantan *et al*., 1999)
114	8,9-Dehydro neoisolongifolene (SH)	*C. wenyujin*	(Cao *et al*., 2006)
115	8,9-Dehydro-9-formyl-cycloisolongifolene (OS)	*C. aeruginosa*	(Kamazeri *et al*., 2012)
116	α-Longipinene (SH)	*C. amada*	(Mustafa *et al*., 2005)
117	(*E*)-Longipinane (SH)	*C. mangga*	(Kamazeri *et al*., 2012)
118	α-Muurolene (SH)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. haritha	(Raj *et al*., 2008)
		C. longa	(Raina *et al*., 2002)
119	γ-Muurolene (SH)	*C. harmandii*	(Dũng *et al*., 1997)
		C. haritha	(Raj *et al*., 2008)
120	α-Muurolol (OS)	*C. amada*	(Singh *et al*., 2002)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. haritha	(Raj *et al*., 2008)
		C. mangga	(Wahab *et al*., 2011)
121	τ-Muurolol (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. mangga	(Wahab *et al*., 2011)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Purkayastha *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
122	(*E*)-Nerolidol (SH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. angustifolia	(Srivastava *et al*., 2006)

		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Chane-Ming *et al*., 2002; Jantan *et al*., 1999; Raina *et al*., 2002; Raina *et al*., 2005; Singh *et al*., 2010)
		C. mangga	(Jantan *et al*., 1999)
123	1,2,3,3α,4,5,6,7-Octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1*R*-(1α,3α-β,4α,7α)]- azulene (SH)	*C. wenyujin*	(Cao *et al*., 2006)
124	β-Oplopenone (OS)	*C. mangga*	(Wahab *et al*., 2011)
125	α-Patchoulene (SH)	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2002)
126	α-Santalene (SH)	*C. comosa*	(Palanuvej & Ruangrungsi, 2007)
		C. longa	(Singh *et al*., 2010)
127	Santalenone (OS)	*C. longa*	(Singh *et al*., 2010)
128	*epi*-β-Santalene (SH)	*C. longa*	(Singh *et al*., 2010)
129	α-Selinene (SH)	*C. aeruginosa*	(Sirat *et al*., 1998)
		C. amada	(Mustafa *et al*., 2005)
		C. amada	(Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Tsai *et al*., 2011)
		C. leucorhiza	(Devi *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Raina *et al*., 2005; Tsai *et al*., 2011)

		C. sichuanensis	(Tsai *et al*., 2011; Zhou *et al*., 2007)
		C. zedoaria	(Mau *et al*., 2003)
130	β-Selinene (SH)	*C. aeruginosa*	(Sirat *et al*., 1998)
		C. amada	(Mustafa *et al*., 2005; Rao *et al*., 1989; Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. aromatica	(Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Tsai *et al*., 2011)
		C. ochrorhiza	(Sirat *et al*., 1997)
		C. sichuanensis	(Tsai *et al*., 2011; Zhou *et al*., 2007)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
131	Sesquicineole (OS)	*C. longa*	(Singh *et al*., 2010)
132	Sesquisabinene (SH)	*C. longa*	(Singh *et al*., 2010)
133	*cis*-Sesquisabinene hydrate (SH)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
		C. longa	(Raina *et al*., 2002; Singh *et al*., 2010)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
134	β-Sesquiphellandrene (SH)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010; Singh *et al*., 2002; Usman *et al*., 2009)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. xanthorrhiza	(Jantan *et al*., 1999)
135	Spathulenol (OS)	*C. amada*	(Srivastava *et al*., 2001)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Mau *et al*., 2003)
136	Isospathulenol (OS)	*C. zedoaria*	(Mau *et al*., 2003)
137	*ar*-Turmenone (OS)	*C. sichuanensis*	(Zhou *et al*., 2007)
138	*ar*-Turmerol (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Gounder & Lingamallu, 2012)
		C. longa	(Singh *et al*., 2010)
		C. longa	(Chane-Ming *et al*., 2002; Jantan *et al*., 1999; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2002)
139	*ar*-Tumerone (OS)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Rao *et al*., 1989)

		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. caesia	(Pandey & Chowdhury, 2003)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010; Tsai *et al*., 2011; Usman *et al*., 2009)
		C. sichuanensis	(Tsai *et al*., 2011)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Singh *et al*., 2002)
140	Dihydro-*ar*-turmerone (OS)	*C. longa*	(Chane-Ming *et al*., 2002; Singh *et al*., 2010)
141	α-Turmerone (OS)	*C. longa*	(Singh *et al*., 2010)
142	β-Turmerone (OS)	*C. longa*	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. zedoaria	(Singh *et al*., 2002)
143	Velleral (OS)	*C. aeruginosa*	(Kamazeri *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
144	Viridifloral (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. caesia	(Pandey & Chowdhury, 2003)

		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
145	Xanthorrhizol (OS)	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. xanthorrhiza	(Jantan *et al*., 1999)
146	Xanthinin (OS)	*C. aeruginosa*	(Kamazeri *et al*., 2012)
147	α-Ylangene (SH)	*C. wenyujin*	(Cao *et al*., 2006)
148	Zingiberene (SH)	*C. aeruginosa*	(Jantan *et al*., 1999)
		C. amada	(Rao *et al*., 1989; Srivastava *et al*., 2001)
		C. angustifolia	(Srivastava *et al*., 2006)
		C. aromatica	(Bordoloi *et al*., 1999)
		C. longa	(Chane-Ming *et al*., 2002; Gounder & Lingamallu, 2012; Jantan *et al*., 1999; Leela *et al*., 2002; Raina *et al*., 2002; Raina *et al*., 2005; Sharma *et al*., 1997; Singh *et al*., 2010; Singh *et al*., 2002; Usman *et al*., 2009)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. xanthorrhiza	(Jantan *et al*., 1999)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
149	Zerumbone (OS)	*C. amada*	(Srivastava *et al*., 2001)
		C. wenyujin	(Cao *et al*., 2006)
150	Zedoarol (OS)	*C. aeruginosa*	(Sirat *et al*., 1998)
151	*epi*-Zonarene (SH)	*C. wenyujin*	(Cao *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
	Diterpenoids		

1	(*Z*)-Biformene (DH)	*C. mangga*	(Wahab *et al*., 2011)
2	Coronarin E (OD)	*C. mangga*	(Wahab *et al*., 2011)
3	(*E*)-15,16-Dinorlabda-8 (17),11-dien-13-one (OD)	*C. mangga*	(Wahab *et al*., 2011)
4	(*E*)-15,16-Dinorlabda-8 (17),12-dien-14-al (OD)	*C. mangga*	(Wahab *et al*., 2011)
5	(*E*,*E*)-Geranyllinalool (OD)	*C. mangga*	(Kamazeri *et al*., 2012)
6	Phytol (OD)	*C. angustifolia*	(Srivastava *et al*., 2006)
Phenylpropanoids			
1	*cis*-Anethole	*C. wenyujin*	(Cao *et al*., 2006)
2	Methyl eugenol	*C. angustifolia*	(Srivastava *et al*., 2006)
3	Elemicin	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2002; Sharma *et al*., 1997)
		C. mangga	(Wahab *et al*., 2011)
4	Cinnamyl cinnamate	*C. longa*	(Raina *et al*., 2002; Raina *et al*., 2005)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
Miscellaneous			

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
Aromatic compounds			
1	(Ethoxymethyl) benzene	*C. amada*	(Rao *et al*., 1989)
2	2-Methyl-1-propenyl benzene	*C. comosa*	(Palanuvej & Ruangrungsi, 2007)
3	(1-Phenyl-1-trimetylsilyl)-methylene-cyclopentane	*C. wenyujin*	(Cao *et al*., 2006)
4	Cyclohexane,2-ethenyl-1,dimethyl-3-methylene	*C. mangga*	(Kamazeri *et al*., 2012)
5	1,2-Dihydronaphthalene	*C. comosa*	(Palanuvej & Ruangrungsi, 2007)
6	4-Vinyl-2-methoxy-phenol	*C. sichuanensis*	(Zhou *et al*., 2007)
7	2-Methyl-4-(2,6,6-trimethylcyclohex-1-enyl)but-2-en-1-ol	*C. mangga*	(Kamazeri *et al*., 2012)
8	1-Formyl-2,2-dimethyl-3-trans-(3-methyl-but-2-enyl)-6-methylidene-cyclohexane	*C. mangga*	(Kamazeri *et al*., 2012)
9	(2,4,6-Trimethylcyclohexyl) methanol	*C. mangga*	(Kamazeri *et al*., 2012)
10	5-Isopropenyl-1,2-dimethylcyclohex-2-enol	*C. mangga*	(Kamazeri *et al*., 2012)
11	Cyclohexanol, 2-methylene-5-(1-methylethenyl)-	*C. mangga*	(Kamazeri *et al*., 2012)
12	*endo*-1,5,6,7-Tetramethylbicyclo[3.2.0] hept-6-en-3-ol	*C. mangga*	(Kamazeri *et al*., 2012)
13	4-methoxy- Benzaldehyde	*C. wenyujin*	(Cao *et al*., 2006)

14	Myrac aldehyde	*C. mangga*	(Wahab *et al*., 2011)
15	*ar*-Zingiberone	*C. wenyujin*	(Cao *et al*., 2006)
16	1-[4-(4-Methylpent-3-enyl)cyclohex-3-en-1-yl]- ethanone	*C. mangga*	(Wahab *et al*., 2011)
17	2,10,10-Trimethyltricyclo[7.1.1.0 (2,7)] undec-6-en-8- one	*C. wenyujin*	(Cao *et al*., 2006)
18	11,12-Dinordriman-8-one	*C. mangga*	(Wahab *et al*., 2011)
19	Heptyl salicylate	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. longa	(Raina *et al*., 2002; Raina *et al*., 2005)
20	Isobutyl phthalate	*C. mangga*	(Wahab *et al*., 2011)
Non-aromatic compounds			
1	Hexadecane	*C. amada*	(Rao *et al*., 1989)
2	Heptadecane	*C. amada*	(Rao *et al*., 1989)
		C. angustifolia	(Srivastava *et al*., 2006)
3	Octane	*C. longa*	(Raina *et al*., 2005)
4	2,6-Dimethylocta-2,6-diene	*C. mangga*	(Wahab *et al*., 2011)
5	Tetradecane	*C. longa*	(Raina *et al*., 2002; Raina *et al*., 2005)
6	Octadecane	*C. amada*	(Rao *et al*., 1989)
7	*n*-Nonadecane	*C. angustifolia*	(Srivastava *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	**Chemical constituents**	**Sources**	**References**

8	Eicosane	*C. angustifolia*	(Srivastava *et al*., 2006)
9	Tetracosane	*C. angustifolia*	(Srivastava *et al*., 2006)
10	(*E*,*E*)-7,11,15-Trimethyl-3-methylene-hexadeca-1,6,10,14-tetraene	*C. mangga*	(Kamazeri *et al*., 2012)
11	2,6,11,15-Tetramethyl-hexadeca-2,6,8,10,14-pentaene	*C. mangga*	(Kamazeri *et al*., 2012)
12	3-Buten-2-ol	*C. longa*	(Raina *et al*., 2002)
13	*n*-Hexan-2-ol	*C. longa*	(Raina *et al*., 2002)
14	*cis*-3-Hexenol	*C. longa*	(Raina *et al*., 2002)
15	2-Heptanol	*C. aromatica*	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. haritha	(Raj *et al*., 2008)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002; Tsai *et al*., 2011)
		C. sichuanensis	(Tsai *et al*., 2011)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Purkayastha *et al*., 2006)
16	2-Methylheptan-3-ol	*C. amada*	(Rao *et al*., 1989)
17	1-Heptene-1-ol acetate	*C. amada*	(Rao *et al*., 1989)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
18	2-Octanol	*C. aromatica*	(Bordoloi *et al*., 1999)
		C. harmandii	(Dũng *et al*., 1997)
		C. longa	(Raina *et al*., 2005)
		C. zedoaria	(Purkayastha *et al*., 2006)
19	(5*E*)-2,6-Dimethylocta-1,5,7-trien-3-ol	*C. mangga*	(Wahab *et al*., 2011)
20	2-Nonanol	*C. amada*	(Rao *et al*., 1989)
		C. aromatica	(Bordoloi *et al*., 1999; Tsai *et al*., 2011)
		C. kwangsiensis	(Zeng *et al*., 2009)
		C. longa	(Sharma *et al*., 1997; Tsai *et al*., 2011)
		C. mangga	(Wong *et al*., 1999)
		C. sichuanensis	(Tsai *et al*., 2011)
		C. wenyujin	(Cao *et al*., 2006)
		C. zedoaria	(Purkayastha *et al*., 2006)
21	Ipsdienol	*C. mangga*	(Wahab *et al*., 2011)
22	2-Decanol	*C. longa*	(Raina *et al*., 2002)
23	2-Undecanol	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. amada	(Rao *et al*., 1989)
		C. sichuanensis	(Zhou *et al*., 2007)
24	Hexadecanol	*C. angustifolia*	(Srivastava *et al*., 2006)
25	Octadecanol	*C. angustifolia*	(Srivastava *et al*., 2006)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
26	Nonadecanol	*C. angustifolia*	(Srivastava *et al*., 2006)
27	2-Hydroxy-2'-methoxy diphenyl ether	*C. amada*	(Rao *et al*., 1989)
28	2-Isopropyl-5-methyl-9-methylene-bicyclo[4.4.0]dec-1-ene	*C. wenyujin*	(Cao *et al*., 2006)
29	3-Methylbut-2-enal	*C. mangga*	(Wahab *et al*., 2011)
30	4-Methylenhex-5-enal	*C. mangga*	(Wahab *et al*., 2011)
31	Octanal	*C. zedoaria*	(Singh *et al*., 2002)
32	2,6-Dimethylhept-5-en1-al	*C. amada*	(Rao *et al*., 1989)
33	Tetradecanal	*C. mangga*	(Jantan *et al*., 1999)
34	Pentadecanal	*C. mangga*	(Wahab *et al*., 2011)
35	Dodecanoic acid	*C. aromatica*	(Tsai *et al*., 2011)
		C. longa	(Tsai *et al*., 2011)
		C. sichuanensis	(Tsai *et al*., 2011)
36	Tridecanoic acid	*C. angustifolia*	(Srivastava *et al*., 2006)
37	Tetradecanonic acid	*C. angustifolia*	(Srivastava *et al*., 2006)
38	Pentadecanoic acid	*C. angustifolia*	(Srivastava *et al*., 2006)
39	Hexadecanoic acid	*C. angustifolia*	(Srivastava *et al*., 2006)
		C. mangga	(Wahab *et al*., 2011)
40	Oleic acid	*C. angustifolia*	(Srivastava *et al*., 2006)
41	14-Methyl pentadecanoic acid methyl ester	*C. mangga*	(Kamazeri *et al*., 2012)

Table 8. Chemical constituents of essential oil of *Curcuma* plants (cont.)

No.	Chemical constituents	Sources	References
42	(*E*)-9-Octadecenoic acid	*C. wenyujin*	(Cao *et al.*, 2006)
43	Propanone	*C. amada*	(Singh *et al.*, 2002)
44	Heptan-2-one	*C. longa*	(Raina *et al.*, 2002)
45	(*E*)-6-Methylhepta-3,5-dien-2-one	*C. mangga*	(Wahab *et al.*, 2011)
46	2-Nonene-4-one	*C. amada*	(Rao *et al.*, 1989)
47	2-Nonanone	*C. aeruginosa*	(Sirat *et al.*, 1998)
		C. amada	(Rao *et al.*, 1989; Srivastava *et al.*, 2001)
		C. leucorhiza	(Devi *et al.*, 2012)
		C. mangga	(Wahab *et al.*, 2011; Wong *et al.*, 1999)
		C. zedoaria	(Mau *et al.*, 2003; Purkayastha *et al.*, 2006)
48	5-Nonanone	*C. caesia*	(Pandey & Chowdhury, 2003)
49	2,6-Dimethyleneoct-7-en-3-one	*C. amada*	(Rao *et al.*, 1989)
50	Nopinone	*C. mangga*	(Wahab *et al.*, 2011)
51	6-Methyl-5- hepten- 2-one	*C. mangga*	(Wong *et al.*, 1999)
		C. zedoaria	(Singh *et al.*, 2002)
52	2-Decanone	*C. mangga*	(Wahab *et al.*, 2011)
		C. zedoaria	(Mau *et al.*, 2003)

53	2-Undecanone	*C. amada*	(Rao *et al*., 1989)
		C. harmandii	(Dũng *et al*., 1997)
		C. leucorhiza	(Devi *et al*., 2012)
		C. longa	(Raina *et al*., 2002)
		C. mangga	(Wahab *et al*., 2011)
		C. sichuanensis	(Zhou *et al*., 2007)
		C. zedoaria	(Mau *et al*., 2003; Purkayastha *et al*., 2006)
54	2-Heptadecanone	*C. angustifolia*	(Srivastava *et al*., 2006)
55	2-Nonadecanone	*C. mangga*	(Wahab *et al*., 2011)
		C. wenyujin	(Cao *et al*., 2006)
56	2-Methy1-6-methyleneocta-1,7-dien-3-one	*C. amada*	(Rao *et al*., 1989)
57	6-(1-Hydroxymethylvinyl)-4,8α -dimethyl-3,5,6,7,8,8α -hexahydro-1H-naphthalen-2-one	*C. mangga*	(Kamazeri *et al*., 2012)
58	(*Z*)-Hex-3-enyl butanoate	*C. mangga*	(Wahab *et al*., 2011)
59	Methyl hexadecanoate	*C. mangga*	(Wahab *et al*., 2011)
60	Ethyl hexadecanoate	*C. mangga*	(Wahab *et al*., 2011)
61	Hexadecyl acetate	*C. angustifolia*	(Srivastava *et al*., 2006)
62	Methyl palmitate	*C. angustifolia*	(Srivastava *et al*., 2006)
63	Isopropyl myristate	*C. angustifolia*	(Srivastava *et al*., 2006)
64	Methyl octadecanoate	*C. angustifolia*	(Srivastava *et al*., 2006)
65	Methyl eicosanoate	*C. angustifolia*	(Srivastava *et al*., 2006)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants

No.	Compound	Source	Reference
Terpenoids			
Monoterpenoids			
1	Borneol (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. angustifolia	(Bhuiyan *et al*., 2008; Vipunngeun *et al*., 2007)
		K. galanga	(Helen *et al*., 2011; Jantan *et al*., 1999; Tewtrakul *et al*., 2005)
		K. pandurata	(Miksusanti, Jenie, Priosoeryanto, Syarief, & Rekso, 2008)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
2	Bornyl acetate (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
3	Bornyl formate (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008)
4	Isobornyl acetate (OM)	*K. galanga*	(Helen *et al*., 2011)
5	Isobornyl formate (OM)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)

* Letters in the parentheses after the name of terpenoid compounds represent their types according to the presence or absence of O-atom in the molecule; MH= monoterpene hydrocarbon, OM= oxygenated monoterpene, SH= sesquiterpene hydrocarbon, OS= oxygenated sesquiterpene

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
6	Camphene (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Helen *et al*., 2011; Jantan *et al*., 1999; Tewtrakul *et al*., 2005)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
7	Camphene hydrate (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
8	Camphor (OM)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. pandurata	(Miksusanti *et al*., 2008)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
9	δ-3-Carene (MH)	*K. galanga*	(Helen *et al*., 2011; Jantan *et al*., 1999)
10	Carvacrol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
11	*cis*-Carveol (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
12	*trans*-Carveol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
13	*cis*-Carvyl acetate (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
		K. rotunda	(Woerdenbag *et al*., 2004)
14	Dihydrocarveol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
15	Carvone (OM)	*K. galanga*	(Tewtrakul *et al*., 2005)
16	Methyl chavicol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
17	1,8-Cineole (OM)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999; Tewtrakul *et al*., 2005)
		K. pandurata	(Miksusanti *et al*., 2008)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
18	*o*-Cymene (MH)	*K. galanga*	(Bhuiyan *et al*., 2008)
19	*ρ*-Cymene (MH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
20	γ-Cymen-8-ol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
		K. rotunda	(Woerdenbag *et al*., 2004)
21	5-Tert butyl *m*-cymene (MH)	*K. galanga*	(Bhuiyan *et al*., 2008)
22	Eucarvone (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
23	Fenchone (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
24	Geraniol (OM)	*K. pandurata*	(Miksusanti *et al*., 2008)
25	Geranyl methyl ether (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
26	Isopulegol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
27	Isopulegol acetate (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
28	Limonene (MH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
29	Linalool (OM)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Jantan *et al*., 1999)
		K. pandurata	(Miksusanti *et al*., 2008)
		K. rotunda	(Woerdenbag *et al*., 2004)
30	Linalool oxide (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
31	Myrcene (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Jantan *et al*., 1999)
		K. pandurata	(Miksusanti *et al*., 2008)
		K. rotunda	(Woerdenbag *et al*., 2004)
32	Myrcenone (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
33	Neryl acetate (OM)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
34	Ocimene (MH)	*K. pandurata*	(Miksusanti *et al*., 2008)
35	*Z*-Ocimene (MH)	*K. galanga*	(Bhuiyan *et al*., 2008)
36	*E*-Ocimene (MH)	*K. galanga*	(Bhuiyan *et al*., 2008)
37	α-Phellandrene (MH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999)
		K. rotunda	(Woerdenbag *et al*., 2004)
38	*cis*-2-Pinanol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
39	α-Pinene (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999; Tewtrakul *et al*., 2005)
		K. rotunda	(Woerdenbag *et al*., 2004)
40	β-Pinene (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999)
		K. rotunda	(Woerdenbag *et al*., 2004)
41	3-Pinene (MH)	*K. galanga*	(Helen *et al*., 2011)
42	α-Pinocarveol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
43	Sabinene (MH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
44	*cis*-Sabinene hydrate (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
45	Santolina triene (MH)	*K. galanga*	(Helen *et al*., 2011)
46	Sylvestrene (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
47	α-Terpinene (MH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
48	γ-Terpinene (MH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999)
		K. rotunda	(Woerdenbag *et al*., 2004)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
49	Terpinen-4-ol (OM)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
50	α-Terpineol (OM)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
		K. galanga	(Jantan *et al*., 1999)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
		K. pandurata	(Miksusanti *et al*., 2008)
51	Terpinolene (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. galanga	(Jantan *et al*., 1999)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
52	α-Thujene (MH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Jantan *et al*., 1999)
		K. rotunda	(Woerdenbag *et al*., 2004)
		K. galanga	(Jantan *et al*., 1999)
		K. rotunda	(Woerdenbag *et al*., 2004)
53	β-Thujone (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
54	Thymoquinone (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)
55	Thymol (OM)	*K. galanga*	(Bhuiyan *et al*., 2008)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
56	Tricyclene (MH)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
	Sesquiiterpenoids		
1	Aristolochene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
2	Aromadendrene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
3	Aromadendrene oxide (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
4	Bicyclogermacrene (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
5	δ-Cadinene (SH)	*K. galanga*	(Bhuiyan *et al*., 2008)
6	α-Cadinol (OS)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
7	α-Calacorene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Bhuiyan *et al*., 2008)
8	γ-Calacorene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
9	*trans*- Calamene (SH)	*K. galanga*	(Bhuiyan *et al*., 2008)
10	Carotol (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
11	β-Caryophyllene (SH)	*K. galanga*	(Jantan *et al*., 1999)
		K. rotunda	(Sirat *et al*., 2005)
12	Caryophyllene oxide (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
13	β-Cedren-9-L-ol (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
14	α-Colocalene (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
15	α-Copaene (SH)	*K. rotunda*	(Sirat *et al*., 2005)
16	*cis*-L-Copaene-8-ol (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
17	α-Cubebene (SH)	*K. galanga*	(Jantan *et al*., 1999)
18	β-Cubebene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
19	Cubenol (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
20	*ar*-Curcumene (SH)	*K. rotunda*	(Sirat *et al*., 2005)
21	Cyclocolorenone (OS)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
22	9,10-dehydro Cycloisolongifolene (SH)	*K. galanga*	(Bhuiyan *et al*., 2008)
23	Cyperene (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
24	β-Elemene (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999)
		K. rotunda	(Sirat *et al*., 2005)
25	Elemol (OS)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
26	10-*epi*-γ-Eudesmol (OS)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
27	*E*,*E*-Farnesyl acetate (OS)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
28	Germacrene B (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
29	α-Gurjunene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
30	Δ-7,8-*ar*-Himachalene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
31	α-Humulene (SH)	*K. rotunda*	(Sirat *et al*., 2005)
32	Ishwarane (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007; Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
33	β-Isocomene (SH)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
34	7,10-dehydro Isolongifolene (SH)	*K. galanga*	(Bhuiyan *et al*., 2008)
35	Ledol (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
36	Linalyl iso-valerate (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
37	Longipinocarvone (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
38	Murolan-3,9(11) -diene-10-peroxy (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
39	γ-Muurolene (SH)	*K. galanga*	(Bhuiyan *et al*., 2008)
		K. rotunda	(Woerdenbag *et al*., 2004)
40	*Z*-Nerolidol (OS)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
41	*E*-Nerolidol (OS)	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. galanga	(Jantan *et al*., 1999)
		K. rotunda	(Sirat *et al*., 2005)
42	*E*-Nerolidyl acetate (SH)	*K. galanga*	(Bhuiyan *et al*., 2008)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
43	1,5,5,8-Tetramethyl 12-oxabicyclo (9.1.0) dodeca, 3,7-diene (OS)	*K. galanga*	(Bhuiyan *et al*., 2008)
44	α-Selinene (SH)	*K. galanga*	(Bhuiyan *et al*., 2008)
		K. rotunda	(Sirat *et al*., 2005)
45	β-Selinene (SH)	*K. rotunda*	(Sirat *et al*., 2005)
46	Selin-11-en-4-α-ol (OS)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
		K. rotunda	(Sirat *et al*., 2005)
47	Spathulenol (OS)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
48	Viridiflorol (OS)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
49	α-Ylangene (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
		K. galanga	(Bhuiyan *et al*., 2008)
50	Zonarene (SH)	*K. angustifolia*	(Vipunngeun *et al*., 2007)
Diterpenoids			
1	Phytol (OD)	*K. galanga*	(Bhuiyan *et al*., 2008)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
Phenylpropanoids			
1	Cinnamic acid	*K. pandurata*	(Miksusanti *et al*., 2008)
2	Methyl cinnamate	*K. galanga*	(Bhuiyan *et al*., 2008; Tewtrakul *et al*., 2005)
3	Ethyl cinnamate	*K. galanga*	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999)
4	Ethyl *p*-Methoxy cinnamate	*K. galanga*	(Jantan *et al*., 1999; Tewtrakul *et al*., 2005)
5	γ-Methoxyhydrocinnamic acid	*K. galanga*	(Bhuiyan *et al*., 2008)
Miscellaneous			
- Aromatic compounds			
1	Benzene	*K. galanga*	(Tewtrakul *et al*., 2005)
2	Benzyl alcohol	*K. angustifolia*	(Woerdenbag *et al*., 2004)
3	Guaiacol	*K. galanga*	(Bhuiyan *et al*., 2008)
4	Benzaldehyde	*K. rotunda*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
5	γ-Anisaldehyde	*K. galanga*	(Bhuiyan *et al*., 2008)
6	Salicyl aldehyde	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
7	4-Methoxy benzoic acid	*K. galanga*	(Bhuiyan *et al*., 2008)
8	*m*-Methoxyomandelic acid	*K. galanga*	(Bhuiyan *et al*., 2008)
9	Methyl benzoate	*K. rotunda*	(Woerdenbag *et al*., 2004)
10	Ethyl benzoate	*K. rotunda*	(Woerdenbag *et al*., 2004)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
11	Benzyl benzoate	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
12	Allyl-3-methoxybenzoate	*K. galanga*	(Bhuiyan *et al*., 2008)
13	Megastigmatrienone	*K. galanga*	(Bhuiyan *et al*., 2008)
14	Methyl salicylate	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
15	Ethyl salicylate	*K. rotunda*	(Woerdenbag *et al*., 2004)
16	Benzyl salicylate	*K. rotunda*	(Woerdenbag *et al*., 2004)
17	Benzyl acetate	*K. rotunda*	(Woerdenbag *et al*., 2004)
18	1-Phenylethyl acetate	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
19	2-Phenylethyl acetate	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
20	3-(4-Methoxyphenyl)-2-propenoic acid ethyl ester	*K. galanga*	(Bhuiyan *et al*., 2008)
21	Benzyl butanoate	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
	Non-aromatic compounds		
1	Pentane	*K. galanga*	(Helen *et al*., 2011)
2	Decane	*K. galanga*	(Helen *et al*., 2011)
3	Undecane	*K. galanga*	(Bhuiyan *et al*., 2008)
		K. rotunda	(Woerdenbag *et al*., 2004)
4	Tetradecane	*K. rotunda*	(Woerdenbag *et al*., 2004)
5	Pentadecane	*K. angustifolia*	(Woerdenbag *et al*., 2004)
6	Hexadecane	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
7	Heptadecane	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
8	Cyclohexane	*K. galanga*	(Helen *et al*., 2011)
9	Cyclohexylcyclohexane	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
10	Cyclododecane	*K. galanga*	(Helen *et al*., 2011)
11	Hydrindane	*K. galanga*	(Bhuiyan *et al*., 2008)
12	5-methyl -5-Nonanol	*K. galanga*	(Bhuiyan *et al*., 2008)
13	(3*E*)-3-Octen-1-ol	*K. galanga*	(Bhuiyan *et al*., 2008)
14	13-Tetradece -11yl -1-ol	*K. galanga*	(Bhuiyan *et al*., 2008)
15	Cyclopentanol	*K. galanga*	(Helen *et al*., 2011)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
16	1-(Methylenecyclopropyl) cyclopentanol	*K. galanga*	(Bhuiyan *et al*., 2008)
17	4-Cyclooctene -1-methanol	*K. galanga*	(Bhuiyan *et al*., 2008)
18	4,4,8-Trimethyl tricyclo [6.3.1.0.(1.5) dodecane-2,7,-diol	*K. galanga*	(Bhuiyan *et al*., 2008)
19	4,4,-Dimethyl tetracyclo [6,3,2,0(2.5),0(1,8)] -trdecan-9-ol	*K. galanga*	(Bhuiyan *et al*., 2008)
20	3,7-Dimethyl-6-octenal	*K. galanga*	(Bhuiyan *et al*., 2008)
21	2-Methyl-5-(1-methylethenyl)-2-Cyclohexen-1-one	*K. galanga*	(Bhuiyan *et al*., 2008)
22	*E*-Jasmone	*K. galanga*	(Bhuiyan *et al*., 2008)
		K. galanga	(Bhuiyan *et al*., 2008; Jantan *et al*., 1999; Tewtrakul *et al*., 2005)
		K. rotunda	(Sirat *et al*., 2005; Woerdenbag *et al*., 2004)
23	Ethyl pentadecanoate	*K. rotunda*	(Woerdenbag *et al*., 2004)
24	Ethyl hexadecanoate	*K. rotunda*	(Woerdenbag *et al*., 2004)
25	Ethyl heptadecanoate	*K. rotunda*	(Woerdenbag *et al*., 2004)
26	Ethyl octadecanoate	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)

Table 9. Chemical constituents of essential oil of *Kaempferia* plants (cont.)

No.	Compound	Source	Reference
27	Ethyl hex-3-enoate	*K. angustifolia*	(Woerdenbag *et al*., 2004)
		K. rotunda	(Woerdenbag *et al*., 2004)
28	2-Butyne	*K. galanga*	(Helen *et al*., 2011)
29	2-Octyne	*K. galanga*	(Helen *et al*., 2011)
30	2-Nonyne	*K. galanga*	(Helen *et al*., 2011)

CHAPTER III
MATERIALS AND MET HODS

3.1 Plant materials

Forty-five accessions of *Curcuma* belonging to 13 known species and 9 unidentified species, together with 7 accessions of *Kaempferia* belonging to 5 species, were used in the study. Fresh rhizomes of the plants were collected in June 2009 from different locations in Thailand (Table 10). The shape and colour of the rhizomes were recorded. The rhizomes of all plant samples were employed for cultivation at Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University, Bangkok, Thailand, for 1-2 months. Morphological characters of the cultivated plants, including leaf position, leaf shape, leaf base, leaf apex, colour of midrib, color of bract and coma bract, were recorded. The plant samples were identified by comparison with related literatures and herbarium specimens at the Singapore Herbarium (Singapore Botanic Gardens, Singapore), Suanluang RAMA IX Herbarium (Suanluang RAMA IX, Bangkok) and BGO Plant Database (the Botanical Garden Organization, Bangkok) and by Assoc. Prof. Thatree Phadungcharoen (Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University, Thailand) and Assist. Prof. Thaya Jenjittikull (Department of Plant Science, Faculty of Science, Mahidol University, Thailand). The voucher specimens of these plants have been deposited at Department of Pharmacognosy and Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Chulalongkorn University, Thailand.

All the accessions of the two genera were used for essential oil analysis. For RAPD analysis only one accession belonging to each species was selected for the study. Young leaves of each plant were used for DNA isolation. Two Zingiberaceous plants, *Zingiber montanum* and *Alpinia galanga*, together with *Citrus hystrix* (Rutaceae), were used as outgroup plants. Detial of the plants used in the study are shoen in Table 10.

3.2 Essential oil isolation and Gas Chromatography-Mass Spectrometry analysis

The fresh rhizome of each plant material (500 g) was washed with tap water, air dried and then cut into small pieces. The ground rhizome of the plant was subjected to hydrodistillation using Clevenger-type apparatus for 4 hours. The oils were collected and stored at 4°C in air-tight containers for GC-MS analysis.

Essential oils were diluted 1:100 in ethanol (HPLC grade, RCI Labscan, Thailand) and analyzed by a Finnigan Trace GC ultra-equipped with a Finnigan DSQ quadrupole mass spectrometric detector (MSD). The ZB-5 (Phenyl: Dimethylpolysiloxane 5:95, Phenomenex, USA) capillary column (30 m in length, 0.25 mm i.d., and 0.25 μm in thickness) was used as stationary phase. The carrier gas was Helium with the flow rate of 1 ml/min. One microliter of diluted oil was injected using Finnigan Autosampler AI 3000 (split ratio 1:100). The operating condition of GC oven temperature was start at 60°C for 1 min, ramped at the rate of 3°C/min to 240°C and hold for 5 min. The GC injector and GC-MSD interface temperatures were set at 180°C and 290°C, respectively. MS operating parameters were ion source 200°C; electron impact ionization positive mode at 70 eV with scan mass range of 40-650 m/z, scan rate at 500 amu / second. Essential oil components were identified by comparing their mass fragmentation pattern with Adams Essential Oil Mass Spectral library and NIST05 Mass Spectral library. The content of each oil component was determined on the basis of peak area ratio measurement.

3.3 DNA isolation and random amplified polymorphic DNA (RAPD) fingerprinting

Fresh leaf of each plant was ground in liquid nitrogen with mortar and pestle to obtain a fine powder. Genomic DNA was isolated from the fine powder using the DNeasy Plant Mini Kit (Qiagen, Germany) according to the manufacturer's protocol.

The RAPD reaction was carried out in 20 μl containing 2 μl of genomic DNA, 1X amplification buffer, 3.5 mM $MgCl_2$ (for *Kaempferia* plants, 5 mM $MgCl_2$ were used), 0.4 mM of each dNTP, 1.25 U of *Taq* DNA polymerase (Fermentas, Canada) and 0.4 μM random primers (Eurofins MWG Operon, **Germany**). The details of primer used for RAPD screening are shown in Table 11. The amplification was performed using a DNA thermal cycler (Applied Biosystems, USA) with an initial pre-denaturation at 95°C for 2 min, denaturation at 95°C for 45 sec, annealing at 37°C for 1 min, extension at 72°C for 2 min with 45 cycles and final extension at 72°C for 5 min. The RAPD products were separated on 1.5% agarose gel in TBE buffer and stained with ethidium bromide. The RAPD fragments were photographed using a UV transilluminator and analyzed with a gel documentation system (Syngene, USA).

3.4 Data analysis

3.4.1 Data analysis for essential oil composition

All the compounds with contents > 0.1% were scored as 0 or 1 for the absence or presence of compounds, respectively. The similarity index was calculated from the data that was generated using Dice similarity index coefficient (Nei & Li, 1979). The dendrogram was constructed based on the similarity matrix data using the unweighted pair group method with arithmetic averages (UPGMA), clustering by FreeTree software (Pavlicek, Hrda, & Flegr, 1999). To evaluate the strength of the resulting branches, bootstrap probabilities were calculated using 1,000 bootstrap resampling data with the after mentioned software.

3.4.2 RAPD data analysis

The RAPD bands were scored as 0 or 1 for the absence or presence of bands, respectively. Only clear and reproducible bands were scored as 1. The standard DNA marker (1 kb GeneRuler, Fermentas, Canada) was used to assign the size of each RAPD fragment. The similarity index was calculated from the data that was generated using Dice similarity index coefficient (Nei & Li, 1979). The dendrogram was constructed based on the similarity matrix data using the unweighted pair group method with arithmetic averages (UPGMA), clustering by GeneTool and GeneDirectory software.

Table 10. Details of the plant samples used in the study

Plants	Voucher no.[a]	Code[b]	Locality
C. aeruginosa Roxb.	SING 0042078	AE 1	Chiang Mai
		AE 2	Ratchaburi
		AE 3*	Prachin Buri
C. albicoma S.Q. Tong	-	AL 1*	Chiang Mai
		AL 2	Ratchaburi
		AL 3	Prachin Buri
C. amada Roscoe	QBG 29866	AM 1*	Chiang Mai
		AM 3	Prachin Buri
C. angustifolia Roxb.	SING 0166477	AN 3*	Prachin Buri
C. aromatica Salisb.	SING 0166450	AR 1*	Chiang Mai
		AR 2	Ratchaburi
		AR 3	Prachin Buri
C. comosa Roxb.	-	CO 1	Chiang Mai
		CO 2*	Ratchaburi
		CO 3	Prachin Buri
C. longa L.	SING 0165050	LO 1*	Chiang Mai
		LO 2	Ratchaburi
C. mangga Valeton & Zijp	SING 0166425	MA 1*	Chiang Mai
		MA 2	Ratchaburi
		MA 3	Prachin Buri
C. parviflora Wall.	SING 0166426	PA 1*	Chiang Mai
C. petiolata Roxb.	SING 0166464	PE 3*	Prachin Buri
C. rubrobracteata Skornickova	QBG 29155	RU 1*	Chiang Mai
C. sessilis Gage	-	SE 1*	Chiang Mai

Table 10. Details of the plant samples used in the study (cont.)

Plants	Voucher no.[a]	Code[b]	Locality
C. zedoaria (Berg) Roscoe	SING 0166432	ZE 1	Chiang Mai
		ZE 2*	Ratchaburi
Curcuma sp. 1 (ว่านม้าห้อมัง)	-	SP14*	Phetchabun
Curcuma sp. 2 (ว่านคัณฑมาลา)	-	SP 21*	Chiang Mai
		SP 22	Ratchaburi
Curcuma sp. 3 (ว่านขมิ้นดำ)	-	SP 31*	Chiang Mai
		SP 32	Ratchaburi
		SP 33	Prachin Buri
Curcuma sp. 4 (ว่านม้าขาว)	-	SP 41*	Chiang Mai
		SP 42	Ratchaburi
Curcuma sp. 5 (ว่านม้าเหลือง)	-	SP 51*	Chiang Mai
		SP 53	Prachin Buri
Curcuma sp. 6 (ว่านเอ็นเหลือง)	-	SP 61*	Chiang Mai
		SP 63	Prachin Buri
Curcuma sp. 7 (ว่านมหาจักรพรรดิ)	-	SP 71*	Chiang Mai
		SP 72	Ratchaburi
Curcuma sp. 8 (ว่านม้าห้อ)	-	SP 81	Chiang Mai
		SP 82	Ratchaburi
		SP 83*	Prachin Buri
Curcuma sp. 9 (ว่านมหาอุดม)	-	SP 92*	Ratchaburi
		SP 93	Prachin Buri

Table 10. Details of the plant samples used in the study (cont.)

Plants	Voucher no.[a]	Code[b]	Locality
Kaempferia galanga L.	SING 0176504	KG 1*	Chiang Mai
		KG 2	Ratchaburi
K. larsenii Sirirugsa	SL 006733	KL 5*	Ubon Ratchathani
K. marginata Carey	SL 006515	KM 3*	Prachine Buri
K. parviflora Wall. ex Bake	SL 006523	KP 2*	Ratchaburi
K. rotunda L.	SING 0176530	KR 2*	Ratchaburi
		KR 3	Prachine Buri
Zingiber montanum (J.Koenig)	-	ZM 1*	Chiang Mai
Link ex A. Dietr.		ZM 2	Ratchaburi
Alpinia galanga (L.) Willd.	-	AG*	Pathum Thani
Citrus hystrix DC.	-	CH*	Bangkok

[a] SING= the Singapore Herbarium (Singapore Botanic Gardens, Singapore),
QBG= BGO Plant Database (the Botanical Garden Organization, Bangkok),
SL= Suanluang RAMA IX Herbarium (Suanluang RAMA IX, Bangkok)

[b] Code with the asterisks represent plant samples which were selected for DNA isolation

Table 11. List of primer used for RAPD screening

No.	Primer	Sequences (5′-3′)	No.	Primer	Sequences (5′-3′)
1	OPA-02	TGCCGAGCTG	26	OPI-04	CCGCCTAGTC
2	OPA-03	AGTCAGCCAC	27	OPI-06	AAGGCGGCAG
3	OPA-04	AATCGGGCTG	28	OPI-08	TTTGCCCGGT
4	OPA-05	AGGGGTCTTG	29	OPI-16	TTTGCCCGGT
5	OPA-13	CAGCACCCAC	30	OPJ-17	ACGCCAGTTC
6	OPA-15	TTCCGAACCC	31	OPJ-20	AAGCGGCCTC
7	OPA-17	GACCGCTTGT	32	OPK-09	CCCTACCGAC
8	OPA-20	GTTGCGATCC	33	OPK-12	CCCTACCGAC
9	OPB-07	GGTGACGCAG	34	OPK-14	CCCGCTACAC
10	OPB-16	TTTGCCCGGA	35	OPL-13	ACCGCCTGCT
11	OPC-05	GATGACCGCC	36	OPL-18	ACCACCCACC
12	OPC-17	TTCCCCCCAG	37	OPN-12	CACAGACACC
13	OPD-03	GTCGCCGTCA	38	OPN-16	AAGCGACCTG
14	OPD-04	TCTGGTGAGG	39	OPN-18	GGTGAGGTCA
15	OPD-07	TTGGCACGGG	40	OPS-01	CTACTGCGCT
16	OPE-01	CCCAAGGTCC	41	OPS-03	CAGAGGTCCC
17	OPE-02	GGTGCGGGAA	42	OPS-08	TTCAGGGTGG
18	OPE-04	GTGACATGCC	43	OPS-12	CTGGGTGAGT
19	OPE-07	AGATGCAGCC	44	OPS-19	GAGTCAGCAG
20	OPG-03	GAGCCCTCCA	45	OPT-05	GGGTTTGGCA
21	OPG-07	GAACCTGCGG	46	OPT-11	TTCCCCGCGA
22	OPG-15	ACTGGGACTC	47	OPT-17	CCAACGTCGT
23	OPH-01	GGTCGGAGAA	48	OPU-07	CCTGCTCATC
24	OPH-10	CCTACGTCAG	49	OPV-12	ACCCCCCACT
25	OPH-19	CTGACCAGCC	50	OPX-20	CCCAGCTAGA

Table 11. List of primer used for RAPD screening (cont.)

No.	Primer	Sequences (5′-3′)	No.	Primer	Sequences (5′-3′)
51	OPY-05	GGCTGCGACA	61	RAPD-14	CCCAGAGGGC
52	OPY-15	AGTCGCCCTT	62	RAPD-15	AAAGTATGTA
53	OPY-20	AGCCGTGGAA	63	RAPD-16	TCTCGTATCT
54	OPZ-03	CAGCACCGCA	64	RAPD-17	TCTCGTAGTA
55	RAPD-05	TTCCGGGTGC	65	RAPD-18	CCACGGTAGC
56	RAPD-07	GAGGTCCAGA	66	RAPD-19	CTCTCTCGTC
57	RAPD-09	CCTGGGCTTT	67	RAPD-20	AGCCACGCTA
58	RAPD-11	AGTTTCCATT	68	RAPD-A 29	GGTTCGGGAATG
59	RAPD-12	GTAACAACTC	69	RAPD-F 25	CCAGATCCGAAT
60	RAPD-13	CATTGTTGAG	70	RAPD-F 29	GCCGCTAATATG

CHAPTER IV
RESULTS AND DISCUSSION

4.1 The *Curcuma* plants

4.1.1 Essential oil analysis

The chemical constituents of the oils obtained from all plant samples with their percentages and Kovats Indices (KIs) together with percent yields are shown in Table 23 (Appendix A), in order of their elution on the ZP-5 column. The colour of the oils are shown in Table 24 (Appendix A). Tabel 12 showed the occurrence of the chemical constituents in each of plant species used in this study. Data of the *Curcuma* species, the samples of which were obtained from more than one locations, were deduced from the data of all of the accession belonging to the species. A total of 150 compounds representing 75.74-100% of the total oil composition were identified. The essential oil components in all *Curcuma* plants ranged from 10-25 compounds. AL 1 was found to contain the highest number of oil components (25 compounds) while MA 3 was found contain the lowest (10 compounds).

α-Pinene [3] was found in all *Curcuma* and outgroup plants except *Curcuma* sp. 2, *Curcuma* sp. 3 and *Curcuma* sp. 6 whereas 1,8-cineole [15] was found in all *Curcuma* plants except *C. aromatica*, *C. parviflora*, *Curcuma* sp. 2 and *Curcuma* sp. 4. The main component in essential oil of each species is shown in Table 13.

The results (Table 23, Appendix A) showed that the chemical components of the same *Curcuma* species from different locations were similar; however, there was a great quantitative difference in the amount of each components.

The results were similar to those previously reported by Sirat, Jamil and Hussain (1998). Curzerenone [97] was found to be the main component in *C. aeruginosa* rhizome oil while camphor [28] in *C. angustifolia* (Srivastava, Srivastava,

& Syamsundar, 2006), *C. aromatica* (Bordoloi, Sperkova, & Leclercq, 1999) and *C. caesia* (Pandey & Chowdhury, 2003) rhizome oil. Germacrone [115] was also reported as the main component in rhizome oil of *C. harmadii* (Dũng, Truong, Ky, & Leclercq, 1997), *C. leucorhiza* (Devi, Rana, Devi, Verdeguer, & Blázquez, 2012) and *C. winyujin* (J. Cao *et al*., 2006). In addition, myrcene [7] and *ar*-turmerone [110] were reported as the main component in rhizome oil of *C. mangga* (Wahab, Blagojevic, Radulovic, & Boylan, 2011) and *C. longa* (Singh *et al*., 2010), respectively. This study provided the first report on essential oil compositions in the rhizome of *C. albicoma, C. sessilis, C. parviflora* and *C. rubrobacterta*. The results obtained might be used as additional information for phytochemical and chemotaxonomic studies of the *Curcuma* genus.

Table 12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c] *C. aeruginosa*	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
1	Tricyclene	MH	926	0	0	0	0	0
2	α-Thujene	MH	930	0	0	0	0	0
3	α-Pinene	MH	939	1	1	1	1	1
4	Camphene	MH	954	0	1	1	1	1
5	Sabinene	MH	975	0	0	0	0	0
6	β-Pinene	MH	979	1	1	1	0	0
7	Myrcene	MH	990	0	1	1	1	0
8	α-Phellandrene	MH	1002	0	1	0	0	0
9	δ-3-Carene	MH	1011	0	1	0	1	0
10	α-Terpinene	MH	1017	0	1	0	0	0
11	*p*-Cymene	MH	1024	0	0	0	0	0
12	*o*-Cymene	MH	1026	0	1	0	0	0
13	Limonene	MH	1029	0	1	1	1	0
14	Sylvestrene	MH	1030	0	0	0	0	0
15	1,8-Cineole	OM	1031	1	1	1	1	0
16	(*E*)-β-Ocimene	MH	1050	0	0	0	0	0
17	γ-Terpinene	MH	1059	0	0	0	0	0
18	*cis*-Linalool oxide	OM	1072	0	0	0	0	0
19	*trans*-Linalool oxide	OM	1086	0	0	0	0	0
20	Terpinolene	MH	1088	0	1	0	0	0
21	Linalool	OM	1096	0	0	0	0	0
22	*trans*-Sabinine hydrate	OM	1098	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
1	Tricyclene	MH	926	0	0	0	0	1
2	α-Thujene	MH	930	0	0	0	0	0
3	α-Pinene	MH	939	1	1	1	1	1
4	Camphene	MH	954	0	0	0	1	1
5	Sabinene	MH	975	0	0	0	0	0
6	β-Pinene	MH	979	1	0	1	1	0
7	Myrcene	MH	990	0	0	1	0	1
8	α-Phellandrene	MH	1002	1	1	0	0	0
9	δ-3-Carene	MH	1011	1	0	0	1	0
10	α-Terpinene	MH	1017	1	0	0	0	0
11	*ρ*-Cymene	MH	1024	0	0	0	0	0
12	*o*-Cymene	MH	1026	1	1	0	0	0
13	Limonene	MH	1029	1	0	1	1	0
14	Sylvestrene	MH	1030	0	0	0	1	0
15	1,8-Cineole	OM	1031	1	1	1	0	1
16	(*E*)-β-Ocimene	MH	1050	0	0	1	0	0
17	γ-Terpinene	MH	1059	1	0	0	0	0
18	*cis*-Linalool oxide	OM	1072	0	0	0	0	0
19	*trans*-Linalool oxide	OM	1086	0	0	0	0	0
20	Terpinolene	MH	1088	1	1	0	0	0
21	Linalool	OM	1096	0	0	0	0	0
22	*trans*-Sabinine hydrate	OM	1098	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
1	Tricyclene	MH	926	0	0	0	0	0
2	α-Thujene	MH	930	0	0	0	0	0
3	α-Pinene	MH	939	1	1	1	1	0
4	Camphene	MH	954	1	1	0	1	1
5	Sabinene	MH	975	0	0	0	0	0
6	β-Pinene	MH	979	1	0	0	1	0
7	Myrcene	MH	990	0	0	0	0	0
8	α-Phellandrene	MH	1002	0	0	0	0	0
9	δ-3-Carene	MH	1011	0	0	0	0	0
10	α-Terpinene	MH	1017	0	0	0	0	0
11	*ρ*-Cymene	MH	1024	0	0	0	0	0
12	*o*-Cymene	MH	1026	0	0	1	0	0
13	Limonene	MH	1029	0	1	0	0	0
14	Sylvestrene	MH	1030	0	0	0	0	0
15	1,8-Cineole	OM	1031	1	1	1	1	0
16	(*E*)-β-Ocimene	MH	1050	0	0	0	0	0
17	γ-Terpinene	MH	1059	0	0	0	0	0
18	*cis*-Linalool oxide	OM	1072	0	0	0	0	0
19	*trans*-Linalool oxide	OM	1086	0	0	0	0	0
20	Terpinolene	MH	1088	0	0	1	0	0
21	Linalool	OM	1096	0	0	0	0	0
22	*trans*-Sabinine hydrate	OM	1098	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
1	Tricyclene	MH	926	0	0	0	0	0
2	α-Thujene	MH	930	0	0	0	0	0
3	α-Pinene	MH	939	0	1	1	0	1
4	Camphene	MH	954	0	1	1	1	1
5	Sabinene	MH	975	0	0	0	1	0
6	β-Pinene	MH	979	1	1	1	1	1
7	Myrcene	MH	990	0	0	0	0	0
8	α-Phellandrene	MH	1002	0	0	0	0	0
9	δ-3-Carene	MH	1011	0	0	0	0	0
10	α-Terpinene	MH	1017	0	0	0	0	0
11	*ρ*-Cymene	MH	1024	0	0	0	0	0
12	*o*-Cymene	MH	1026	0	0	0	0	0
13	Limonene	MH	1029	0	1	0	0	1
14	Sylvestrene	MH	1030	0	0	0	0	0
15	1,8-Cineole	OM	1031	1	0	1	1	1
16	(*E*)-β-Ocimene	MH	1050	0	0	0	0	0
17	γ-Terpinene	MH	1059	0	0	0	0	0
18	*cis*-Linalool oxide	OM	1072	0	0	0	0	0
19	*trans*-Linalool oxide	OM	1086	0	0	0	0	0
20	Terpinolene	MH	1088	0	0	0	0	0
21	Linalool	OM	1096	0	0	0	0	0
22	*trans*-Sabinine hydrate	OM	1098	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]					
				Curcuma sp. 8	*Curcuma* sp. 9	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
1	Tricyclene	MH	926	0	1	1	0	0	0
2	α-Thujene	MH	930	0	0	0	1	0	0
3	α-Pinene	MH	939	1	1	1	1	1	1
4	Camphene	MH	954	1	1	1	0	0	0
5	Sabinene	MH	975	0	1	0	1	1	1
6	β-Pinene	MH	979	1	0	1	0	1	1
7	Myrcene	MH	990	0	0	1	1	1	1
8	α-Phellandrene	MH	1002	0	0	0	0	0	0
9	δ-3-Carene	MH	1011	0	0	0	0	0	0
10	α-Terpinene	MH	1017	0	0	0	1	1	1
11	*ρ*-Cymene	MH	1024	0	1	0	0	0	0
12	*o*-Cymene	MH	1026	0	0	0	1	0	0
13	Limonene	MH	1029	1	0	1	1	1	1
14	Sylvestrene	MH	1030	0	1	0	0	0	0
15	1,8-Cineole	OM	1031	1	1	1	0	1	0
16	(*E*)-β-Ocimene	MH	1050	0	0	0	0	0	1
17	γ-Terpinene	MH	1059	0	0	0	1	0	0
18	*cis*-Linalool oxide	OM	1072	0	0	0	0	0	1
19	*trans*-Linalool oxide	OM	1086	0	0	0	0	0	1
20	Terpinolene	MH	1088	1	0	0	1	0	0
21	Linalool	OM	1096	0	1	1	0	0	1
22	*trans*-Sabinine hydrate	OM	1098	0	0	0	1	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. aeruginosa	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
23	2-Nonanol	Other	1098	0	0	0	0	0
24	Perillene	OM	1103	0	0	0	0	0
25	α-Campholenal	OM	1126	0	0	0	0	0
26	*trans*-Pinocarveol	OM	1139	0	0	0	0	0
27	Nopinone	Other	1140	0	0	0	0	0
28	Camphor	OM	1146	1	1	1	1	1
29	*neo*-Isopulegol	OM	1148	0	0	0	0	0
30	Citronellal	OM	1153	0	0	0	0	0
31	Isoborneol	OM	1160	0	0	0	0	1
32	Pinocarvone	OM	1164	0	0	0	0	0
33	Borneol	OM	1169	0	0	0	0	1
34	Terpinen-4-ol	OM	1177	0	0	0	0	0
35	*p*-Cymene-8-ol	OM	1182	0	0	0	0	0
36	α-Terpineol	OM	1188	0	0	0	0	0
37	Myrtenal	OM	1195	0	0	1	0	0
38	Citronellol	OM	1225	0	0	0	0	0
39	Geraniol	OM	1252	0	0	0	0	0
40	Isobornyl acetate	OM	1285	0	0	0	0	0
41	Bornyl acetate	OM	1288	0	0	0	0	0
42	Sesquithujene (7-*epi*)	SH	1301	0	0	0	0	1
43	δ-Elemene	SH	1338	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
23	2-Nonanol	Other	1098	0	0	0	0	0
24	Perillene	OM	1103	0	0	1	0	0
25	α-Campholenal	OM	1126	0	0	0	0	0
26	*trans*-Pinocarveol	OM	1139	0	0	0	0	0
27	Nopinone	Other	1140	0	0	0	0	0
28	Camphor	OM	1146	0	0	0	1	1
29	*neo*-Isopulegol	OM	1148	0	0	0	0	0
30	Citronellal	OM	1153	0	0	0	0	0
31	Isoborneol	OM	1160	0	0	0	0	0
32	Pinocarvone	OM	1164	0	0	0	0	0
33	Borneol	OM	1169	0	0	0	1	0
34	Terpinen-4-ol	OM	1177	0	0	0	0	0
35	*p*-Cymene-8-ol	OM	1182	1	0	0	0	0
36	α-Terpineol	OM	1188	0	0	0	0	0
37	Myrtenal	OM	1195	0	0	0	0	0
38	Citronellol	OM	1225	0	0	0	0	0
39	Geraniol	OM	1252	0	0	0	0	0
40	Isobornyl acetate	OM	1285	0	0	0	0	0
41	Bornyl acetate	OM	1288	0	0	0	0	0
42	Sesquithujene (7-*epi*)	SH	1301	0	0	0	0	0
43	δ-Elemene	SH	1338	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
23	2-Nonanol	Other	1098	0	0	0	0	0
24	Perillene	OM	1103	0	0	0	0	0
25	α-Campholenal	OM	1126	0	0	0	0	0
26	*trans*-Pinocarveol	OM	1139	0	0	0	0	0
27	Nopinone	Other	1140	0	0	0	0	0
28	Camphor	OM	1146	1	1	0	0	1
29	*neo*-Isopulegol	OM	1148	0	0	0	0	0
30	Citronellal	OM	1153	0	0	0	0	0
31	Isoborneol	OM	1160	0	1	0	0	0
32	Pinocarvone	OM	1164	0	0	0	0	0
33	Borneol	OM	1169	0	1	0	0	0
34	Terpinen-4-ol	OM	1177	0	0	0	0	0
35	*p*-Cymene-8-ol	OM	1182	0	0	0	0	0
36	α-Terpineol	OM	1188	0	0	0	0	0
37	Myrtenal	OM	1195	0	0	0	0	0
38	Citronellol	OM	1225	0	0	0	0	0
39	Geraniol	OM	1252	0	0	0	0	0
40	Isobornyl acetate	OM	1285	0	0	0	0	0
41	Bornyl acetate	OM	1288	0	0	0	0	0
42	Sesquithujene (7-*epi*)	SH	1301	0	0	0	0	0
43	δ-Elemene	SH	1338	0	1	0	0	1

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
23	2-Nonanol	Other	1098	0	0	0	0	1
24	Perillene	OM	1103	0	0	0	0	0
25	α-Campholenal	OM	1126	0	0	0	0	0
26	*trans*-Pinocarveol	OM	1139	0	0	0	0	1
27	Nopinone	Other	1140	0	0	0	0	1
28	Camphor	OM	1146	1	1	1	1	0
29	*neo*-Isopulegol	OM	1148	0	0	0	0	0
30	Citronellal	OM	1153	0	0	0	0	0
31	Isoborneol	OM	1160	0	0	0	0	0
32	Pinocarvone	OM	1164	0	0	0	0	1
33	Borneol	OM	1169	0	1	0	0	0
34	Terpinen-4-ol	OM	1177	0	0	0	0	0
35	*p*-Cymene-8-ol	OM	1182	0	0	0	0	0
36	α-Terpineol	OM	1188	0	0	0	0	1
37	Myrtenal	OM	1195	0	0	0	0	1
38	Citronellol	OM	1225	0	0	0	0	0
39	Geraniol	OM	1252	0	0	0	0	0
40	Isobornyl acetate	OM	1285	0	0	0	0	0
41	Bornyl acetate	OM	1288	0	0	0	0	0
42	Sesquithujene (7-*epi*)	SH	1301	0	0	0	0	0
43	δ-Elemene	SH	1338	1	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]					
				Curcuma sp. 8	*Curcuma* sp. 9	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
23	2-Nonanol	Other	1098	0	0	0	0	0	0
24	Perillene	OM	1103	0	0	0	0	0	0
25	α-Campholenal	OM	1126	0	1	0	0	0	0
26	*trans*-Pinocarveol	OM	1139	0	0	0	0	0	0
27	Nopinone	Other	1140	0	0	0	0	0	0
28	Camphor	OM	1146	1	1	1	0	0	0
29	*neo*-Isopulegol	OM	1148	0	0	1	0	0	1
30	Citronellal	OM	1153	0	0	0	0	0	1
31	Isoborneol	OM	1160	0	1	0	0	0	0
32	Pinocarvone	OM	1164	0	0	0	0	0	0
33	Borneol	OM	1169	1	1	1	0	0	0
34	Terpinen-4-ol	OM	1177	0	1	0	1	1	0
35	*p*-Cymene-8-ol	OM	1182	0	0	0	0	0	0
36	α-Terpineol	OM	1188	0	0	0	1	1	0
37	Myrtenal	OM	1195	0	1	0	0	0	0
38	Citronellol	OM	1225	0	0	0	0	0	1
39	Geraniol	OM	1252	0	0	0	0	0	1
40	Isobornyl acetate	OM	1285	0	0	0	0	1	0
41	Bornyl acetate	OM	1288	0	0	1	0	0	0
42	Sesquithujene (7-*epi*)	SH	1301	0	0	0	0	0	0
43	δ-Elemene	SH	1338	0	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. aeruginosa	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
44	α-Terpinyl acetate	OM	1349	0	0	0	0	0
45	Citronellyl acetate	OM	1352	0	0	0	0	0
46	Eugenol	OM	1359	0	0	0	0	0
47	*trans*-*ρ*-Menth-6-en-2,8-diol	OM	1374	0	0	0	0	0
48	α-Ylargene	SH	1375	0	0	0	0	0
49	α-Copaene	SH	1376	0	0	0	0	0
50	Geranyl acetate	OM	1381	0	0	0	0	0
51	β-Elemene	SH	1390	1	0	0	1	1
52	α-*cis*-Bergamotene	SH	1412	0	0	0	0	1
53	α-Santalene	SH	1417	0	0	0	1	0
54	*E*-Caryophyllene	SH	1419	0	1	1	0	0
55	α-*trans*-Bergamotene	SH	1434	0	0	0	0	0
56	α-Guaiene	SH	1439	0	0	0	0	0
57	(*Z*)-β-Farnesene	SH	1442	0	0	0	0	1
58	*trans*-Muurola-3,5-diene	SH	1453	0	0	0	1	0
59	α-Humulene	SH	1454	1	1	1	0	0
60	(*E*)-β-Farnesene	SH	1456	0	0	0	1	0
61	Ishwarane	SH	1466	0	0	0	0	0
62	9-*epi*-(*E*)-Caryophyllene	SH	1466	0	0	0	0	0
63	β-Chamigrene	SH	1477	0	0	0	0	0
64	*ar*-Curcumene	SH	1480	1	1	1	0	1

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
44	α-Terpinyl acetate	OM	1349	0	0	0	0	0
45	Citronellyl acetate	OM	1352	0	0	0	0	0
46	Eugenol	OM	1359	0	0	0	0	0
47	*trans-ρ*-Menth-6-en-2,8-diol	OM	1374	0	0	0	0	0
48	α-Ylargene	SH	1375	0	0	0	0	0
49	α-Copaene	SH	1376	0	0	0	1	0
50	Geranyl acetate	OM	1381	0	0	0	0	0
51	β-Elemene	SH	1390	0	0	0	0	1
52	α-*cis*-Bergamotene	SH	1412	0	0	0	0	0
53	α-Santalene	SH	1417	1	0	0	0	0
54	*E*-Caryophyllene	SH	1419	1	1	1	1	0
55	α-*trans*-Bergamotene	SH	1434	1	0	0	0	0
56	α-Guaiene	SH	1439	0	0	0	0	0
57	(*Z*)-β-Farnesene	SH	1442	0	1	0	0	0
58	*trans*-Muurola-3,5-diene	SH	1453	0	0	0	0	0
59	α-Humulene	SH	1454	1	0	1	0	0
60	(*E*)-β-Farnesene	SH	1456	1	0	0	0	1
61	Ishwarane	SH	1466	0	0	0	0	0
62	9-*epi*-(*E*)-Caryophyllene	SH	1466	0	0	0	1	0
63	β-Chamigrene	SH	1477	0	0	0	0	0
64	*ar*-Curcumene	SH	1480	0	1	0	1	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
44	α-Terpinyl acetate	OM	1349	0	0	0	0	0
45	Citronellyl acetate	OM	1352	0	0	0	0	0
46	Eugenol	OM	1359	0	0	0	0	0
47	*trans*-*ρ*-Menth-6-en-2,8-diol	OM	1374	0	0	0	0	0
48	α-Ylargene	SH	1375	0	0	0	0	0
49	α-Copaene	SH	1376	0	0	0	0	0
50	Geranyl acetate	OM	1381	0	0	0	0	0
51	β-Elemene	SH	1390	1	1	0	1	1
52	α-*cis*-Bergamotene	SH	1412	0	0	0	0	0
53	α-Santalene	SH	1417	0	1	0	0	0
54	*E*-Caryophyllene	SH	1419	0	0	1	0	0
55	α-*trans*-Bergamotene	SH	1434	0	1	0	0	0
56	α-Guaiene	SH	1439	0	0	0	0	0
57	(*Z*)-β-Farnesene	SH	1442	0	0	0	0	0
58	*trans*-Muurola-3,5-diene	SH	1453	0	0	0	0	0
59	α-Humulene	SH	1454	1	0	1	1	1
60	(*E*)-β-Farnesene	SH	1456	0	1	0	0	0
61	Ishwarane	SH	1466	0	0	0	0	0
62	9-*epi*-(*E*)-Caryophyllene	SH	1466	0	0	0	0	0
63	β-Chamigrene	SH	1477	0	0	0	0	0
64	*ar*-Curcumene	SH	1480	0	0	1	1	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
44	α-Terpinyl acetate	OM	1349	0	0	0	0	0
45	Citronellyl acetate	OM	1352	0	0	0	0	0
46	Eugenol	OM	1359	0	0	0	0	0
47	*trans-ρ*-Menth-6-en-2,8-diol	OM	1374	0	0	0	0	1
48	α-Ylargene	SH	1375	0	0	0	0	0
49	α-Copaene	SH	1376	0	0	0	0	0
50	Geranyl acetate	OM	1381	0	0	0	0	0
51	β-Elemene	SH	1390	1	1	1	1	1
52	α-*cis*-Bergamotene	SH	1412	0	0	0	0	0
53	α-Santalene	SH	1417	0	0	0	0	0
54	*E*-Caryophyllene	SH	1419	0	0	1	1	1
55	α-*trans*-Bergamotene	SH	1434	0	0	0	0	0
56	α-Guaiene	SH	1439	0	0	0	0	0
57	(*Z*)-β-Farnesene	SH	1442	0	0	0	0	0
58	*trans*-Muurola-3,5-diene	SH	1453	0	0	0	0	0
59	α-Humulene	SH	1454	1	0	0	1	1
60	(*E*)-β-Farnesene	SH	1456	0	0	0	0	0
61	Ishwarane	SH	1466	0	0	0	0	0
62	9-*epi*-(*E*)-Caryophyllene	SH	1466	0	0	0	0	0
63	β-Chamigrene	SH	1477	0	0	0	0	0
64	*ar*-Curcumene	SH	1480	0	0	1	1	1

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]					
				Curcuma sp. 8	*Curcuma* sp. 9	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
44	α-Terpinyl acetate	OM	1349	0	0	0	1	0	0
45	Citronellyl acetate	OM	1352	0	0	0	0	0	1
46	Eugenol	OM	1359	0	0	0	0	1	0
47	*trans*-*ρ*-Menth-6-en-2,8-diol	OM	1374	0	1	0	0	0	0
48	α-Ylargene	SH	1375	0	1	1	0	0	0
49	α-Copaene	SH	1376	0	1	0	0	0	1
50	Geranyl acetate	OM	1381	0	0	0	0	1	0
51	β-Elemene	SH	1390	1	0	1	0	1	0
52	α-*cis*-Bergamotene	SH	1412	0	0	0	0	0	0
53	α-Santalene	SH	1417	0	0	0	0	0	0
54	*E*-Caryophyllene	SH	1419	0	1	0	0	1	1
55	α-*trans*-Bergamotene	SH	1434	0	0	0	0	0	0
56	α-Guaiene	SH	1439	0	0	1	0	0	0
57	(*Z*)-β-Farnesene	SH	1442	0	0	0	0	0	0
58	*trans*-Muurola-3,5-diene	SH	1453	0	0	0	0	0	0
59	α-Humulene	SH	1454	1	1	0	0	0	0
60	(*E*)-β-Farnesene	SH	1456	0	0	0	0	1	0
61	Ishwarane	SH	1466	0	0	1	0	0	0
62	9-*epi*-(*E*)-Caryophyllene	SH	1466	0	0	0	0	0	0
63	β-Chamigrene	SH	1477	0	0	0	0	1	0
64	*ar*-Curcumene	SH	1480	0	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. aeruginosa	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
65	γ-Curcumene	SH	1482	0	0	0	0	0
66	Germacrene D	SH	1485	0	0	0	0	0
67	β-Selinene	SH	1490	1	0	0	0	0
68	Drim-8(12)-ene	SH	1491	0	0	0	0	0
69	*trans*-Muurola-4(14),5-diene	SH	1493	0	0	0	0	0
70	α-Zingiberene	SH	1493	0	1	0	1	0
71	Valencene	SH	1496	0	0	0	0	0
72	α-Selinene	SH	1498	0	0	0	0	0
73	Curzerene	OS	1499	0	0	0	1	1
74	Bicyclogermacrene	SH	1500	0	0	0	0	0
75	Pentadecane	Other	1500	0	0	0	0	0
76	(*E*,*E*)-α-Farnesene	SH	1505	0	1	0	0	0
77	β-Bisabolene	SH	1505	1	0	0	1	0
78	Germacrene A	SH	1509	0	0	0	0	0
79	α-Bulnesene	SH	1509	1	0	0	1	0
80	γ-Cadinene	SH	1513	0	0	0	0	0
81	β-Curcumene	SH	1515	0	0	0	1	1
82	7-*epi*-α-Selinene	SH	1520	0	0	0	0	0
83	β-Sesquiphellandrene	SH	1522	1	1	1	1	1
84	δ-Cadinene	SH	1523	0	0	0	0	0
85	(*E*)-γ-Bisabolene	SH	1531	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
65	γ-Curcumene	SH	1482	0	0	0	0	0
66	Germacrene D	SH	1485	0	0	0	0	0
67	β-Selinene	SH	1490	0	0	0	0	0
68	Drim-8(12)-ene	SH	1491	0	0	0	0	0
69	*trans*-Muurola-4(14),5-diene	SH	1493	0	0	0	0	1
70	α-Zingiberene	SH	1493	0	1	0	1	0
71	Valencene	SH	1496	0	0	0	0	0
72	α-Selinene	SH	1498	0	0	0	0	1
73	Curzerene	OS	1499	0	0	0	0	0
74	Bicyclogermacrene	SH	1500	0	0	0	0	0
75	Pentadecane	Other	1500	0	0	0	0	0
76	(*E*,*E*)-α-Farnesene	SH	1505	0	0	0	0	0
77	β-Bisabolene	SH	1505	1	1	0	0	0
78	Germacrene A	SH	1509	0	0	0	0	1
79	α-Bulnesene	SH	1509	0	0	0	0	0
80	γ-Cadinene	SH	1513	0	0	0	0	0
81	β-Curcumene	SH	1515	0	0	0	1	0
82	7-*epi*-α-Selinene	SH	1520	0	0	0	0	0
83	β-Sesquiphellandrene	SH	1522	1	1	0	0	0
84	δ-Cadinene	SH	1523	1	0	0	1	0
85	(*E*)-γ-Bisabolene	SH	1531	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
65	γ-Curcumene	SH	1482	0	0	0	0	0
66	Germacrene D	SH	1485	0	0	0	0	0
67	β-Selinene	SH	1490	1	0	0	1	1
68	Drim-8(12)-ene	SH	1491	0	0	0	0	0
69	*trans*-Muurola-4(14),5-diene	SH	1493	0	1	0	0	1
70	α-Zingiberene	SH	1493	0	1	1	0	0
71	Valencene	SH	1496	0	0	0	0	0
72	α-Selinene	SH	1498	1	0	0	0	0
73	Curzerene	OS	1499	0	0	0	0	1
74	Bicyclogermacrene	SH	1500	0	0	0	0	0
75	Pentadecane	Other	1500	0	0	0	0	0
76	(*E*,*E*)-α-Farnesene	SH	1505	0	0	0	0	0
77	β-Bisabolene	SH	1505	0	1	1	1	0
78	Germacrene A	SH	1509	0	0	0	0	0
79	α-Bulnesene	SH	1509	0	0	0	0	0
80	γ-Cadinene	SH	1513	0	0	0	0	0
81	β-Curcumene	SH	1515	0	1	0	0	0
82	7-*epi*-α-Selinene	SH	1520	0	0	0	0	0
83	β-Sesquiphellandrene	SH	1522	0	1	1	0	0
84	δ-Cadinene	SH	1523	0	0	0	1	0
85	(*E*)-γ-Bisabolene	SH	1531	0	1	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
65	γ-Curcumene	SH	1482	0	0	0	0	0
66	Germacrene D	SH	1485	0	0	0	0	0
67	β-Selinene	SH	1490	1	1	1	0	0
68	Drim-8(12)-ene	SH	1491	0	0	0	0	1
69	*trans*-Muurola-4(14),5-diene	SH	1493	1	1	0	0	0
70	α-Zingiberene	SH	1493	0	0	0	0	0
71	Valencene	SH	1496	0	0	0	0	0
72	α-Selinene	SH	1498	0	0	1	1	0
73	Curzerene	OS	1499	1	1	0	0	0
74	Bicyclogermacrene	SH	1500	0	0	0	0	0
75	Pentadecane	Other	1500	0	0	0	0	0
76	(*E*,*E*)-α-Farnesene	SH	1505	0	0	0	0	0
77	β-Bisabolene	SH	1505	0	0	0	1	0
78	Germacrene A	SH	1509	0	0	0	0	0
79	α-Bulnesene	SH	1509	1	0	1	0	0
80	γ-Cadinene	SH	1513	0	0	0	0	0
81	β-Curcumene	SH	1515	0	0	1	0	0
82	7-*epi*-α-Selinene	SH	1520	0	0	0	0	0
83	β-Sesquiphellandrene	SH	1522	0	0	1	1	0
84	δ-Cadinene	SH	1523	0	0	0	0	1
85	(*E*)-γ-Bisabolene	SH	1531	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]					
				Curcuma sp. 8	*Curcuma* sp. 9	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
65	γ-Curcumene	SH	1482	0	0	1	0	0	0
66	Germacrene D	SH	1485	0	0	1	0	0	0
67	β-Selinene	SH	1490	1	0	1	0	1	0
68	Drim-8(12)-ene	SH	1491	0	0	0	0	0	0
69	*trans*-Muurola-4(14),5-diene	SH	1493	1	0	0	0	0	0
70	α-Zingiberene	SH	1493	1	0	0	0	0	0
71	Valencene	SH	1496	0	0	1	0	0	0
72	α-Selinene	SH	1498	0	0	0	0	1	0
73	Curzerene	OS	1499	0	0	0	0	0	0
74	Bicyclogermacrene	SH	1500	0	0	0	0	0	1
75	Pentadecane	Other	1500	0	0	1	0	0	0
76	(*E*,*E*)-α-Farnesene	SH	1505	1	0	0	0	0	1
77	β-Bisabolene	SH	1505	0	0	0	0	1	0
78	Germacrene A	SH	1509	0	0	0	0	0	0
79	α-Bulnesene	SH	1509	1	0	0	0	0	0
80	γ-Cadinene	SH	1513	0	0	1	0	0	0
81	β-Curcumene	SH	1515	0	0	0	1	0	0
82	7-*epi*-α-Selinene	SH	1520	0	1	0	0	1	0
83	β-Sesquiphellandrene	SH	1522	1	0	0	1	1	0
84	δ-Cadinene	SH	1523	0	0	0	0	0	1
85	(*E*)-γ-Bisabolene	SH	1531	0	0	0	0	1	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. aeruginosa	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
86	*cis*-Sesquisabinene hydrate (IPP)	OS	1544	0	0	0	0	1
87	Elemol	OS	1549	0	0	0	0	0
88	Germacrene B	SH	1561	1	1	1	1	1
89	(*E*)-Nerolidol	OS	1563	0	0	0	0	0
90	Santalenone	OS	1577	0	0	0	1	0
91	Spathulenol	OS	1578	1	0	0	0	0
92	Caryophyllene oxide	OS	1583	1	1	1	0	0
93	*ar*-Tumerol	OS	1583	0	0	0	0	0
94	Carotol	OS	1594	0	0	0	0	0
95	Rosifoliol	OS	1600	0	0	0	0	0
96	Guaiol	OS	1600	0	0	0	0	0
97	Curzerenone	OS	1606	1	1	1	0	1
98	Humulene epoxide II	OS	1608	0	0	0	0	0
99	β-Biotol	OS	1613	0	0	0	0	0
100	*Z*-Asarone	PP	1617	0	1	1	1	0
101	Helifolen-12-al C (anti-syn-syn-)	OS	1620	0	0	0	0	0
102	1-*epi*-Cubenol	OS	1628	0	0	0	0	0
103	γ-Eudesmol	OS	1632	0	0	0	0	0
104	*epi*-α-Cadinol	OS	1640	1	0	0	0	0
105	β-Eudesmol	OS	1650	0	0	0	0	0
106	α-Cadinol	OS	1654	1	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
86	*cis*-Sesquisabinene hydrate (IPP)	OS	1544	0	0	0	0	0
87	Elemol	OS	1549	0	0	0	0	0
88	Germacrene B	SH	1561	0	0	0	0	1
89	(*E*)-Nerolidol	OS	1563	1	0	0	0	0
90	Santalenone	OS	1577	0	0	0	0	0
91	Spathulenol	OS	1578	0	0	0	0	1
92	Caryophyllene oxide	OS	1583	1	0	1	1	0
93	*ar*-Tumerol	OS	1583	0	1	0	0	0
94	Carotol	OS	1594	0	1	0	0	0
95	Rosifoliol	OS	1600	0	0	0	0	0
96	Guaiol	OS	1600	0	0	0	0	0
97	Curzerenone	OS	1606	0	0	1	0	1
98	Humulene epoxide II	OS	1608	1	0	0	0	0
99	β-Biotol	OS	1613	0	0	0	0	0
100	*Z*-Asarone	PP	1617	1	0	1	0	0
101	Helifolen-12-al C (anti-syn-syn-)	OS	1620	0	1	0	0	0
102	1-*epi*-Cubenol	OS	1628	0	0	0	0	0
103	γ-Eudesmol	OS	1632	0	0	0	0	0
104	*epi*-α-Cadinol	OS	1640	0	0	0	0	0
105	β-Eudesmol	OS	1650	0	0	0	0	0
106	α-Cadinol	OS	1654	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
86	*cis*-Sesquisabinene hydrate (IPP)	OS	1544	0	0	0	0	0
87	Elemol	OS	1549	0	0	0	0	0
88	Germacrene B	SH	1561	1	1	0	1	1
89	(*E*)-Nerolidol	OS	1563	0	0	0	0	0
90	Santalenone	OS	1577	0	1	0	0	0
91	Spathulenol	OS	1578	1	0	0	1	1
92	Caryophyllene oxide	OS	1583	1	0	0	1	0
93	*ar*-Tumerol	OS	1583	0	0	1	0	0
94	Carotol	OS	1594	0	0	0	0	0
95	Rosifoliol	OS	1600	0	0	0	0	0
96	Guaiol	OS	1600	0	0	0	0	0
97	Curzerenone	OS	1606	0	0	0	1	1
98	Humulene epoxide II	OS	1608	0	0	0	0	0
99	β-Biotol	OS	1613	0	0	1	0	0
100	*Z*-Asarone	PP	1617	0	0	0	0	0
101	Helifolen-12-al C (anti-syn-syn-)	OS	1620	0	0	1	0	0
102	1-*epi*-Cubenol	OS	1628	0	0	0	0	0
103	γ-Eudesmol	OS	1632	0	0	0	0	0
104	*epi*-α-Cadinol	OS	1640	0	0	0	1	0
105	β-Eudesmol	OS	1650	0	0	0	0	0
106	α-Cadinol	OS	1654	0	0	0	1	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
86	*cis*-Sesquisabinene hydrate (IPP)	OS	1544	0	0	0	0	0
87	Elemol	OS	1549	0	1	0	0	0
88	Germacrene B	SH	1561	1	1	0	1	1
89	(*E*)-Nerolidol	OS	1563	0	0	0	0	0
90	Santalenone	OS	1577	0	0	0	0	0
91	Spathulenol	OS	1578	1	1	0	0	0
92	Caryophyllene oxide	OS	1583	0	1	1	1	1
93	*ar*-Tumerol	OS	1583	0	0	0	0	0
94	Carotol	OS	1594	0	0	0	0	0
95	Rosifoliol	OS	1600	0	0	1	1	0
96	Guaiol	OS	1600	0	1	0	0	0
97	Curzerenone	OS	1606	1	1	0	1	0
98	Humulene epoxide II	OS	1608	0	0	0	0	1
99	β-Biotol	OS	1613	0	0	0	0	0
100	*Z*-Asarone	PP	1617	0	0	0	0	0
101	Helifolen-12-al C (anti-syn-syn-)	OS	1620	0	0	0	0	0
102	1-*epi*-Cubenol	OS	1628	0	0	0	0	0
103	γ-Eudesmol	OS	1632	0	0	0	0	0
104	*epi*-α-Cadinol	OS	1640	0	0	0	0	1
105	β-Eudesmol	OS	1650	1	0	0	0	0
106	α-Cadinol	OS	1654	0	0	0	1	1

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

				Occurrence in the oil[c]					
No.	Compound	Class[a]	KI[b]	*Curcuma sp. 8*	*Curcuma sp. 9*	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
86	*cis*-Sesquisabinene hydrate (IPP)	OS	1544	0	0	0	0	0	0
87	Elemol	OS	1549	0	0	0	0	0	0
88	Germacrene B	SH	1561	1	0	1	1	1	0
89	(*E*)-Nerolidol	OS	1563	0	0	0	0	0	1
90	Santalenone	OS	1577	0	0	0	0	0	0
91	Spathulenol	OS	1578	1	0	0	0	0	0
92	Caryophyllene oxide	OS	1583	1	1	0	0	0	0
93	*ar*-Tumerol	OS	1583	0	0	0	0	0	0
94	Carotol	OS	1594	0	0	0	0	0	0
95	Rosifoliol	OS	1600	0	0	0	0	0	0
96	Guaiol	OS	1600	0	0	0	0	0	0
97	Curzerenone	OS	1606	1	0	0	0	0	0
98	Humulene epoxide II	OS	1608	0	0	0	0	0	0
99	β-Biotol	OS	1613	0	0	0	0	0	0
100	*Z*-Asarone	PP	1617	0	0	0	0	0	0
101	Helifolen-12-al C (anti-syn-syn-)	OS	1620	0	0	0	0	0	0
102	1-*epi*-Cubenol	OS	1628	0	0	1	0	0	0
103	γ-Eudesmol	OS	1632	0	0	1	0	0	0
104	*epi*-α-Cadinol	OS	1640	0	0	0	0	0	0
105	β-Eudesmol	OS	1650	0	0	1	0	0	0
106	α-Cadinol	OS	1654	0	0	1	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

				Occurrence in the oil[c]				
No.	Compound	Class[a]	KI[b]	*C. aeruginosa*	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
107	Atractylone	OS	1658	0	0	0	0	0
108	Selin-11-en-4-α-ol	OS	1659	0	0	0	0	0
109	*neo*-Intermedeol	OS	1660	0	0	0	0	0
110	*ar*-Turmerone	OS	1669	0	0	0	0	0
111	Bulnesol	OS	1671	0	0	0	0	0
112	*epi*-β-Bisabolol	OS	1671	0	0	0	1	1
113	α-Bisabolol	OS	1675	0	0	0	0	0
114	Helifolenol A	OS	1675	0	0	0	0	1
115	Germacrone	OS	1693	1	1	1	1	1
116	(*Z*)-γ-Atlantone	OS	1694	0	0	0	0	0
117	1,3,3-Trimethyl-2-oxabicyclo [2.2.2] octan-6-ol, acetate	OM	1700	0	0	0	0	0
118	Curcuphenol	OS	1718	0	0	0	0	1
119	Curcumenol	OS	1734	1	0	0	0	0
120	*6R,7R*-Bisabolone	OS	1742	0	1	0	0	0
121	2*E*,6*E*-Farnesol	OS	1743	0	0	0	0	0
122	Benzyl benzoate	Other	1760	0	0	0	0	0
123	β-Costol	OS	1767	0	0	0	0	0
124	*E*-α-Atlantone	OS	1778	0	0	0	0	0
125	2*E*,6*E*-Farnesyl acetate	OS	1846	0	0	0	0	0
126	Benzyl salicylate	Other	1865	0	0	0	0	0
127	Pimaradiene	DH	1949	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
107	Atractylone	OS	1658	0	0	0	0	0
108	Selin-11-en-4-α-ol	OS	1659	0	0	0	0	0
109	*neo*-Intermedeol	OS	1660	0	0	0	0	0
110	*ar*-Turmerone	OS	1669	0	1	0	0	0
111	Bulnesol	OS	1671	0	0	0	0	0
112	*epi*-β-Bisabolol	OS	1671	0	0	0	0	0
113	α-Bisabolol	OS	1675	0	0	0	0	0
114	Helifolenol A	OS	1675	0	0	0	0	0
115	Germacrone	OS	1693	0	0	1	0	1
116	(*Z*)-γ-Atlantone	OS	1694	0	1	0	0	0
117	1,3,3-Trimethyl-2-oxabicyclo [2.2.2] octan-6-ol, acetate	OM	1700	0	0	0	0	0
118	Curcuphenol	OS	1718	0	0	0	0	0
119	Curcumenol	OS	1734	0	0	0	0	0
120	*6R,7R*-Bisabolone	OS	1742	0	1	0	0	0
121	2*E*,6*E*-Farnesol	OS	1743	0	0	0	0	0
122	Benzyl benzoate	Other	1760	0	0	0	0	0
123	β-Costol	OS	1767	0	0	0	0	0
124	*E*-α-Atlantone	OS	1778	0	1	0	0	0
125	2*E*,6*E*-Farnesyl acetate	OS	1846	0	0	0	0	0
126	Benzyl salicylate	Other	1865	0	0	0	0	0
127	Pimaradiene	DH	1949	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
107	Atractylone	OS	1658	0	0	0	0	1
108	Selin-11-en-4-α-ol	OS	1659	0	0	0	0	0
109	*neo*-Intermedeol	OS	1660	0	0	0	0	0
110	*ar*-Turmerone	OS	1669	0	0	1	0	0
111	Bulnesol	OS	1671	0	0	0	0	0
112	*epi*-β-Bisabolol	OS	1671	0	0	0	0	0
113	α-Bisabolol	OS	1675	0	1	0	0	0
114	Helifolenol A	OS	1675	0	0	0	0	0
115	Germacrone	OS	1693	1	1	0	1	1
116	(*Z*)-γ-Atlantone	OS	1694	0	0	1	0	0
117	1,3,3-Trimethyl-2-oxabicyclo [2.2.2] octan-6-ol, acetate	OM	1700	0	0	0	0	0
118	Curcuphenol	OS	1718	0	0	0	0	0
119	Curcumenol	OS	1734	0	0	0	1	0
120	*6R,7R*-Bisabolone	OS	1742	0	0	1	0	0
121	2*E*,6*E*-Farnesol	OS	1743	0	0	0	0	0
122	Benzyl benzoate	Other	1760	0	0	0	0	0
123	β-Costol	OS	1767	0	0	0	0	0
124	*E*-α-Atlantone	OS	1778	0	0	1	0	0
125	2*E*,6*E*-Farnesyl acetate	OS	1846	0	0	0	0	0
126	Benzyl salicylate	Other	1865	0	0	0	0	0
127	Pimaradiene	DH	1949	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
107	Atractylone	OS	1658	0	1	0	0	0
108	Selin-11-en-4-α-ol	OS	1659	0	0	1	0	0
109	*neo*-Intermedeol	OS	1660	0	0	0	0	0
110	*ar*-Turmerone	OS	1669	0	0	1	0	1
111	Bulnesol	OS	1671	0	1	0	0	0
112	*epi*-β-Bisabolol	OS	1671	0	0	0	0	0
113	α-Bisabolol	OS	1675	0	0	0	0	0
114	Helifolenol A	OS	1675	0	0	0	0	0
115	Germacrone	OS	1693	1	1	1	1	1
116	(*Z*)-γ-Atlantone	OS	1694	0	0	1	0	0
117	1,3,3-Trimethyl-2-oxabicyclo [2.2.2] octan-6-ol, acetate	OM	1700	0	0	0	0	0
118	Curcuphenol	OS	1718	0	0	0	0	0
119	Curcumenol	OS	1734	0	0	0	0	0
120	*6R,7R*-Bisabolone	OS	1742	0	0	0	0	0
121	2*E*,6*E*-Farnesol	OS	1743	0	0	0	0	0
122	Benzyl benzoate	Other	1760	0	0	0	0	0
123	β-Costol	OS	1767	0	1	0	0	0
124	*E*-α-Atlantone	OS	1778	0	0	0	0	0
125	2*E*,6*E*-Farnesyl acetate	OS	1846	0	0	0	0	0
126	Benzyl salicylate	Other	1865	0	0	0	0	0
127	Pimaradiene	DH	1949	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]					
				Curcuma sp. 8	*Curcuma* sp. 9	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
107	Atractylone	OS	1658	1	0	0	0	0	0
108	Selin-11-en-4-α-ol	OS	1659	1	0	1	0	0	0
109	*neo*-Intermedeol	OS	1660	0	0	0	0	1	0
110	*ar*-Turmerone	OS	1669	0	0	0	0	0	0
111	Bulnesol	OS	1671	0	0	0	0	0	0
112	*epi*-β-Bisabolol	OS	1671	0	0	0	0	0	0
113	α-Bisabolol	OS	1675	0	0	0	0	0	0
114	Helifolenol A	OS	1675	0	0	0	0	0	0
115	Germacrone	OS	1693	1	0	0	0	0	0
116	(*Z*)-γ-Atlantone	OS	1694	0	0	0	0	0	0
117	1,3,3-Trimethyl-2-oxabicyclo [2.2.2] octan-6-ol, acetate	OM	1700	0	0	0	0	1	0
118	Curcuphenol	OS	1718	0	0	0	0	0	0
119	Curcumenol	OS	1734	0	0	0	0	0	0
120	*6R,7R*-Bisabolone	OS	1742	0	0	0	0	0	0
121	2*E*,6*E*-Farnesol	OS	1743	0	0	0	0	1	0
122	Benzyl benzoate	Other	1760	0	0	1	0	0	0
123	β-Costol	OS	1767	1	0	0	0	0	0
124	*E*-α-Atlantone	OS	1778	0	0	0	0	0	0
125	2*E*,6*E*-Farnesyl acetate	OS	1846	0	0	0	0	1	0
126	Benzyl salicylate	Other	1865	0	0	1	0	0	0
127	Pimaradiene	DH	1949	0	0	1	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

				Occurrence in the oil[c]				
No.	Compound	Class[a]	KI[b]	*C. aeruginosa*	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
128	13-*epi*-Manool	OD	2060	0	0	0	0	0
129	1,3,8-*ρ*-Menthatriene	MH	-	0	0	0	0	0
130	*trans*-1-methyl-2-(1-methylethenyl)-cyclobutaneethanol	OM	-	0	0	0	0	0
131	Hydroxy-α-terpenyl acetate	OM	-	0	0	0	0	0
132	Viridiflorene	SH	-	1	0	0	0	0
133	Selina-6-en-4-ol	OS	-	0	0	0	0	0
134	Neocurdione	OS	-	1	0	0	0	0
135	Curlone	OS	-	0	0	0	0	0
136	Santalol	OS	-	0	0	0	0	0
137	Veridiflorol	OS	-	0	0	0	0	0
138	(*E*,*E*)-(11*S*)- 6α-Hydroxy-t-lactone germacra-1(10), 4-diene-12-oic acid	OS	-	1	0	0	0	0
139	2,6,11,15-Tetramethyl-hexadeca-2,6,8,10,14-pentaene	DH	-	0	0	0	0	0
140	Methyl 3,4-dimethoxycinnamate	PP	-	0	0	0	0	0
141	8-Heptadecene	Other	-	0	0	0	0	0
142	(*E*)-1-(3,4)-dimethoxyphenylbutadiene	Other	-	0	0	0	0	0
143	Chiapin B	Other	-	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
128	13-*epi*-Manool	OD	2060	0	0	0	0	1
129	1,3,8-ρ-Menthatriene	MH	-	1	0	0	0	0
130	*trans*-1-methyl-2-(1-methylethenyl)-cyclobutaneethanol	OM	-	0	0	0	0	0
131	Hydroxy-α-terpenyl acetate	OM	-	0	0	0	0	0
132	Viridiflorene	SH	-	0	0	0	0	0
133	Selina-6-en-4-ol	OS	-	0	0	0	0	1
134	Neocurdione	OS	-	0	0	0	0	0
135	Curlone	OS	-	0	1	0	0	0
136	Santalol	OS	-	0	0	0	0	0
137	Veridiflorol	OS	-	1	0	0	0	0
138	(*E*,*E*)-(11*S*)- 6α-Hydroxy-t-lactone germacra-1(10), 4-diene-12-oic acid	OS	-	0	0	0	0	0
139	2,6,11,15-Tetramethyl-hexadeca-2,6,8,10,14-pentaene	DH	-	0	0	1	0	0
140	Methyl 3,4-dimethoxycinnamate	PP	-	0	0	0	0	0
141	8-Heptadecene	Other	-	0	0	0	0	0
142	(*E*)-1-(3,4)-dimethoxyphenylbutadiene	Other	-	0	0	0	0	0
143	Chiapin B	Other	-	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
128	13-*epi*-Manool	OD	2060	1	0	0	0	0
129	1,3,8-*ρ*-Menthatriene	MH	-	0	0	0	0	0
130	*trans*-1-methyl-2-(1-methylethenyl)-cyclobutaneethanol	OM	-	0	0	0	0	0
131	Hydroxy-α-terpenyl acetate	OM	-	0	0	0	0	0
132	Viridiflorene	SH	-	0	0	0	0	0
133	Selina-6-en-4-ol	OS	-	1	0	0	0	0
134	Neocurdione	OS	-	0	0	0	0	0
135	Curlone	OS	-	0	0	1	0	0
136	Santalol	OS	-	0	0	0	0	0
137	Veridiflorol	OS	-	0	0	0	0	0
138	(*E*,*E*)-(11*S*)- 6α-Hydroxy-t-lactone germacra-1(10), 4-diene-12-oic acid	OS	-	0	0	0	0	0
139	2,6,11,15-Tetramethyl-hexadeca-2,6,8,10,14-pentaene	DH	-	0	0	0	0	0
140	Methyl 3,4-dimethoxycinnamate	PP	-	0	0	0	0	0
141	8-Heptadecene	Other	-	0	0	0	0	0
142	(*E*)-1-(3,4)-dimethoxyphenylbutadiene	Other	-	0	0	0	0	0
143	Chiapin B	Other	-	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
128	13-*epi*-Manool	OD	2060	0	0	0	0	1
129	1,3,8-*ρ*-Menthatriene	MH	-	0	0	0	0	0
130	*trans*-1-methyl-2-(1-methylethenyl)-cyclobutaneethanol	OM	-	0	0	1	0	0
131	Hydroxy-α-terpenyl acetate	OM	-	0	0	0	0	0
132	Viridiflorene	SH	-	0	0	0	0	0
133	Selina-6-en-4-ol	OS	-	0	0	0	0	0
134	Neocurdione	OS	-	1	0	1	1	0
135	Curlone	OS	-	0	0	1	1	0
136	Santalol	OS	-	1	0	0	0	0
137	Veridiflorol	OS	-	0	0	0	0	0
138	(*E*,*E*)-(11*S*)- 6α-Hydroxy-t-lactone germacra-1(10), 4-diene-12-oic acid	OS	-	0	0	0	0	0
139	2,6,11,15-Tetramethyl-hexadeca-2,6,8,10,14-pentaene	DH	-	0	0	0	0	0
140	Methyl 3,4-dimethoxycinnamate	PP	-	0	0	0	0	0
141	8-Heptadecene	Other	-	0	0	0	0	0
142	(*E*)-1-(3,4)-dimethoxyphenylbutadiene	Other	-	0	0	0	0	0
143	Chiapin B	Other	-	0	1	0	1	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]					
				Curcuma sp. 8	*Curcuma* sp. 9	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
128	13-*epi*-Manool	OD	2060	0	0	0	0	0	0
129	1,3,8-*ρ*-Menthatriene	MH	-	0	0	0	0	0	0
130	*trans*-1-methyl-2-(1-methylethenyl)-cyclobutaneethanol	OM	-	0	0	0	0	0	0
131	Hydroxy-α-terpenyl acetate	OM	-	0	0	0	0	1	0
132	Viridiflorene	SH	-	0	0	0	0	0	0
133	Selina-6-en-4-ol	OS	-	0	0	0	0	0	0
134	Neocurdione	OS	-	1	0	0	0	0	0
135	Curlone	OS	-	0	0	0	0	0	0
136	Santalol	OS	-	1	0	0	0	0	0
137	Veridiflorol	OS	-	0	0	0	0	0	0
138	(*E*,*E*)-(11*S*)- 6α-Hydroxy-t-lactone germacra-1(10), 4-diene-12-oic acid	OS	-	0	0	0	0	0	0
139	2,6,11,15-Tetramethyl-hexadeca-2,6,8,10,14-pentaene	DH	-	0	0	0	0	0	0
140	Methyl 3,4-dimethoxycinnamate	PP	-	0	0	0	1	0	0
141	8-Heptadecene	Other	-	0	0	0	0	1	0
142	(*E*)-1-(3,4)-dimethoxy phenylbutadiene	Other	-	0	0	0	1	0	0
143	Chiapin B	Other	-	1	0	0	0	0	0

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. aeruginosa	*C. albicoma*	*C. amada*	*C. angustifolia*	*C. aromatica*
144	7-Hydroxycadalene	Other	-	0	0	0	0	0
145	α-Methyl-benzenepropanol	Other	-	0	0	0	0	0
146	α-Methoxy-α,α-dimethylstyrene	Other	-	0	1	0	0	0
147	5-Methoxy-7-methyl-1,2-naphthoquinone	Other	-	0	1	0	0	0
148	(*E*,*E*) 8-Methyl-7-(1-methylethyl)-3,5,7-nonatriene-2-one	Other	-	0	0	0	0	0
149	4-Ethenyl-6-(2-hydroxyacetoxy)-2,4,7,1] 4-tetramethyl tricyclo 5.4.3.0 (1,8) [tetradecan-ol-9-one,	Other	-	1	0	0	0	0
150	2-Methyl-4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-(*E*)-1-Buten-1-ol, formate	Other	-	0	0	0	0	0

[a] MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;

SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes;

DH: Diterpene hydrocarbons; OD: Oxygenated sesquiterpenes:

PP: Phenylprppanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

[c] 0: absence of compounds; 1: presence of compounds

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. comosa	*C. longa*	*C. mangga*	*C. parviflora*	*C. petiolata*
144	7-Hydroxycadalene	Other	-	0	0	0	1	0
145	α-Methyl-benzenepropanol	Other	-	1	0	0	0	0
146	α-Methoxy-α,α-dimethylstyrene	Other	-	0	0	0	0	0
147	5-Methoxy-7-methyl-1,2-naphthoquinone	Other	-	0	0	0	0	0
148	(*E*,*E*) 8-Methyl-7-(1-methylethyl)-3,5,7-nonatriene-2-one	Other	-	0	0	0	0	0
149	4-Ethenyl-6-(2-hydroxyacetoxy)-2,4,7,1] 4-tetramethyl tricyclo 5.4.3.0 (1,8) [tetradecan-ol-9-one,	Other	-	0	0	0	0	0
150	2-Methyl-4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-(*E*)-1-Buten-1-ol, formate	Other	-	0	0	1	0	0

[a] MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;

SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes;

DH: Diterpene hydrocarbons; OD: Oxygenated sesquiterpenes:

PP: Phenylprppanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

[c] 0: absence of compounds; 1: presence of compounds

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				C. rubrobracteata	*C. sessilis*	*C. zedoaria*	*Curcuma* sp. 1	*Curcuma* sp. 2
144	7-Hydroxycadalene	Other	-	0	0	0	0	0
145	α-Methyl-benzenepropanol	Other	-	0	0	0	0	0
146	α-Methoxy-α,α-dimethylstyrene	Other	-	0	0	0	0	0
147	5-Methoxy-7-methyl-1,2-naphthoquinone	Other	-	0	0	0	0	0
148	(*E*,*E*) 8-Methyl-7-(1-methylethyl)-3,5,7-nonatriene-2-one	Other	-	0	0	0	0	0
149	4-Ethenyl-6-(2-hydroxyacetoxy)-2,4,7,1] 4-tetramethyl tricyclo 5.4.3.0 (1,8) [tetradecan-ol-9-one,	Other	-	0	0	0	0	0
150	2-Methyl-4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-(*E*)-1-Buten-1-ol, formate	Other	-	0	0	0	0	0

[a] MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;

SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes;

DH: Diterpene hydrocarbons; OD: Oxygenated sesquiterpenes:

PP: Phenylprppanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

[c] 0: absence of compounds; 1: presence of compounds

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				Curcuma sp. 3	*Curcuma* sp. 4	*Curcuma* sp. 5	*Curcuma* sp. 6	*Curcuma* sp. 7
144	7-Hydroxycadalene	Other	-	0	0	0	0	0
145	α-Methyl-benzenepropanol	Other	-	0	0	0	0	0
146	α-Methoxy-α,α-dimethylstyrene	Other	-	0	0	0	0	0
147	5-Methoxy-7-methyl-1,2-naphthoquinone	Other	-	0	0	0	0	0
148	(*E*,*E*) 8-Methyl-7-(1-methylethyl)-3,5,7-nonatriene-2-one	Other	-	0	0	0	0	0
149	4-Ethenyl-6-(2-hydroxyacetoxy)-2,4,7,1] 4-tetramethyl tricyclo 5.4.3.0 (1,8) [tetradecan-ol-9-one,	Other	-	0	0	0	0	0
150	2-Methyl-4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-(*E*)-1-Buten-1-ol, formate	Other	-	0	0	0	0	0

[a] MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;

SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes;

DH: Diterpene hydrocarbons; OD: Oxygenated sesquiterpenes:

PP: Phenylprppanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

[c] 0: absence of compounds; 1: presence of compounds

Table12. Chemical compounds found in the essential oils of the *Curcuma* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]					
				Curcuma sp. 8	*Curcuma sp. 9*	*K. rotunda*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
144	7-Hydroxycadalene	Other	-	0	0	0	0	0	0
145	α-Methyl-benzenepropanol	Other	-	0	0	0	0	0	0
146	α-Methoxy-α,α-dimethylstyrene	Other	-	0	0	0	0	0	0
147	5-Methoxy-7-methyl-1,2-naphthoquinone	Other	-	0	0	0	0	0	0
148	(*E*,*E*) 8-Methyl-7-(1-methylethyl)-3,5,7-nonatriene-2-one	Other	-	0	1	0	0	0	0
149	4-Ethenyl-6-(2-hydroxyacetoxy)-2,4,7,1] 4-tetramethyl tricyclo 5.4.3.0 (1,8) [tetradecan-ol-9-one,	Other	-	0	0	0	0	0	0
150	2-Methyl-4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-(*E*)-1-Buten-1-ol, formate	Other	-	0	0	0	0	0	0

[a] MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;

SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes;

DH: Diterpene hydrocarbons; OD: Oxygenated sesquiterpenes:

PP: Phenylprppanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

[c] 0: absence of compounds; 1: presence of compounds

Table 13. The main component in essential oil of *Curcuma* species

Main component	Species*
(*Z*)-γ-Atlantone [116]	*C. longa*, *C. zedoaria* (ZE2)
Camphene [4]	*Curcuma* sp. 9
Camphor [28]	*C. parviflora*
Caryophyllene oxide [92]	*Curcuma* sp. 7 (SP71)
Chiapin B [143]	*Curcuma* sp. 8 (SP81, SP83)
β-Curcumene [81]	*C. aromatica*
Curzerenone [97]	*C. aeruginosa* (AE1, AE2), *Curcuma* sp. 3, *Curcuma* sp. 6 (SP63)
trans-1-methyl-2-(1-methylethenyl)-Cyclobutaneethanol [130]	*Curcuma* sp. 5 (SP51)
Germacrene B [88]	*Curcuma* sp. 2
Germacrone [115]	*C. aeruginosa* (AE3), *C. angustifolia*, *C. petiolata*, *C. rubrobracteata*, *C. sesselis*, *Curcuma* sp. 1, *Curcuma* sp. 4, *Curcuma* sp. 5 (SP53), *Curcuma* sp. 7 (SP72), *Curcuma* sp. 8 (SP82)
Myrcene [7]	*C. mangga*
Neocurdione [134]	*Curcuma* sp. 6 (SP61)
β-Pinene [6]	*C. amada*
Terpinolene [20]	*C. comosa*
ar-Turmerone [110]	*C. zedoaria* (ZE1)
α-Zingiberene [70]	*C. albicoma*

* Letters in the parentheses after the name of the plants represent the difference accessions of plant samples. Abbreviations of the plant samples are according to the codes used in Table 10.

A dendrogram obtained from the cluster analysis based on essential oil compositions of all *Curcuma* accessions is shown in Figure 2. The dendrogram showed that the accessions which belonged to the same *Curcuma* species from different locations were grouped together. The whole data on essential oil compositions of different accessions belonging to the same species (Table 12) were used as the representative data for such *Curcuma* species and employed in cluster analysis, resulting in a dendrogram shown in Figure 3.

The dendrogram showed the division of *Curcuma* species into five clusters. Cluster I was divided into two subgroups, Ia and Ib. Subgroup Ia consisted of *Curcuma* sp. 7, *C. comosa*, *C. mangga*, *C. albicoma* and *C. amada* while subgroup Ib consisted of *C. angustifolia* and *C. sessilis*. This cluster was characterized by the presence of *Z*-asarone [100]. Limonene [13] was found in all member of this cluster but not common in other cluster. In addition, santalenone [90] was only found in subgroup Ib.

Cluster II was divided into two subgroups IIa and IIb. *C. longa* and *C. zedoaria* were clustered in subgroup IIa while *Curcuma* sp. 5 and *Curcuma* sp. 6 were clustered in subgroup IIb. This cluster was characterized by the presence of curlone [135] and (*Z*)-γ-atlantone [116]. Compounds which were found in all member of this cluster but not common in the other cluster and outgroup plants included β-sesquiphellandrene [83] and *ar*-curcumene [93]. In addition, Subgroup IIa was characterized by the presence of *ar*-Tumerol [93], helifolen-12-al C (anti-syn-syn-) [101] and *E*-α-atlantone [124] whereas subgroup IIb was characterized by the presence of rosifoliol [95].

Cluster III was divided into two subgroups IIIa and IIIb. Subgroup IIIa consisted of *C. aromatica, Curcuma* sp. 1, *C. aeruginosa*, *Curcuma* sp. 2, *Curcuma* sp. 3 while subgroup IIIb consisted of *Curcuma* sp. 4 and *Curcuma* sp. 8. Subgroup IIIb was characterized by the presence of β-costol [123].

Cluster IV consists of *C. rubrobracteata* and *C. petiolata*. This cluster was characterized by presence of selina-6-en-4-ol [133]. α-Selinene [72] and 13-*epi*-

manool [128] were found in both member of this cluster but not common in other cluster and outgroup plants.

The last cluster, *C. parviflora* and *Curcuma* sp. 9, was characterized by presence of sylvestrene [14] and α-copanene [49]. Borneol [33] was found in both member of this cluster but not common in other cluster and outgroup plants.

The characteristic compounds of each cluster are shown in Table 14.

From the data on essential oil compositions of *Curcuma* plants grouped in each cluster, oxygenated sesquiterpenes were found to be the main group of compounds in cluster II, III and IV (46.18-59.61%) while monoterpene hydrocarbons were found to be the main group in cluster V (44.27%). In cluster Ia, monoterpene hydrocarbons were found to be the main group (43.11%) whereas in cluster Ib was sesquiterpene hydrocarbons (40.93%) (Figure 4).

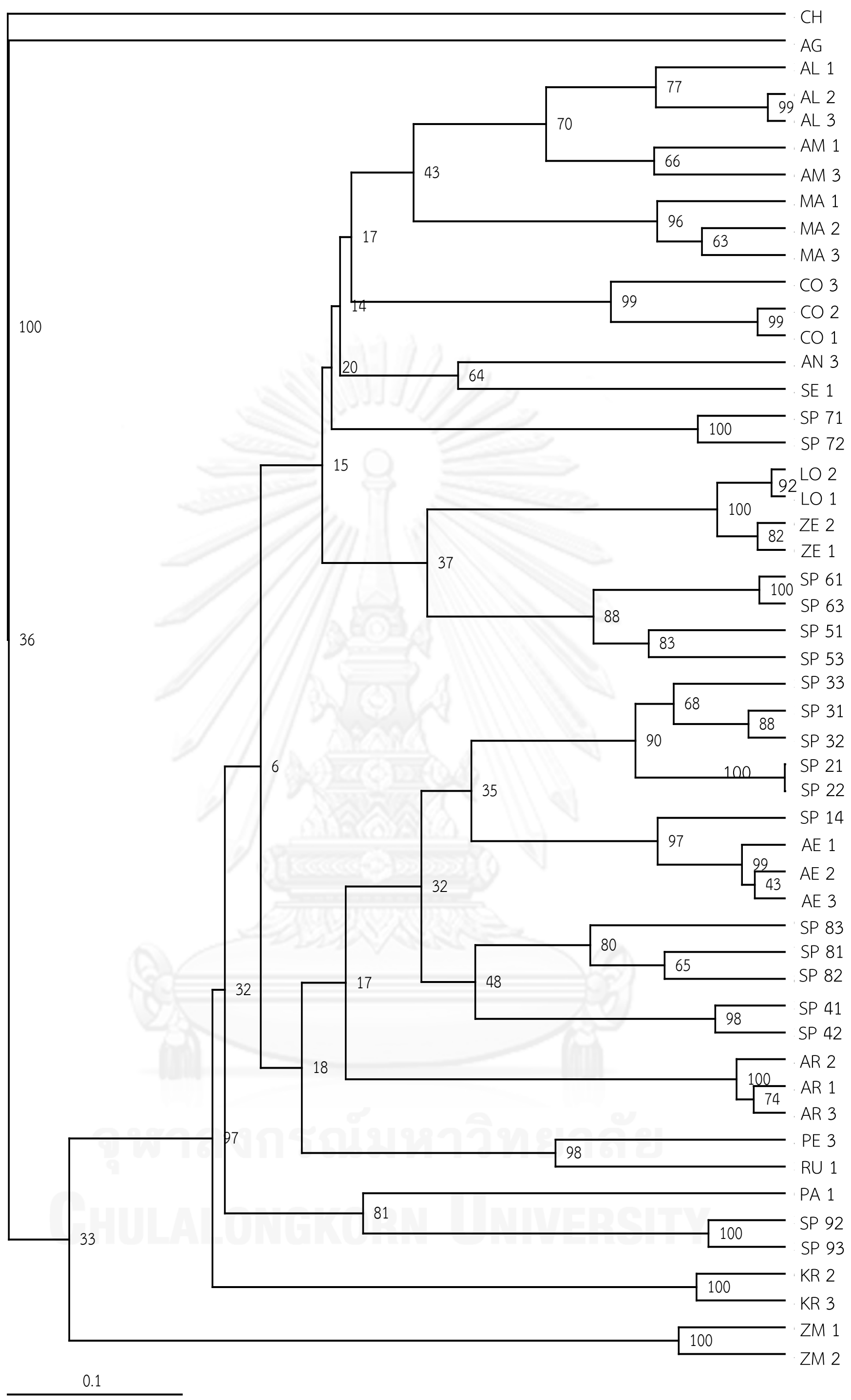


Figure 2. Dendrogram based on essential oil compositions of all accession of *Curcuma* and outgroup plants. Abbreviations of the plant samples are according to the codes used in Table 10.

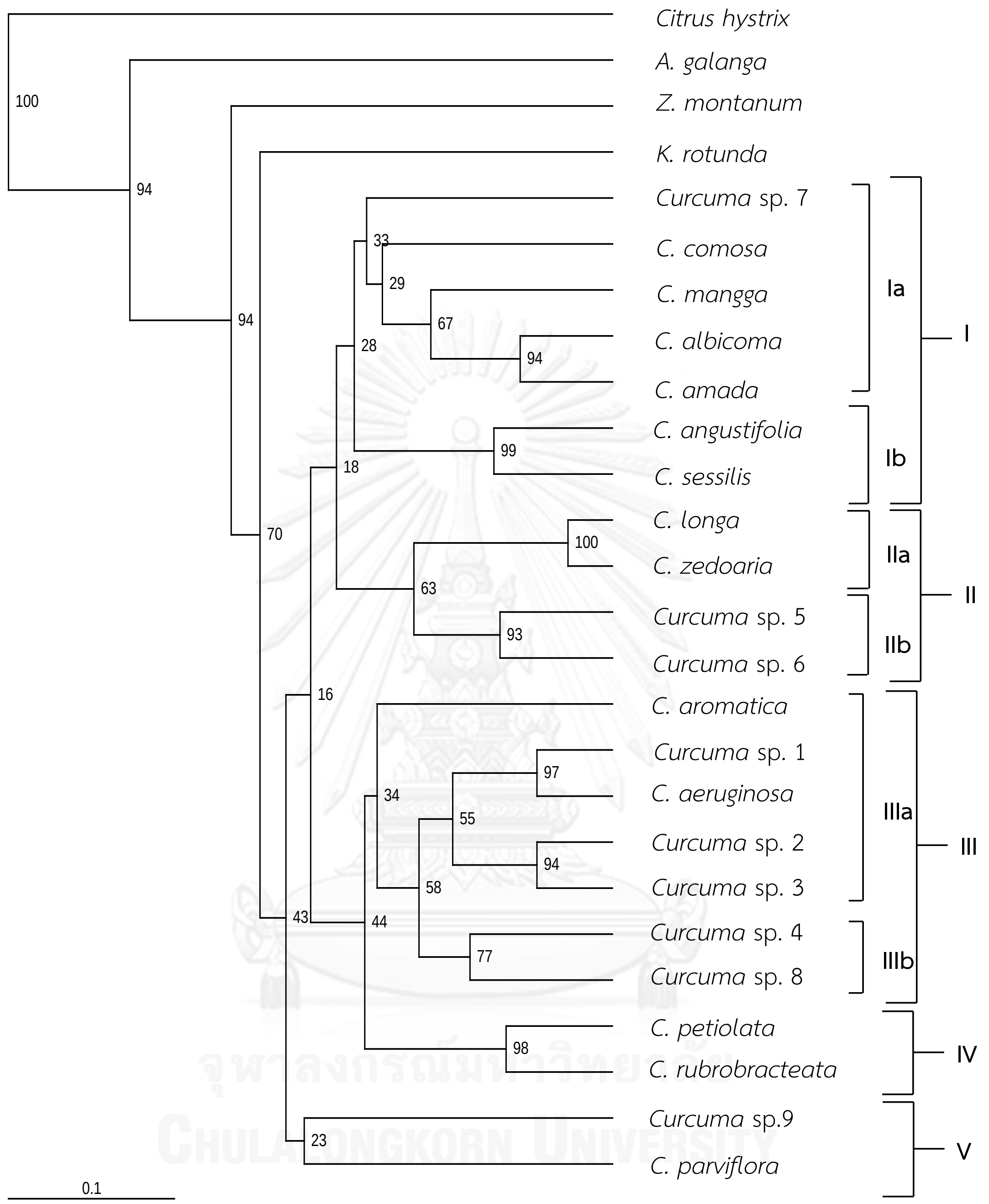


Figure 3. Dendrogram based on essential oil compositions of 22 *Curcuma* and outgroup plants.

Table 14. The characteristic compounds of each cluster

Cluster		Compounds
I		*Z*-Asarone
	Ia	-
	Ib	-
II		Curlone, (*Z*)-γ-Atlantone
	IIa	*ar*-Tumerol, Helifolen-12-al C (anti-syn-syn-), *E*-α-Atlantone
	IIb	Rosifoliol
III		–
	IIIa	–
	IIIb	Costol
IV		Selina-6-en-4-ol
V		Sylvestrene, α-Copanene

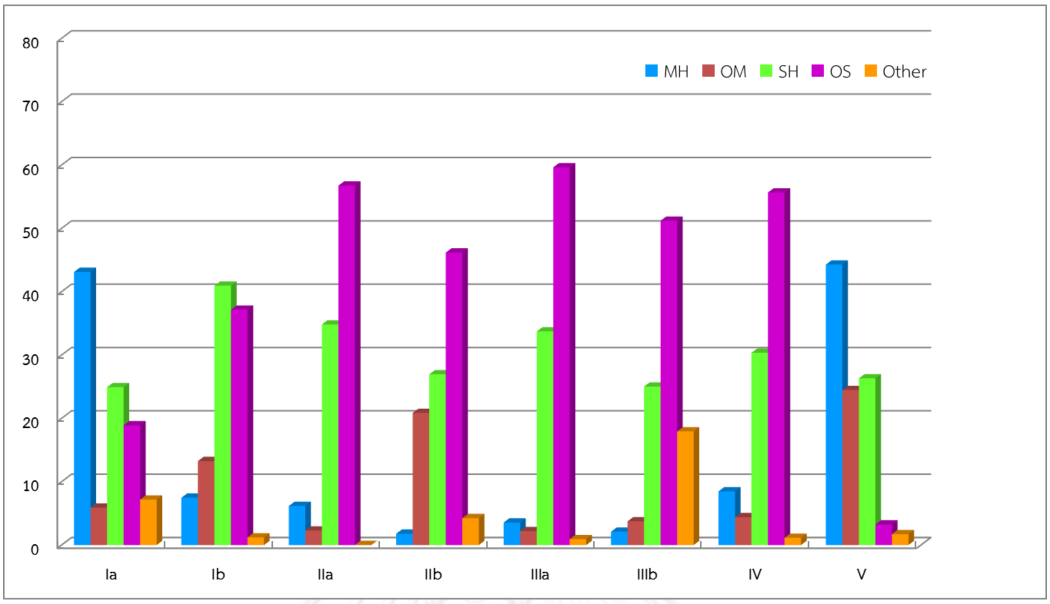


Figure 4. The percentage of classes of compound in *Curcuma*'s rhizome oil in each cluster

MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;

SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes

4.1.2 RAPD analysis

Seventy random primers were screened, only twelve primers (OPC-05, OPD-07, OPE-01, OPG-03, OPI-16, OPJ-20, OPK-09, OPS-01, OPS-12, OPS-19, OPV-12 and RAPD F-29) produced clear and reproducible polymorphic bands in all plant samples. Seventeen to thirty-six PCR products were amplified, with an average of 25.8 bands by each primer. The highest number of RAPD bands (36 bands) was generated from OPD-07 while the lowest (17 bands) was from OPJ-20. A total of 310 amplified bands ranging from 209 to 3901 bp in size were amplified, with 96 polymorphic bands being observed. Primer RAPD F-29 produced the highest percentage of polymorphism (45.00%) while OPK-09 and OPS-12 produced the lowest (13.04%) (Table15).

According to the twelve primers that produced clear and reproducible polymorphic bands, the OPC-5 primer produced the polymorphic bands of 666 bp in *C. longa*, 500 bp in *Curcuma* sp. 6, 372 and 2230 bp in *Curcuma* sp. 8 and 1812 bp in *Citrus hystrix* (Figure 5). The OPD-07 primer produced the polymorphic bands of 531 bp in *C. aromatica*, 253 bp in *C. mangga*, 282 bp in *C. comosa*, 628 bp in *C. albicoma*, 1919 bp in *C. angustifolia,* 224 and 1490 bp in *C. rubrobracteata*, 3015 bp in *Curcuma* sp. 4, 3216 bp in *Curcuma* sp. 8, 225, 273 and 524 bp in *A. galanga* and 553 bp in *Citrus hystrix* (Figure 6). The polymorphic bands of 653 bp in *C. albicoma*, 1632 bp in *C. sessilis*, 241, 774 and 2830 bp in *K. rotunda,* 393 and 552 bp in *A. galanga* and 1597 bp in *Citrus hystrix* were generated by the OPE-01 primer (Figure 7). The OPG-03 primer produced the polymorphic bands of 947 and 1984 bp in *C. longa*, 750 bp in *C. mangga*, 506 bp in *C. sessilis*, 485 and 1132 bp in *C. petiolata*, 1430 bp in *Curcuma* sp. 1, 3122 bp in *Curcuma* sp. 3, 441 bp in *Curcuma* sp. 4, 401 bp in *Curcuma* sp. 5, 694 in *K. rotunda* and 314 bp in *Citrus hystrix* (Figure 8). The OPI-16 primer produced the polymorphic bands of 440 bp in *C. longa*, 381 bp in *C. albicoma*, 223 and 255 bp in *C. sessilis*, 1494 bp in *C. petiolata*, 531 bp in *C. parviflora*, 519 bp in *Curcuma* sp. 9, 882 bp in *Curcuma* sp. 6, 1372 bp in *K. rotunda* and 1748 bp in *Citrus hystrix* (Figure 9). The polymorphic bands of 1045 bp in *C. longa*, 295 bp in *Curcuma* sp. 1 and 1482 bp in *A. galanga* were generated by the OPJ-20 primer (Figure 10) while the polymorphic bands of

278 and 409 bp in *C. aromatica* and 552 bp in *Z. montanum* were generated by the OPK-09 primer (Figure 11). The OPS-01 primer produced the polymorphic bands of 1064 bp in *C. longa*, 2340 bp in *C. aromatica*, 486 bp in *C. albicoma*, 858 bp in *Curcuma* sp. 9, 3647 bp in *Curcuma* sp. 8, 400 and 606 bp in *A. galanga* (Figure 12). The polymorphic bands of 919 bp in *Curcuma* sp. 5, 438 bp in *Curcuma* sp. 7 and 606 bp in *A. galanga* were generated by the OPS-12 primer (Figure 13). Moreover, the OPS-12 primer generated the approximately 250 bp characteristic band of all *Curcuma* species, which was not observed in case of all outgroup plants (Figure 13), indicating that the OPS-12 primer produced the characteristic band of *Curcuma* species. The OPS-19 primer produced the polymorphic bands of 235 bp in *C. sessilis*, 339 bp in *Curcuma* sp. 9, 1325 bp in *Curcuma* sp. 2, 2651 and 3500 bp in *Curcuma* sp. 4, 354 bp in *K. rotunda*, 312, 1546 and 2036 bp in *Z. montanum* and 1433 bp in *Citrus hystrix* (Figure 14). The polymorphic bands of 209 bp in *C. mangga*, 589 bp in *C. angustifolia*, 734 bp in *Curcuma* sp. 9, 589 bp in *C. rubrobracteata,* 500 bp in *Curcuma* sp. 6, 1189 bp in *Curcuma* sp. 7, 1976 and 2187 bp in *K. rotunda*, 958 bp in *Z. montanum*, and 833, 2356 and 3901 bp in *Citrus hystrix* were generated by the OPV-12 primer (Figure 15). The RAPD F-29 primer produced the polymorphic bands of 2347 bp in *C. zedoaria*, 1769 bp in *C. aeruginosa*, 918 bp in *C. angustifolia*, 707 and 1582 bp in *K. rotunda*, 422 in *A. galanga* and 229, 360 and 625 bp in *Citrus hystrix* (Figure 16). This primer generated the approximately 1000 bp characteristic band of all *Curcuma* species and three Zingiberaceous outgroup plants. In contrast, this band was not observed in Rutaceous plant (*Citrus hystrix*) (Figure 16). The results indicated that the RAPD F-29 primer produced the characteristic band of Zingiberaceous plants.

From the information mention above, sequencing of characteristic bands obtained from OPS-12 and RAPD-F 29 primers could be further developed for gene sequence similarity search. The results obtained might be useful information for characteristic gene of the *Curcuma* and Zingiberaceous plants, respectively. Furthermore, sequence characterized amplified regions (SCARs) could be further developed to differentiate plants that have similar morphological characteristics.

The pair-wise comparisons of the RAPD profiles based on both of the shared and unique amplification bands were used to generate a similarity index. Among 22 *Curcuma* species including outgroup plants, Dice similarity index ranged from 0.0615 to 0.7948 (Table 16). The highest genetic similarity index (0.7948) was found between *Curcuma* sp. 2 and *Curcuma* sp. 3, whereas the lowest (0.0615) was found between *C. longa* and *Citrus hystrix*.

A dendrogram was constructed according to the UPGMA cluster analysis using Dice similarity coefficient. The UPGMA dendrogram showed the division of 22 *Curcuma* species into five clusters (Figure 17). Cluster I, consists of *C. aeruginisa*, *Curcuma* sp. 1, *Curcuma* sp. 2, *Curcuma* sp. 3 with 0.5256-0.7948 similarity index. Cluster II includes 5 species which are *Curcuma* sp. 4, *Curcuma* sp. 5, *Curcuma* sp. 6, *Curcuma* sp. 7, and *Curcuma* sp. 8, with 0.4179-0.6749 similarity index. Cluster III consists of *C. angustifolia*, *C. sessilis*, *C. comosa*, *C. mangga*, *C. amada*, *C. albicoma*, *C. aromatica*, *C. longa* and *C. zedoaria*, with 0.2177-0.7178 similarity index. Cluster IV includes 2 species, *C. rubrobracteata* and *C. petiolata*, with 0.6877 similarity index. Cluster V consists of *C. parviflora* and *Curcuma* sp. 9, with 0.2810 similarity indexes. All outgroup plants were completely separated from the *Curcuma* species (Figure 17).

The result was similar to those previously reported by Angel *et al*. (2008) and Syamkumar and Sasikumar (2007). Based on RAPD and ISSR marker, *C. longa* and *C. zedoaria* were clustered in the same group whereas *C. aeruginosa* was classified in different subgroup from *C. comosa* and *C. amada*. Based on PCR-RFLP, *C. aromatica* and *C. zedoaria* were clustered in the same group (Ahmad, Kikuchi, Jatoi, Mimura, & Watanabe, 2009). In addition, based on ITS, *trn*K and chloroplast DNA sequences, *C. rubrobracteata* was grouped with *C. petiolata* and *C. longa* with *C. zedoaria* (H. Cao, Sasaki, Fushimi, & Komatsu, 2001; Zaveska *et al*., 2012).

Table 15. The sequence of the oligonucleotide primers used for the RAPD analysis and the number of PCR products obtained from *Curcuma* species and outgroup plants

Primer	Nucleotide sequence (5′ to 3′)	No. of bands	Size of bands	No. of polymorphic bands	Polymorphism (%)
OPC-05	GATGACCGCC	28	2230-372	5	17.86
OPD-07	TTGGCACGGG	36	3216-225	13	36.11
OPE-01	CCCAAGGTCC	20	2830-241	8	40.00
OPG-03	GAGCCCTCCA	32	3122-314	12	37.50
OPI-16	TCTCCGCCCT	26	1748-223	10	38.46
OPJ-20	AAGCGGCCTC	17	1482-295	3	17.65
OPK-09	CCCTACCGAC	23	3364-278	3	13.04
OPS-01	CTACTGCGCT	30	3647-400	7	23.33
OPS-12	CTGGGTGAGT	23	3657-257	3	13.04
OPS-19	GAGTCAGCAG	31	3500-235	10	32.26
OPV-12	ACCCCCCACT	31	3901-209	12	38.71
RAPD F-29	GCCGCTAATATG	20	3259-229	9	45.00

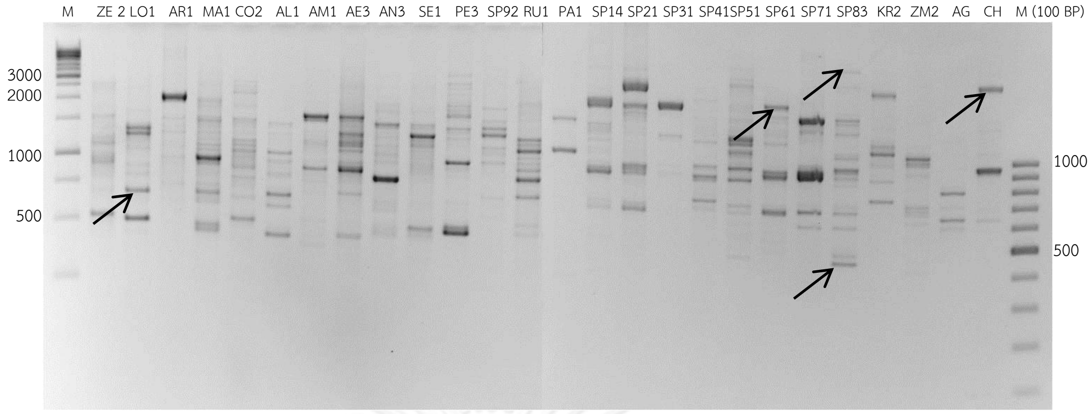


Figure 5. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPC-05 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

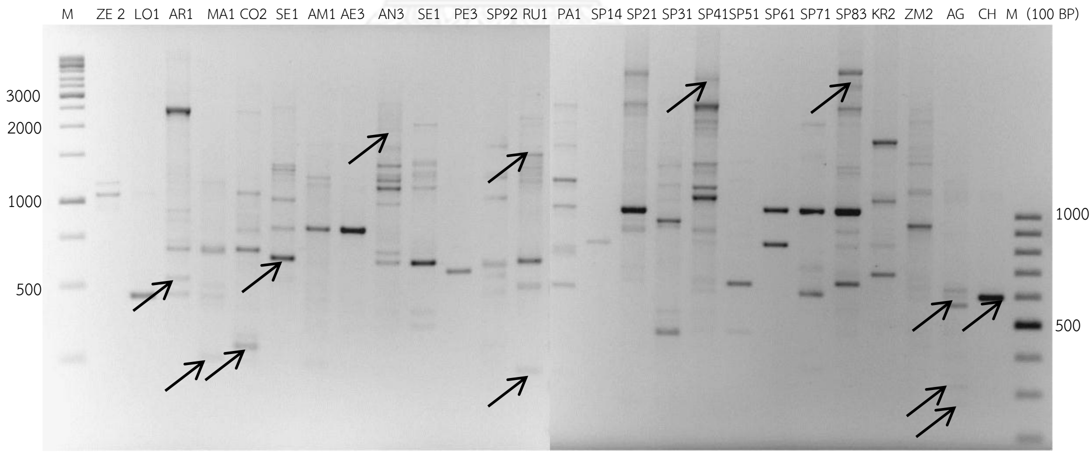


Figure 6. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPD-07 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

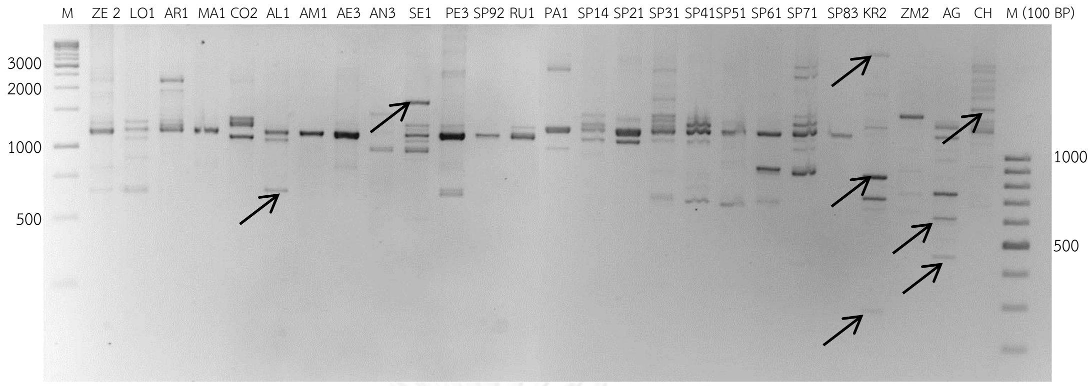


Figure 7. RAPD fingerpri nt of 22 *Curcuma* and outgroup plants obtained from the OPE-01 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

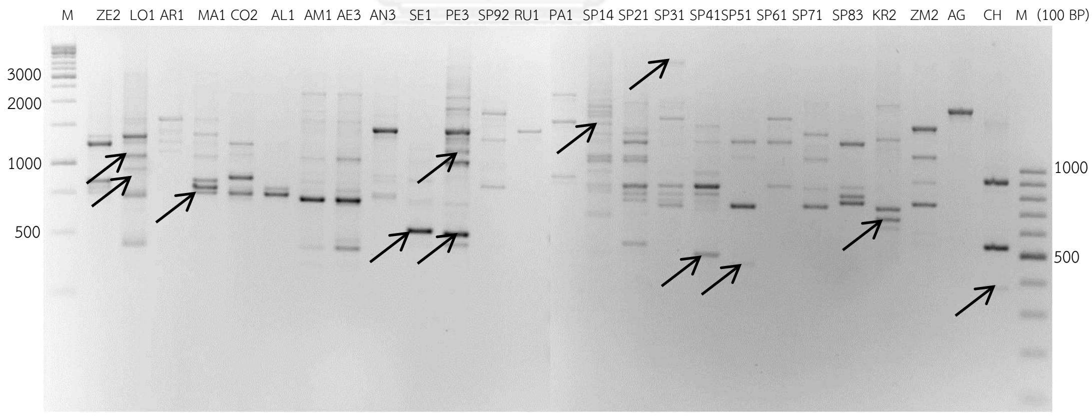


Figure 8. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPG-03 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

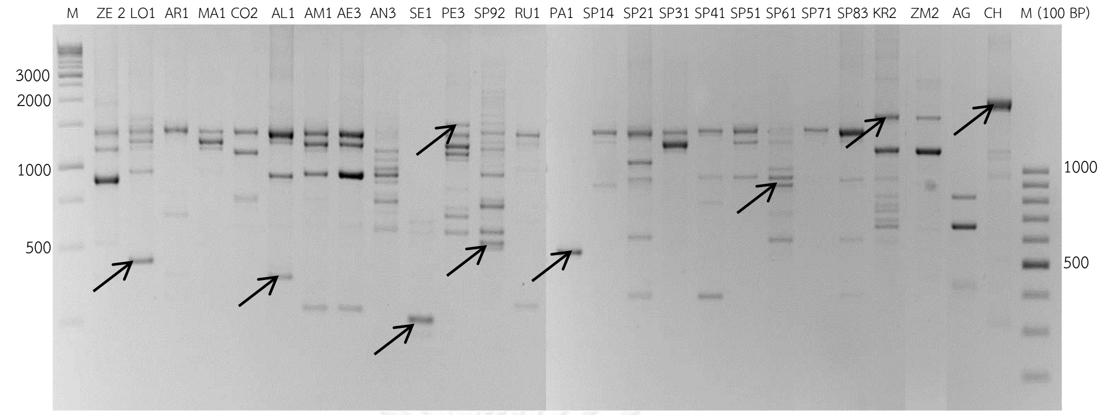


Figure 9. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPI-16 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

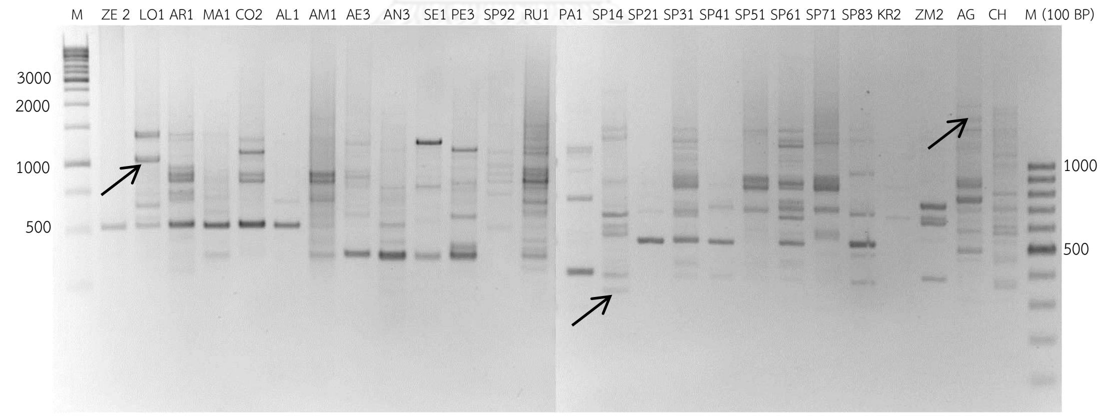


Figure 10. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPJ-20 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

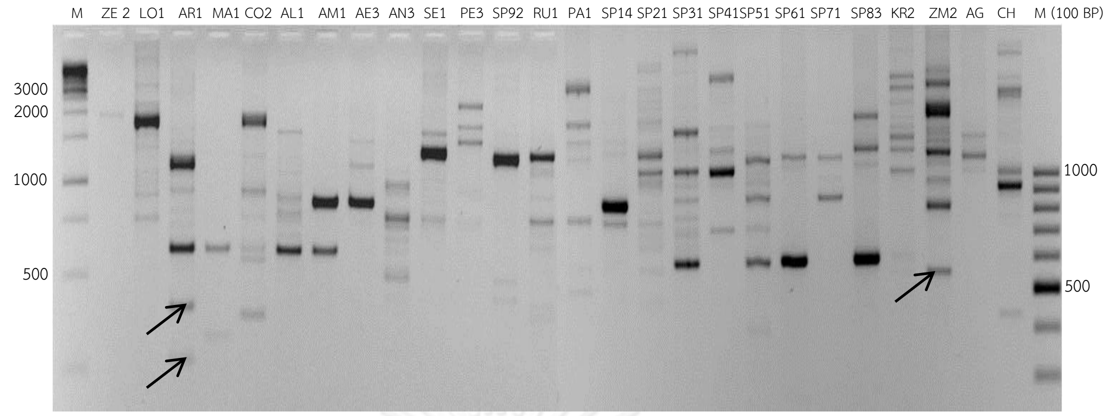


Figure 11. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPK-09 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

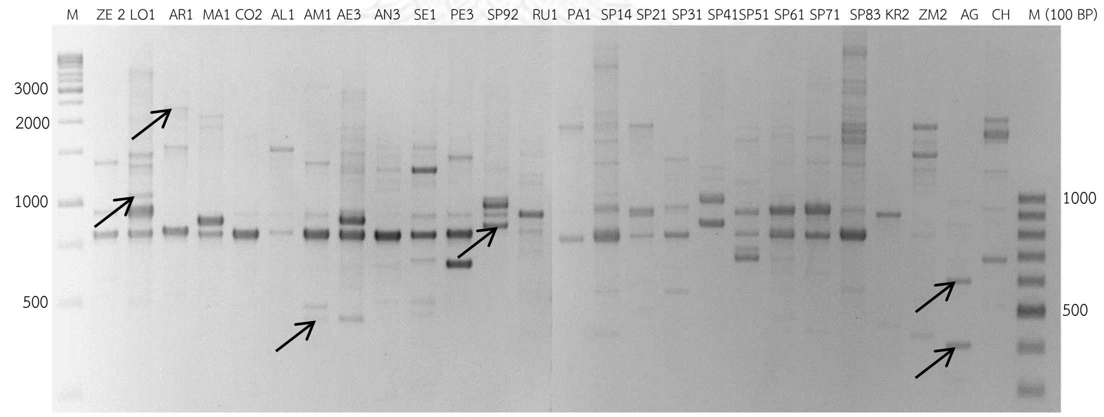


Figure 12. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPS-01 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

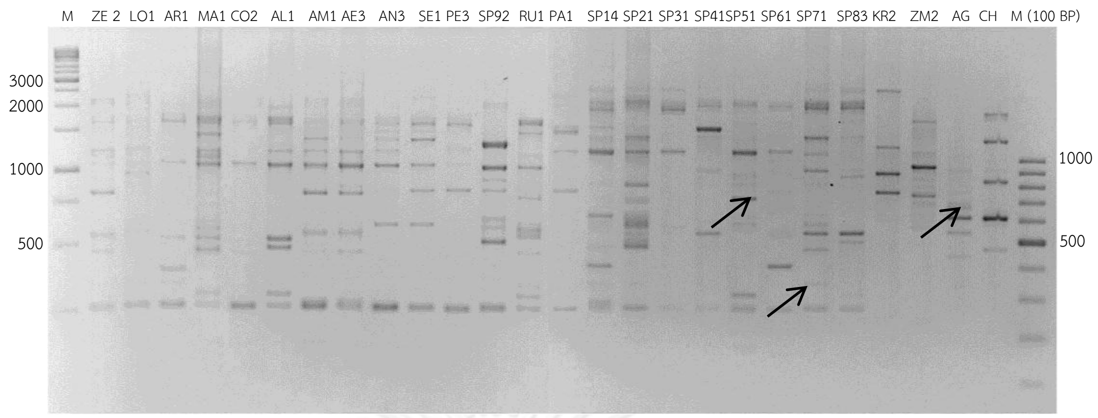


Figure 13. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPS-12 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

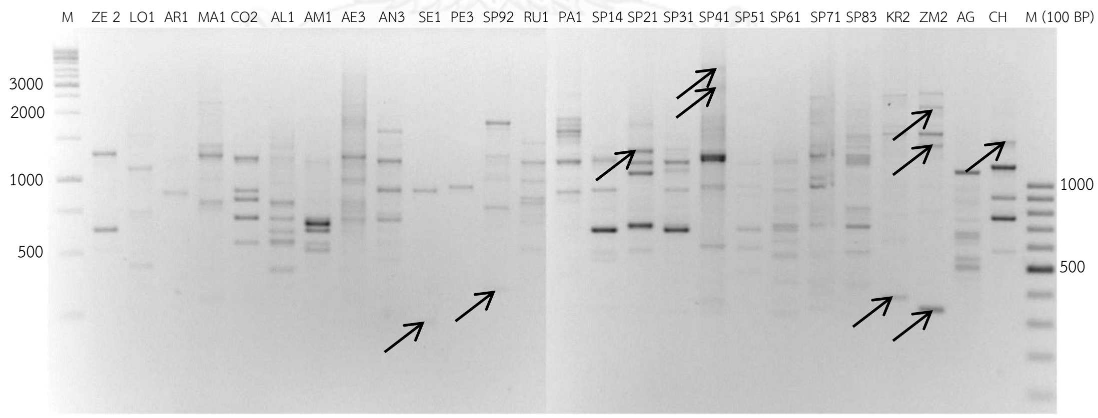


Figure 14. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPS-19 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

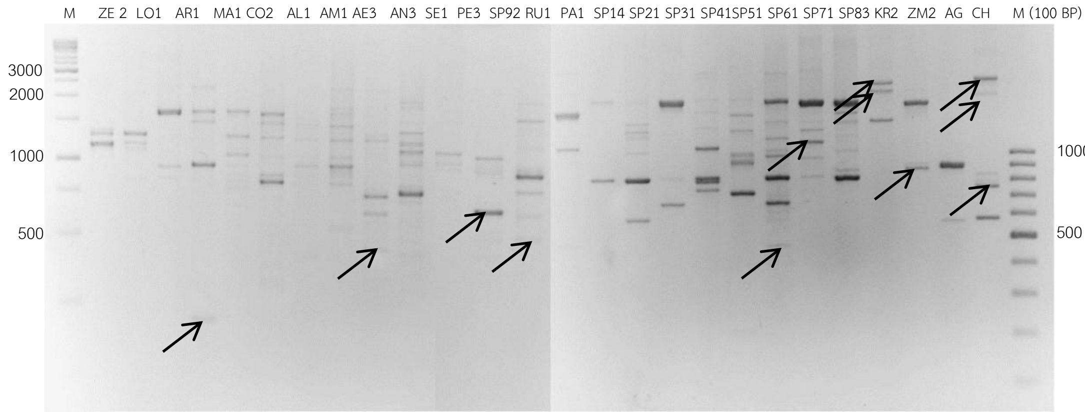


Figure 15. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the OPV-12 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

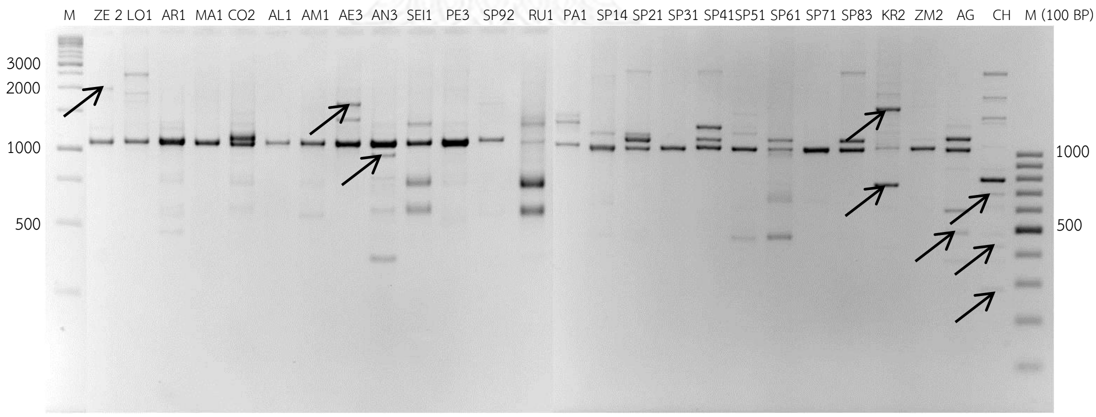


Figure 16. RAPD fingerprint of 22 *Curcuma* and outgroup plants obtained from the RAPD-F 29 primer.

Abbreviations of the plant samples are according to codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

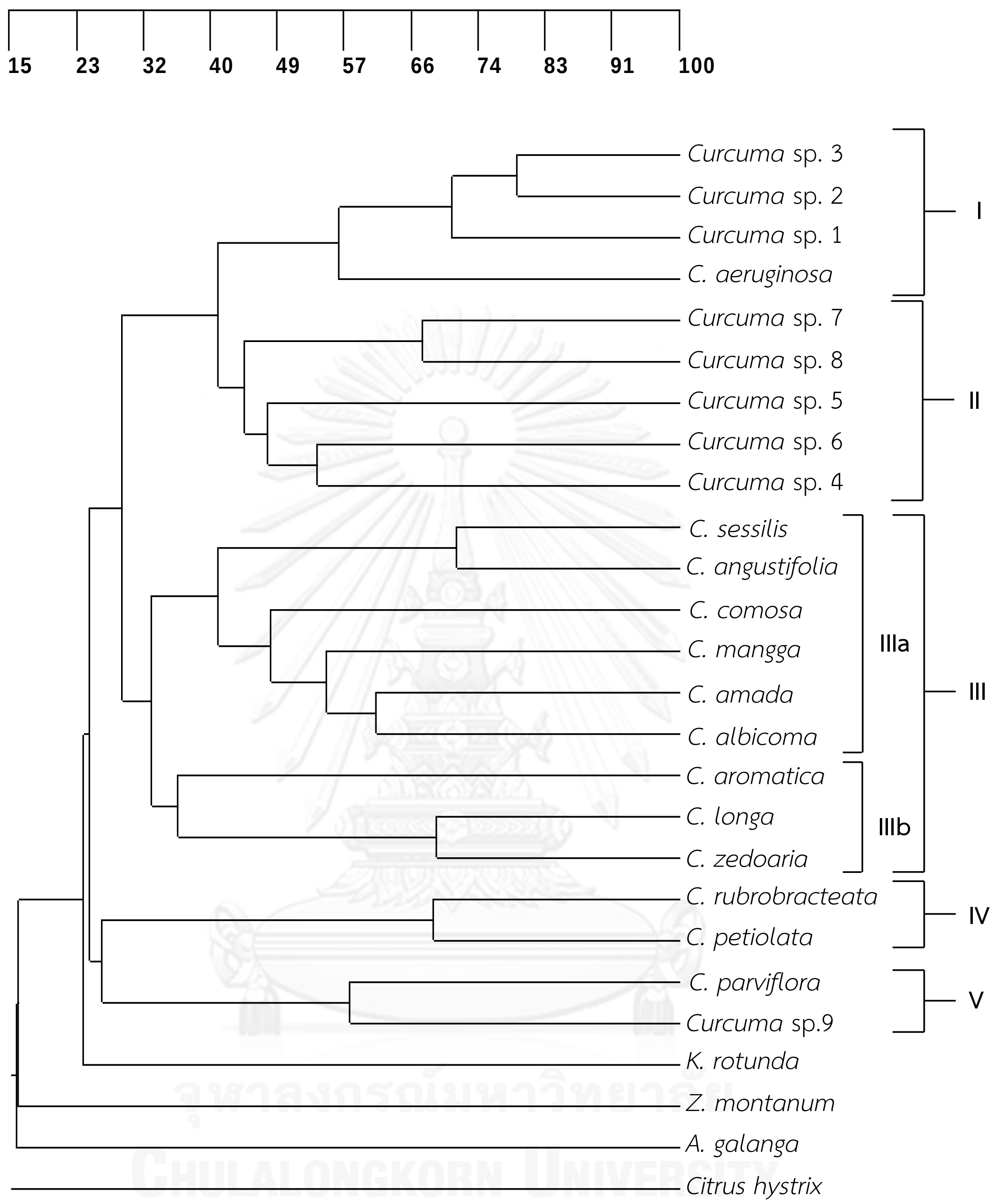


Figure 17. Dendrogram produced by UPGMA cluster analysis of RAPD data showing the genetic relationship among 22 *Curcuma* plants and outgroup plants.

Table 16. Similarity matrix of *Curcuma* and outgroup plants generated using Dice similarity coefficient

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1 *Curcuma* sp. 2	1.0000																									
2 *Curcuma* sp. 3	0.7948	1.0000																								
3 *Curcuma* sp. 1	0.7019	0.7217	1.0000																							
4 *C. aeruginosa*	0.5426	0.5256	0.6325	1.0000																						
5 *Curcuma* sp. 7	0.4724	0.4183	0.3652	0.3581	1.0000																					
6 *Curcuma* sp. 8	0.4309	0.4113	0.3651	0.3563	0.6749	1.0000																				
7 *Curcuma* sp. 5	0.4399	0.4615	0.4166	0.3685	0.4411	0.4179	1.0000																			
8 *Curcuma* sp. 6	0.4616	0.4687	0.3847	0.3900	0.4659	0.4511	0.4371	1.0000																		
9 *Curcuma* sp. 4	0.4343	0.4752	0.3899	0.4361	0.5025	0.4065	0.5162	0.5408	1.0000																	
10 *C. sesssilis*	0.3133	0.3923	0.3168	0.3645	0.2933	0.2462	0.3567	0.2796	0.3134	1.0000																
11 *C. angustifolia*	0.3371	0.3464	0.3094	0.3675	0.3104	0.2930	0.3475	0.3525	0.3220	0.7178	1.0000															
12 *C. comosa*	0.2222	0.2844	0.2565	0.2688	0.2932	0.2478	0.3712	0.2254	0.3308	0.4295	0.4872	1.0000														
13 *C.manga*	0.1861	0.2542	0.2806	0.3567	0.2195	0.1900	0.2612	0.2189	0.2957	0.3703	0.3852	0.4658	1.0000													
14 *C. amada*	0.2701	0.3214	0.2977	0.4420	0.2903	0.2211	0.2764	0.1669	0.3671	0.3657	0.4087	0.4808	0.5904	1.0000												
15 *C. albicoma*	0.3220	0.3519	0.3119	0.3879	0.2395	0.1798	0.3368	0.1894	0.4059	0.3932	0.4770	0.4954	0.5127	0.6147	1.0000											
16 *C. aromatica*	0.2303	0.3154	0.3394	0.4290	0.2276	0.3371	0.2802	0.2409	0.3561	0.2177	0.3087	0.3315	0.3509	0.3504	0.3504	1.0000										
17 *C. longa*	0.2944	0.3103	0.3444	0.2620	0.2227	0.1770	0.2761	0.2471	0.2329	0.2723	0.2566	0.3531	0.3883	0.2835	0.3848	0.3201	1.0000									
18 *C. zeoaria*	0.2641	0.3333	0.2743	0.3501	0.3049	0.3000	0.2880	0.2290	0.2541	0.3697	0.3150	0.3183	0.3995	0.3371	0.3484	0.4048	0.6927	1.0000								
19 *C.rubrobracteata*	0.2839	0.3017	0.2353	0.2861	0.2025	0.2108	0.2075	0.1911	0.2333	0.2893	0.2339	0.2634	0.2193	0.2711	0.2576	0.1810	0.1936	0.1413	1.0000							
20 *C. petiolata*	0.2568	0.3102	0.2580	0.3242	0.2449	0.1519	0.1517	0.2008	0.1924	0.2939	0.3009	0.2834	0.1597	0.2473	0.2264	0.2253	0.2227	0.2078	0.6877	1.0000						
21 *C. parviflora*	0.2971	0.3396	0.2837	0.2901	0.2676	0.2391	0.2716	0.1939	0.3012	0.3093	0.3073	0.2378	0.2281	0.2758	0.2177	0.3220	0.2201	0.2656	0.2605	0.2810	1.0000					
22 *Curcuma* sp. 9	0.2623	0.3356	0.2593	0.3053	0.2293	0.2201	0.2579	0.2407	0.2931	0.3057	0.3437	0.2167	0.1576	0.2304	0.3381	0.2436	0.2394	0.2249	0.2506	0.2737	0.5809	1.0000				
23 *Z. montanum*	0.3099	0.2996	0.3108	0.2806	0.2525	0.2042	0.2456	0.2602	0.2950	0.2823	0.2657	0.1588	0.2025	0.2001	0.2203	0.2225	0.2113	0.2514	0.2229	0.2294	0.2077	0.2227	1.0000			
24 *K. rotunda*	0.1364	0.1072	0.1469	0.1752	0.1479	0.1738	0.2094	0.1535	0.1595	0.1871	0.1605	0.1708	0.1856	0.1423	0.1612	0.1233	0.1235	0.1400	0.1688	0.1652	0.1705	0.2188	0.2368	1.0000		
25 *A. galanga*	0.1265	0.1186	0.1200	0.2363	0.1800	0.0804	0.1649	0.1775	0.1189	0.1844	0.1558	0.1248	0.1469	0.1176	0.1359	0.1585	0.1365	0.1496	0.2038	0.2299	0.1986	0.2075	0.1718	0.1346	1.0000	
26 *Citrus hystrix*	0.1697	0.1696	0.2118	0.1970	0.0782	0.1223	0.1350	0.1097	0.1187	0.1379	0.1564	0.1880	0.1165	0.1634	0.1296	0.1365	0.0615	0.0993	0.2303	0.2351	0.1636	0.2189	0.1654	0.0836	0.0765	1.0000

4.1.3 The relation of essential oil and RAPD profiles with morphological characteristics

According to the UPGMA dendrograms based on essential oil compositions and RAPD profiles, 22 *Curcuma* plants were divided into five clusters (Figure 3 and 17). Clusters I, II and III in either of the dendrograms should be considered together as the Longa group (see Table 4, page 10) because all of identified species in these clusters belong to this group. By the same reason, clusters IV and V should be considered as the Petiolata and Alismatifolia groups, respectively. According to the dendrograms, it should be expected that the Petiolata group was more closely related to the Longa group than the Alismatifolia group.

Based on the deduction mentioned above, *Curcuma* sp. 1, *Curcuma* sp. 2, *Curcuma* sp. 3, *Curcuma* sp. 4, *Curcuma* sp. 5, *Curcuma* sp. 6, *Curcuma* sp. 7 and *Curcuma* sp. 8 should be members of the Longa group. The morphological characters of these plants were also found to be closely related to *Curcuma* spp. in the Longa group (Table 18).

C. albicoma and *C. sessilis*, which have never been reported of it position in the classification system of Sirirugsa *et al*, should be placed in the Longa group because it were clustered with *C. amada* and *C. angustifolia* of the Longa group, respectively.

Curcuma sp. 1, *Curcuma* sp. 2, *Curcuma* sp. 3 were clustered with *C. aeruginosa*. These plants have greenish-yellow or greenish-blue rhizomes together with reddish purple mid ribs and leaf sheaths (Table 18). Moreover, based on essential oil composition all of them were found to contain α-humulene [59], β-selinene [67] and spathulenol [91].

Based on either essential oil composition or RAPD profiles, *Curcuma* sp. 9, was clustered with *C. parviflora* of the Alismatifolia group, therefore this unidentified species should be a member of the Alismatifolia group. *Curcuma* sp. 9 was also found to be morphologically related to *C. parviflora* (Table 18).

The phylogenetic relationships through essential oil composition and RAPD markers were also related with the morphological characters. By considering the information obtained from the study together with morphological characters of the plants, the twenty-two *Curcuma* species can be divided into six groups (A-F). Member of each group are shown in Table 17. The important morphological characters of the plants in group A-f are shown in Table 18.

Sirirugsa, Larsen and Maknoi (2007) noted that the important characteristics for differentiating *Curcuma* species were the anther spurs and stylodial gland. *Curcuma* spp. in group A, B and C have the triangular anther spurs and cylindrical or long-conical stylodial gland along with coma bract with acute bract apex. The identified species in these tree groups belong to the Longa group. *Curcuma* spp. in group D, all of which are unidentified, have incomplete morphological data, however, they are expected to be members of the Longa group, based on the UPGMA dendrograms. Therefore, group A-D are considered together as the Longa group. *Curcuma* spp. in group E have the triangular anther spurs, clavate stylodial gland and coma bract with rounded to obtuse or rounded to truncate bract apex. *Curcuma* spp. in group F have the coma bract and obtuse to rounded or acute bract apex; the anther spurs and stylodial gland are absent. Group E and F are considered as the Petiolata and Alismatifolia groups, respectively.

Table 17. *Curcuma* species in group A-F

Group	Species
A	*C. longa*, *C. zedoaria*, *C. aromatica*
B	*C. comosa*, *C. mangga, C. albicoma*, *C. amada*, *C. angustifolia, C. sessilis*
C	*C. aeruginosa*, *Curcuma* sp. 1*, *Curcuma* sp. 2*, *Curcuma* sp. 3*
D	*Curcuma* sp. 4*, *Curcuma* sp. 5* and *Curcuma* sp. 6* *Curcuma* sp. 7*, *Curcuma* sp. 8**
F	*C. petiolata*, *C. rubrobacteata*
F	*C. parviflora*, *Curcuma* sp. 9*

***** Data on morphological characters of the plants are not complete.

Table 18. The important morphological characters of the plants in group A-F

Morphological characters	Group A	Group B	Group C
Colour of rhizome	Orangish-yellow or bright yellow	Pale yellow or pale brown	Greenish-yellow or greenish-blue
Leaf shape	Lanceolate	Lanceolate	Lanceolate or elliptic oblong
Leaf apex	Acuminate	Acuminate or acute	Acuminate
Leaf base	Cuneate	Cuneate or attenuate	Cuneate
Indumentum	Glabrous on both surfaces	Glabrous on both surfaces	Glabrous on both surfaces
Colour of midrib	Green	Green	Reddish purple
Position of Inflorescence	Lateral or terminal	Lateral or terminal	Lateral or terminal
Colour of flower	White or reddish-pink	White, yellow or reddish-pink	White or reddish-pink
Colour of bract	Green	Green	Green
Colour of coma bract	White or reddish-pink	White or pink	Pale yellow or reddish-pink
Bract apex	Broadly acute	Acute	Acute
Colour of labellum	Pale yellow	Pale yellow	Pale yellow

Table 18. The important morphological characters of the plants in group A-F

Morphological characters	Group A	Group B	Group C
Filament shape	Flat, pubescent	Flat, glabrous	Flat, scattered hairy
Anther spur shape	Triangular, sharply acute	Triangular, flat	Triangular, flat or acute
Ovary shape	Barrel, pubescent	Barrel, hairy or glabrous	Barrel, hairy
Stylodial gland shape	Cylindrical	Cylindrical or long-conical	Cylindrical

Table 18. The important morphological characters of the plants in group A-F

Morphological characters	Group D	Group E	Group F
Colour of rhizome	Pale yellow	Pale yellow	White
Leaf shape	Lanceolate	Ovate	Lanceolate
Leaf apex	Acuminate	Acuminate	Acuminate
Leaf base	Cuneate	Rounded to broadly cuneate	Narrowly attenuate or cuneate to rounded
Indumentum	Glabrous on both surfaces	Glabrous on both surfaces or upper surface hairy along secondary nerve, lower surface glabrous	Glabrous on both surfaces
Colour of midrib	Green	Green	Green
Position of Inflorescence	-	Terminal	Terminal
Colour of flower	-	White or red	White
Colour of bract	-	Green or red	Green
Colour of coma bract	-	Absent or pink	White or pink

Table18. The important morphological characters of the plants in group A-F

Morphological characters	Group D	Group E	Group F
Colour of coma bract	-	Absent or pink	White or pink
Bract apex	-	Rounded to obtuse or rounded to truncate	Obtuse to rounded or acute
Colour of labellum	-	Yellow	White or violet
Filament shape	-	Flat, glandular hairy or concave, glabrous	Flat or concave, glabrous or hairy
Anther spur shape	-	Triangular, flat	Absent
Ovary shape	-	Barrel, hairy	Barrel, glabrous
Stylodial gland shape	-	Clavate	Absent

4.2 The *Kaempferia* plants

4.2.1 Essential oil analysis

The oil obtained from the fresh rhizomes of *K. galanga*, *K. larsenii*, *K. marginata*, *K. parviflora*, *K. rotunda* were clear and pale yellow in colour. The chemical constituents of the essential oils obtained from the plant materials are compiled in Table 19, in order of their elution on the ZP-5 column. The data of the occurrences belonging to the same species were considered as a whole to represent the data of such species. A total of 106 compounds were identified in the oils of five *Kaempferia* species and four out group plants. The essential oil components in all *Kaempferia* plants ranged from 20-31 compounds. KL 5 was found to contain the highest number of oil components (29 compounds) while KM 3 was found to contain the lowest (20 compounds).

The oils component α-pinene [3], was found in all of the *Kaempferia* and outgroup plants, and myrcene [7] was found in all except *C. longa*. Seven components, including camphene [4], β-pinene [6], 1,8-cineole [13], borneol [24], germacrene D [50], γ-cadinene [60], and germacrene B [67] were found in all of the *Kaempferia* species.

The results (Table 25, Appendix B) showed that the oil components of the same *Kaempferia* species from different locations were similar; however, there was a great quantitative difference in the amounts of each components.

3-(4-Methoxyphenyl)-2-propenoic acid, ethyl ester [102] was found to be the main component in the oil of *K. marginata* while 3-(4-methoxyphenyl)-2-propenoic acid, ethyl ester [102] and camphene [4] in that of *K. galanga*. Germacrene D [50], benzyl benzoate [91] and *epi*-13-manool [98] were found to be the main components in the oil of *K. parviflora*, *K. larsenii* and *K. rotunda*, respectively.

Similar experimental results were previously reported for other *Kaempferia* species. 3-(4-methoxyphenyl)-2-propenoic acid, ethyl ester was reported as the major component in rhizome oil of *K. galanga* (Bhuiyan *et al*., 2008) while camphene and benzyl benzoate were reported as those of *K. angustifolia* (Vipunngeun *et al*., 2007) and *K. rotunda* (Woerdenbag *et al*., 2004), respectively.

This study provided the first report on essential oil compositions of *K. larsenii* and *K. marginata* rhizomes. The results obtained might be used as information for phytochemical and chemotaxonomic studies of the *Kaempferia* plants, especially, *K. larsenii* which is an endemic and rare species in Thailand.

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]			
				K. galanga	*K. larsenii*	*K. marginata*	*K. parviflora*
1	Tricyclene	MH	926	1	1	0	1
2	α-Thujene	MH	930	0	0	0	0
3	α-Pinene	MH	939	1	1	1	1
4	Camphene	MH	954	1	1	1	1
5	Sabinene	MH	975	0	0	0	0
6	β-Pinene	MH	979	1	1	1	1
7	Myrcene	MH	990	1	1	1	1
8	α-Phellandrene	MH	1002	0	0	0	0
9	δ-3-Carene	MH	1011	1	0	1	0
10	α-Terpinene	MH	1017	0	0	0	0
11	*o*-Cymene	MH	1026	1	0	0	0
12	Limonene	MH	1029	0	1	0	1
13	1,8-Cineole	OM	1031	1	1	1	1
14	(*E*)-β-Ocimene	MH	1050	0	0	0	0
15	γ-Terpinene	MH	1059	0	0	0	0
16	*cis*-Linalool oxide	OM	1072	0	0	0	0
17	*trans*-Linalool oxide	OM	1086	0	0	0	0
18	Terpinolene	MH	1088	0	0	0	0
19	Linalool	OM	1096	0	1	0	1
20	*trans*-Sabinine hydrate	OM	1098	0	0	0	0
21	Camphor	OM	1146	1	1	0	0
22	*neo*-Isopulegol	OM	1148	0	0	0	0
23	Citronellal	OM	1153	0	0	0	0

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				K. rotunda	*C. longa*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
1	Tricyclene	MH	926	1	0	0	0	0
2	α-Thujene	MH	930	0	0	1	0	0
3	α-Pinene	MH	939	1	1	1	1	1
4	Camphene	MH	954	1	0	0	0	0
5	Sabinene	MH	975	0	0	1	1	1
6	β-Pinene	MH	979	1	0	0	1	1
7	Myrcene	MH	990	1	0	1	1	1
8	α-Phellandrene	MH	1002	0	1	0	0	0
9	δ-3-Carene	MH	1011	0	0	0	0	0
10	α-Terpinene	MH	1017	0	0	1	1	1
11	*o*-Cymene	MH	1026	0	1	1	0	0
12	Limonene	MH	1029	1	0	1	1	1
13	1,8-Cineole	OM	1031	1	1	0	1	0
14	(*E*)-β-Ocimene	MH	1050	0	0	0	0	1
15	γ-Terpinene	MH	1059	0	0	1	0	0
16	*cis*-Linalool oxide	OM	1072	0	0	0	0	1
17	*trans*-Linalool oxide	OM	1086	0	0	0	0	1
18	Terpinolene	MH	1088	0	1	1	0	0
19	Linalool	OM	1096	1	0	0	0	1
20	*trans*-Sabinine hydrate	OM	1098	0	0	1	0	0
21	Camphor	OM	1146	1	0	0	0	0
22	*neo*-Isopulegol	OM	1148	0	0	0	0	1
23	Citronellal	OM	1153	0	0	0	0	1

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]			
				K. galanga	*K. larsenii*	*K. marginata*	*K. parviflora*
24	Borneol	OM	1169	1	1	1	1
25	Terpinen-4-ol	OM	1177	0	0	0	0
26	α-Terpineol	OM	1188	0	0	0	0
27	Citronellol	OM	1225	0	0	0	0
28	Geraniol	OM	1252	0	0	0	0
29	Isobornyl acetate	OM	1285	0	0	0	0
30	Bornyl acetate	OM	1288	1	1	0	1
31	α-Terpinyl acetate	OM	1349	0	0	0	0
32	Citronellyl acetate	OM	1352	0	0	0	0
33	Eugenol	OM	1359	0	0	0	0
34	α-Ylangene	SH	1375	0	0	0	0
35	α-Copaene	SH	1376	0	1	0	1
36	Geranyl acetate	OM	1381	0	0	0	0
37	β-Elemene	SH	1390	0	1	0	1
38	Cyperene	SH	1398	1	0	1	0
39	α-Gurjunene	SH	1409	1	1	1	0
40	*E*-Caryophyllene	SH	1419	0	1	0	1
41	α-Guaiene	SH	1439	0	0	0	0
42	(*Z*)-β-Farnesene	SH	1442	0	0	0	0
43	α-Humulene	SH	1454	0	1	0	1
44	(*E*)-β-Farnesene	SH	1456	0	0	0	0
45	Ishwarane	SH	1466	0	0	0	0
46	*E*-Ethyl cinnamate	PP	1467	1	1	1	0

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				K. rotunda	*C. longa*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
24	Borneol	OM	1169	1	0	0	0	0
25	Terpinen-4-ol	OM	1177	0	0	1	1	0
26	α-Terpineol	OM	1188	0	0	1	1	0
27	Citronellol	OM	1225	0	0	0	0	1
28	Geraniol	OM	1252	0	0	0	0	1
29	Isobornyl acetate	OM	1285	0	0	0	1	0
30	Bornyl acetate	OM	1288	1	0	0	0	0
31	α-Terpinyl acetate	OM	1349	0	0	1	0	0
32	Citronellyl acetate	OM	1352	0	0	0	0	1
33	Eugenol	OM	1359	0	0	0	1	0
34	α-Ylangene	SH	1375	1	0	0	0	0
35	α-Copaene	SH	1376	0	0	0	0	1
36	Geranyl acetate	OM	1381	0	0	0	1	0
37	β-Elemene	SH	1390	1	0	0	1	0
38	Cyperene	SH	1398	0	0	0	0	0
39	α-Gurjunene	SH	1409	0	0	0	0	0
40	*E*-Caryophyllene	SH	1419	0	1	0	1	1
41	α-Guaiene	SH	1439	1	0	0	0	0
42	(*Z*)-β-Farnesene	SH	1442	0	1	0	0	0
43	α-Humulene	SH	1454	0	0	0	0	0
44	(*E*)-β-Farnesene	SH	1456	0	0	0	1	0
45	Ishwarane	SH	1466	1	0	0	0	0
46	*E*-Ethyl cinnamate	PP	1467	0	0	0	0	0

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				K. galanga	*K. larsenii*	*K. marginata*	*K. parviflora*	
47	β-Chamigrene	SH	1477	0	0	0	0	
48	*ar*-Curcumene	SH	1480	0	0	0	0	
49	γ-Curcumene	SH	1482	0	0	0	0	
50	Germacrene D	SH	1485	1	1	1	1	
51	β-Selinene	SH	1490	0	0	0	0	
52	Drim-8(12)-ene	SH	1491	0	1	0	0	
53	α-Zingiberene	SH	1493	0	0	0	0	
54	Valencene	SH	1496	0	0	0	0	
55	α-Selinene	SH	1498	0	0	0	0	
56	Pentadecane	SH	1500	1	0	1	0	
57	Bicyclogermacrene	SH	1500	0	1	0	1	
58	β-Bisabolene	SH	1505	0	0	0	0	
59	*E*- *E*-α-Farnesene	SH	1505	0	0	0	0	
60	γ-Cadinene	SH	1513	1	1	1	1	
61	β-Curcumeme	SH	1515	0	0	0	0	
62	7-*epi*-α-Selinene	SH	1520	0	0	0	0	
63	β-Sesquiphellandrene	SH	1522	0	0	0	0	
64	δ-Cadinene	SH	1523	1	1	0	1	
65	*E*-γ- Bisabolene	SH	1531	0	0	0	0	
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	1	0	0	0	
67	Germacrene B	SH	1561	1	1	1	1	
68	*E*-Nerolidol	OS	1563	0	0	0	0	
69	Caryophyllene oxide	OS	1583	0	0	0	0	0

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				K. rotunda	*C. longa*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
47	β-Chamigrene	SH	1477	0	0	0	1	0
48	*ar*-Curcumene	SH	1480	0	1	0	0	0
49	γ-Curcumene	SH	1482	1	0	0	0	0
50	Germacrene D	SH	1485	1	0	0	0	0
51	β-Selinene	SH	1490	1	0	0	1	0
52	Drim-8(12)-ene	SH	1491	0	0	0	0	0
53	α-Zingiberene	SH	1493	0	1	0	0	0
54	Valencene	SH	1496	1	0	0	0	0
55	α-Selinene	SH	1498	0	0	0	1	0
56	Pentadecane	SH	1500	1	0	0	0	0
57	Bicyclogermacrene	SH	1500	0	0	0	0	1
58	β-Bisabolene	SH	1505	0	1	0	1	0
59	*E*- *E*-α-Farnesene	SH	1505	0	0	0	0	1
60	γ-Cadinene	SH	1513	1	0	0	0	0
61	β-Curcumeme	SH	1515	0	0	1	0	0
62	7-*epi*-α-Selinene	SH	1520	0	0	0	1	0
63	β-Sesquiphellandrene	SH	1522	0	1	1	1	0
64	δ-Cadinene	SH	1523	0	0	0	0	1
65	*E*-γ- Bisabolene	SH	1531	0	0	0	1	0
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	0	0	0	0	0
67	Germacrene B	SH	1561	1	0	1	1	0
68	*E*-Nerolidol	OS	1563	0	0	0	0	1
69	Caryophyllene oxide	OS	1583	0	0	0	0	0

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound Name	Class	KI			K. galanga	
70	**Caryophyllene** oxide	**OS**	**158** **3**	*1*	*1*	*1*	*1*
71	*ar-Tumerol*	OS	158 3	0	0	0	0
72	Carotol	OS	159 4	0	0	0	0
73	Guaiol	OS	160 0	1	0	0	0
74	Humulene epoxide II	OS	160 8	1	1	0	0
75	Helifolen-12-al C (anti-syn-syn-)	OS	162 0	0	0	0	0
76	1-epi-Cubenol	OS	162 8	1	0	0	0
77	γ–Ευδεσμολ	OS	163 2	1	0	0	0
78	*epi-a-Cadinol*	OS	164 0	0	0	0	1
79	*epi-a-Murrolol*	OS	164 2	0	1	0	0
80	α–Μυυρολολ	OS	164 6	0	0	0	1
81	β–Ευδεσμολ	OS	165 0	1	0	1	0
82	α–Χαδινολ	OS	165 4	0	1	0	1
83	Selin-11-en-4-alpha-ol	OS	165 9	0	0	0	0
84	*neo-Intermedeol*	OS	166	0	0	0	0

i *ata* *ora*

			0				
85	*ar-Turmerone*	OS	1669	0	0	0	0
86	Germacrone	OS	1693	0	1	0	0
87	(*Z*)-g-Atlantone	OS	1694	0	0	0	0
88	Heptadecane	Other	1700	1	0	0	0
89	2-Oxabicyclo[2.2.2]octan-6-ol, 1,3,3-trimethyl-, acetate	OM	1700	0	0	0	0
90	*6R,7R-Bisabolone*	OS	1742	0	0	0	0
91	2E,6E-Farnesol	OS	1743	0	0	0	0

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Occurrence in the oil[c]				
				K. rotunda	*C. longa*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
70	*ar*-Tumerol	OS	1583	0	1	0	0	0
71	Carotol	OS	1594	0	1	0	0	0
72	Guaiol	OS	1600	0	0	0	0	0
73	Humulene epoxide II	OS	1608	0	0	0	0	0
74	Helifolen-12-al C (anti-syn-syn-)	OS	1620	0	1	0	0	0
75	1-*epi*-Cubenol	OS	1628	1	0	0	0	0
76	γ-Eudesmol	OS	1632	1	0	0	0	0
77	*epi*-α-Cadinol	OS	1640	0	0	0	0	0
78	*epi*-α-Murrolol	OS	1642	0	0	0	0	0
79	α-Muurolol	OS	1646	0	0	0	0	0
80	β-Eudesmol	OS	1650	1	0	0	0	0
81	α-Cadinol	OS	1654	1	0	0	0	0
82	Selin-11-en-4-α-ol	OS	1659	1	0	0	0	0
83	*neo*-Intermedeol	OS	1660	0	0	0	1	0
84	*ar*-Turmerone	OS	1669	0	1	0	0	0
85	Germacrone	OS	1693	0	0	0	0	0
86	(*Z*)-γ-Atlantone	OS	1694	0	1	0	0	0
87	Heptadecane	Other	1700	0	0	0	0	0
88	1,3,3-trimethyl-2-Oxabicyclo[2.2.2]octan-6-ol, acetate	OM	1700	0	0	0	1	0
89	*6R,7R*-Bisabolone	OS	1742	0	1	0	0	0
90	2*E*,6*E*-Farnesol	OS	1743	0	0	0	1	0

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound Name	Class	KI	*K. galanga*	*K. larsenii*	*K. marginata*	*K. parviflora*
92	*Benzyl* benzoate	PP	1760	0	0	0	0
93	E-a-Atlantone	OS	1778	0	0	0	0
94	Octadecane	Other	1800	0	0	1	0
95	2E,6E-Farnesyl acetate	OS	1846	0	0	0	0
96	Benzyl salicylate	PP	1865	0	0	0	0
97	Pimaradiene	DH	1949	1	1	1	0
98	Sandaracopimara-8(14),15-diene	DH	1969	0	0	1	0
99	Curlone	OS	-	0	0	0	0
100	Methyl 3,4-dimethoxycinnamate	PP	-	0	0	0	0
101	2-Propenoic acid, 3-(4-methoxyphenyl)-, ethyl ester	PP	-	1	1	1	1
102	5-Cyclohexadecen-1-one	Other	-	1	0	0	0
103	8-Heptadecene	Other	-	0	0	0	0
104	Hydroxy-a-terpenyl acetate	Other	-	0	0	0	0

[a] MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;
SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpene;
PP: Phenylpropanoids

[b] KI: Retention indices determined relative to *n*-alkanes (C6–C24) on a ZP-5 GC column.

[c] 0: absence; 1: presence

Table 19. Chemical compounds found in the essential oils of the *Kaempferia* and outgroup plants (cont.)

No.	Compound Name	Class	KI	*K. rotunda*	*C. longa*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
92	*Benzyl* benzoate	PP	1760	1	0	0	0	0
93	E-a-Atlantone	OS	1778	0	1	0	0	0
94	Octadecane	Other	1800	0	0	0	0	0
95	2E,6E-Farnesyl acetate	OS	1846	0	0	0	1	0
96	Benzyl salicylate	PP	1865	1	0	0	0	0
97	Pimaradiene	DH	1949	1	0	0	0	0
98	Sandaracopimara-8(14),15-diene	DH	1969	0	0	0	0	0
99	Curlone	OS	-	0	1	0	0	0
100	Methyl 3,4-dimethoxycinnamate	PP	-	0	0	1	0	0
101	2-Propenoic acid, 3-(4-	PP	-	0	0	0	0	0

	methoxyphenyl)-, ethyl ester							
102	5-Cyclohexadecen-1-one	Other	-	0	0	0	0	0
103	8-Heptadecene	Other	-	0	0	0	1	0
104	Hydroxy-a-terpenyl acetate	Other	-	0	0	0	1	0

[a] MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes; SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpene; PP: Phenylpropanoids

[b] KI: Retention indices determined relative to *n*-alkanes (C6–C24) on a ZP-5 GC column.

[c] 0: absence; 1: presence

A dendrogram obtained from the cluster analysis based on essential oil compositions of all *Kaempferia* accessions is shown in Figure 18. The dendrogram showed that the accessions belonging to the same *Kaempferia* species from different locations were grouped together. The whole data on essential oil compositions of different accessions belonging to the same species were used as the representative data for such *Kaempferia* species and employed in cluster analysis, resulting in a dendrogram shown in Figure 19.

The dendrogram showed the division of *Kaempferia* species into two clusters. The first cluster, *K. rotunda, K. parviflora* and *K. larsenii* was characterized by the presence of α-cadinol [81]. Compounds which were found in all member of this cluster but not common in the other cluster and outgroup plants included tricyclene [1], linalool [19], bornyl acetate [30] and β-elemene [37]. α-Copaene [35], α-humulene [43], bicyclogermacrene [57] and *epi*-13-manool [98] were only found in *K. parviflora* and *K. larsenii* while α-ylangene [34], α-guaiene [41], ishwarane [45], γ-curcumene [49], β-selinene [51], valencene [54], selin-11-en-4-α-ol [82], benzyl benzoate [91] and benzyl salicylate [95] were only found in *K. rotunda*.

The second cluster consisted of *K. galanga* and *K. marginata*. This cluster was characterized by the presence of δ-3-carene [9] and cyperene [38]. α-Gurjunene

[39], *E*-ethyl cinnamate [46] and β-eudesmol [80] were found in both member of this cluster but not common in the first cluster and outgroup plants.

From the data on essential oil composition of *Kaempferia* plants monoterpene hydrocarbons (24.63%) and phenylpropanoids (48.64%) were found to be the main groups of compounds in clusters I and II, respectively (Figure 20). β-Pinene [6] and camphene [4] were found to be the main compounds in the monoterpene hydrocarbon group while 3-(4-methoxyphenyl)-2-propenoic acid, ethyl ester [102] was the main compound in the phenylpropanoid group.

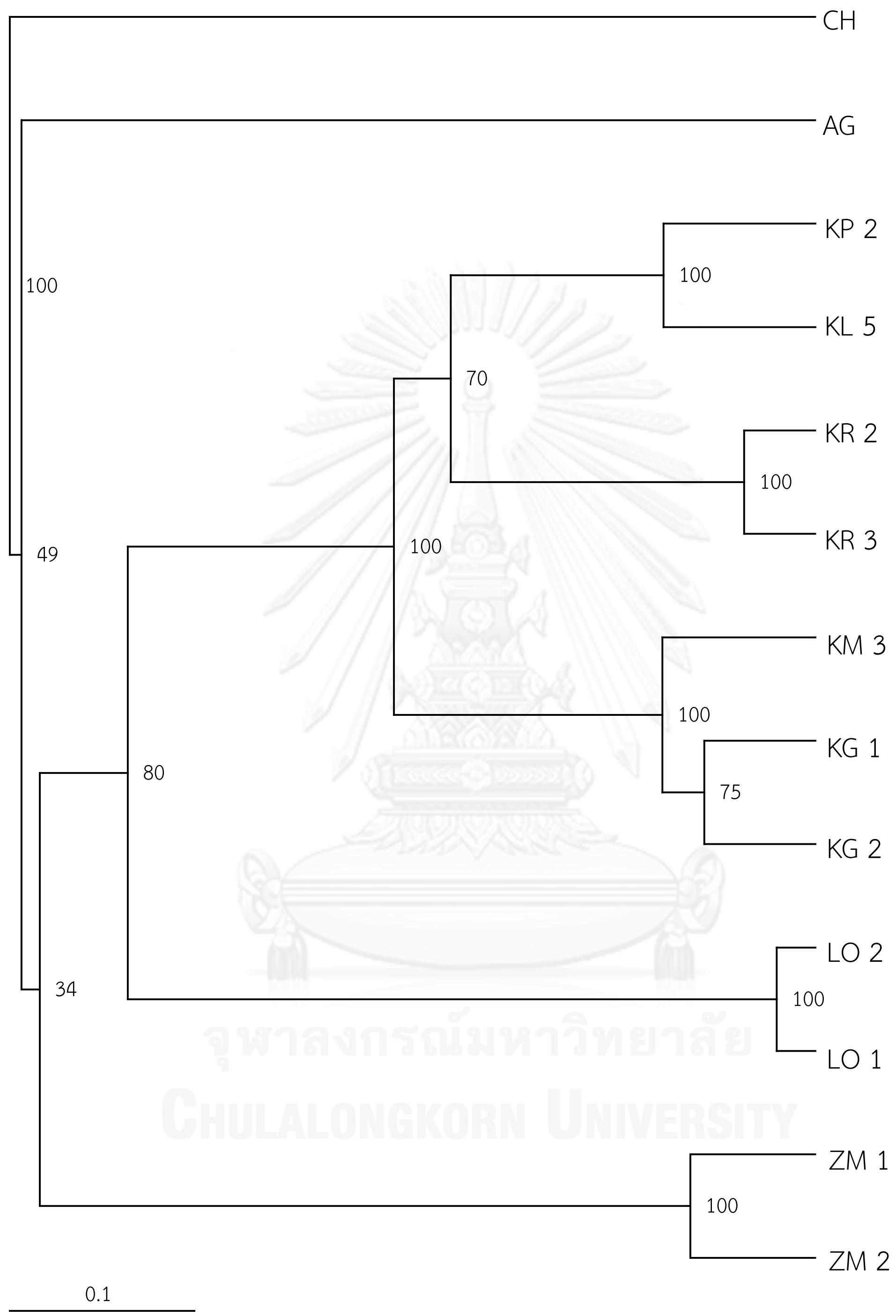


Figure 18. Dendrogram based on essential oil compositions of all accession of *Kaempfetia* and outgroup plants.

Abbreviations of the plant samples are according to the codes used in Table 10.

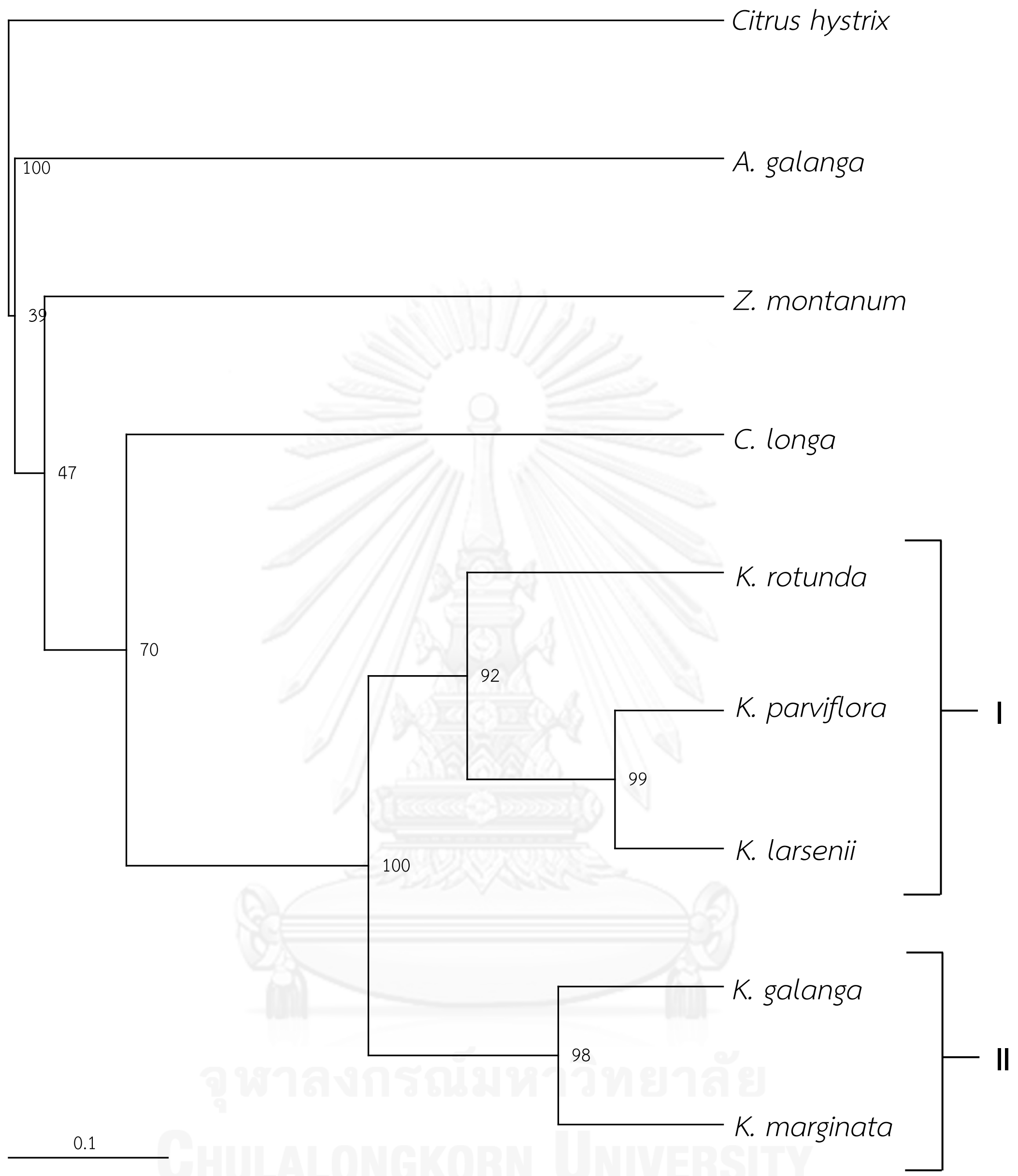


Figure 19. Dendrogram based on essential oil compositions of 5 *Kaempfetia* and outgroup plants.

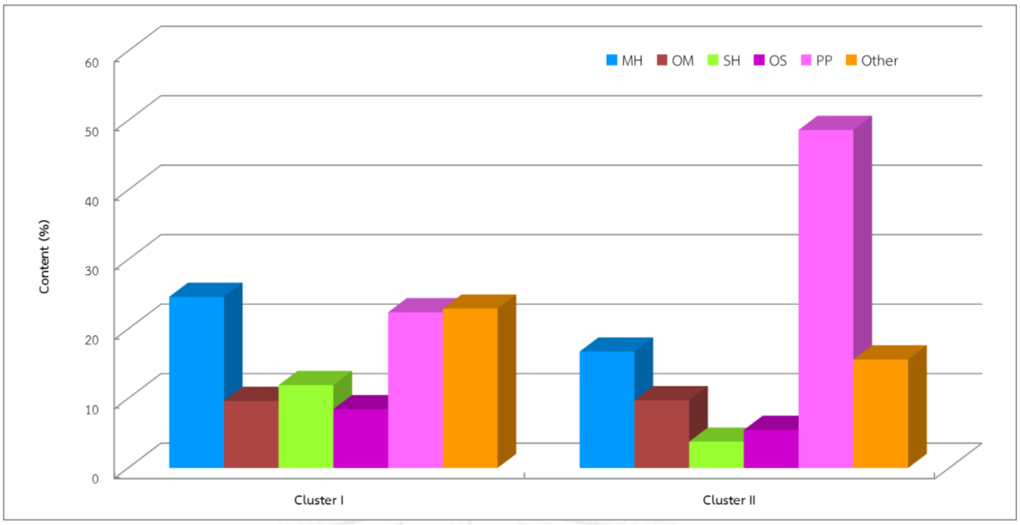


Figure 20. The percentage of classes of compounds in *Kaempferia*'s rhizome oil in each cluster.

MH: Monoterpene hydrocarbons; OM: Oxygenated monoterpenes;

SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes;

PP: Phenylpropanoids

4.2.2 RAPD analysis

Seventy random primers were initial screened, only ten primers (OPA-15, OPB-07, OPL-18, OPT-05, OPY-05, OPY-15, OPY-20, RAPD-05, RAPD-18 and RAPD F-29) produced clear and reproducible polymorphic bands in all plant samples. Nineteen to thirty PCR products were amplified, with an average of 24.8 bands by each primer. The highest number of RAPD bands (30 bands) was generated from OPY-20 whiles the lowest (19 bands) from RAPD-05. A total of 248 amplified bands ranging from 159 to 3418 bp in size were amplified, among which 112 product bands were found to be polymorphic. Primer OPY-15 produced the highest percentage of polymorphism (66.67%) while OPY-20 produced the lowest (30.00%) (Table 20).

According to the ten primers that produced clear and reproducible polymorphic bands, the OPA 15 primer produced the polymorphic bands of 1023 bp in *K. galanga*, 380 and 584 bp in *K. rotunda*, 1399 and 1875 bp in *K. larsenii*, 402, 534 and 1808 bp in *C. longa*, 929 bp in *Z. montanum*, 2057 and 2928 bp in *A. galanga*, and 384 bp in *Citrus hystrix* (Figure 21). The OPB-07 primer produced the polymorphic bands of 255 bp in *K. galanga*, 877 bp in *K. rotunda*, 988 and 1129 bp in *K. marginata*, 1857 bp in *C. longa*, 663 bp in *Z. montanum*, 1284 and 2396 bp in *A. galanga* 291, 981 and 1697 bp in *Citrus hystrix* (Figure 22). The OPL-18 primer produced the polymorphic bands of 346 and 581 bp in *K. galanga*, 263, 546 and 1462 bp in *K. parviflora*, 1835 bp in *K. marginata*, 1065 and 1683 bp in *K. larsenii*, 969 bp in *C. longa*, 1194 bp in *Z. montanum*, 500 and 2070 bp in *Citrux hystrix* (Figure 23). The OPT-05 primer produced the polymorphic bands of 839 bp in *K. marginata*, 538 bp in *K. larsenii*, 310 bp in *C. longa*, 466 bp in *Z. montanum*, 493 and 524 bp in *A. galanga*, 519, 587 and 910 bp in *Citrus hystrix* (Figure 24). The OPY-05 primer produced the polymorphic bands of 587 and 995 bp in *K. galanga*, 483 bp in *K. parviflora*, 432 and 467 bp in *K. rotunda*, 348 bp in *K. marginata*, 2079 bp in *K. larsenii*, 639 bp in *C. longa*, 926 bp in *Z. montanum*, 670 and 733 bp in *A. galanga*, 1402 and 2866 bp in *Citrus hystrix*. This primer generated polymorphic bands in all plant samples (Figure 25). The OPY-15 primer produced the polymorphic bands of 1888 bp in *K. galanga*, 1159 bp in *K. parviflora*, 418 and 456 bp in *K. rotunda*, 759 and 914 bp in *K. marginata*, 1031 in *K. larsenii*, 1097 and

1464 bp in *C. longa*, 252, 303, 598 and 755 bp in *A. galanga*, 519 bp in *Citrus hystrix* (Figure 26). The OPY-20 primer produced the polymorphic bands of 1316 bp in *K. rotunda*, 994 and 1639 bp in *K. larsenii*, 159 bp in *Z. montanum*, 232, 338, 414 and 688 bp in *A. galanga*, 298 bp in *Citrus hystrix* (Figure 27). The polymorphic bands of 1078 bp in *K. rotunda*, 442 and 472 bp in *K. marginata*, 505, 774 and 1556 bp in *C. longa*, 595, 656 and 1399 bp in *Z. montanum* and 554 bp in *Citrus hystrix* were generated by the RAPD-05 primer (Figure 28). The polymorphic bands of 340 and 1424 bp in *K. galanga*, 383 bp in *K. rotunda*, 2409 bp in *K. larsenii*, 2278 bp in *C. longa*, 231, 438 and 1745 bp in *A. galanga* were generated by the RAPD-18 primer (Figure 29). The RAPD-F-29 primer produced the polymorphic bands of 1334 bp in *K. galanga*, 429 bp in *K. parviflora*, 1644 bp in *K. rotunda*, 800 bp in K *larsenii*, 2000 and 3000 in *C. longa*, 466 and 691 in *Z. montanum*. This primer generated the approximately 1000 bp characteristic band of zingiberaceous plants but not observed in *Citrus hystrix* (Figure30).

In addition, sequencing of characteristic bands from RAPD-F 29 primer could be further developed for gene sequence similarity search. The results obtained might be useful information for characteristic gene of the Zingiberaceous plants. Furthermore, sequence characterized amplified regions (SCARs) could be further developed to differentiate plants that have similar morphological characteristics.

The pair-wise comparisons of the RAPD profiles based on both of the shared and unique amplification bands were used to generate a similarity index. Among five *Kaempferia* species including four outgroup plants, Dice similarity index ranged from 0.1336 to 0.6284 (Table 21). The highest genetic similarity index (0.6284) was found between *K. marginata* and *K. galanga*, whereas the lowest genetic similarity index (0.1336) was found among *Z. montanum* and *Citrus hystrix*.

A dendrogram was constructed according to the UPGMA cluster analysis using Dice similarity coefficient. The UPGMA dendrogram showed the division of *Kaempferia* species into two clusters. Cluster I includes 2 species of *K. marginata* and *K. galangal* showing the similarity index 0.6284, and cluster II includes 3 species of *K. larsenii*, *K. rotunda* and *K. parviflora* showing 0.3603 to 0.4897 similarity indexes.

Outgroup plants, *C. longa, Z. montanum*, *A. galanga* and *Citrus hystrix*, were clearly separated from *Kaempferia* plants (Figure 31).

A previous study supports that *K. marginata* and *K. galanga* were clustered in the same group based on the chloroplast DNA, *mat*K and combined ITS and *mat*K region sequences (Kress *et al*., 2002; Techaprasan *et al*., 2010). Based on the *mat*K and combined ITS and *mat*K region sequence, *K. parviflora* and *K. rotunda* were clustered in the same group (Kress *et al*., 2002).

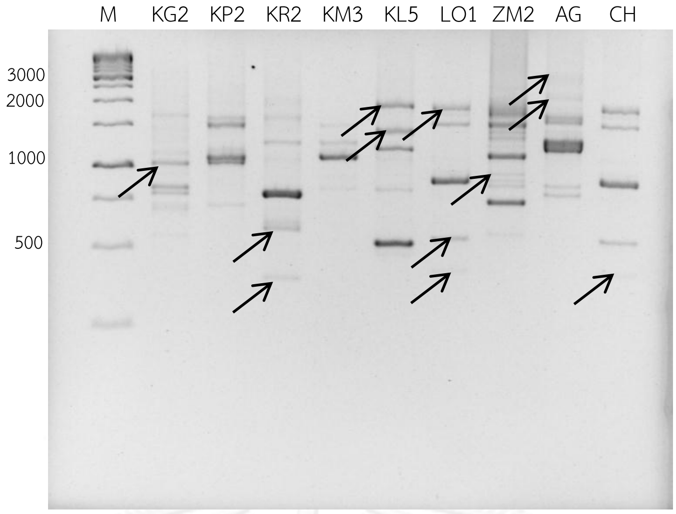


Figure 21. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the OPA-15 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

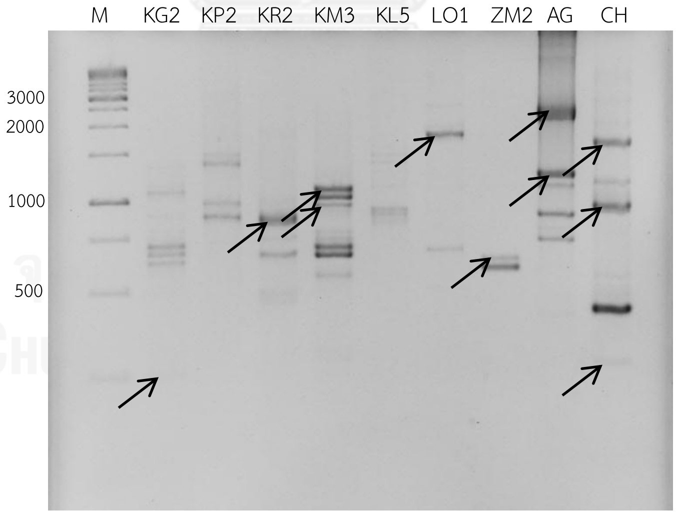


Figure 22. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the OPB-07 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

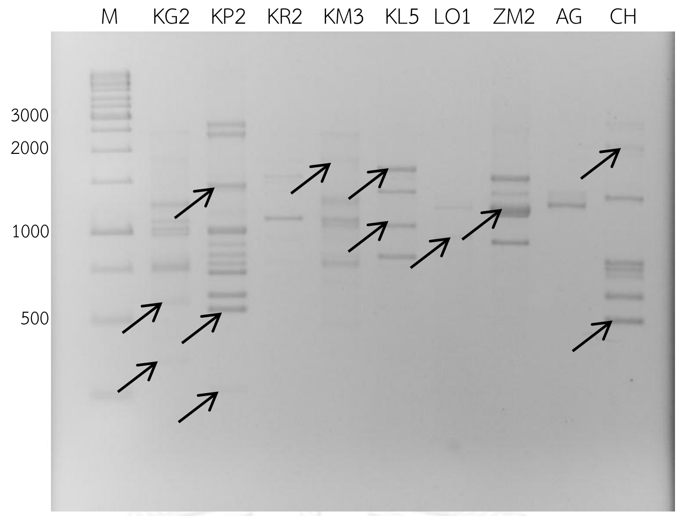


Figure 23. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the OPL-18 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

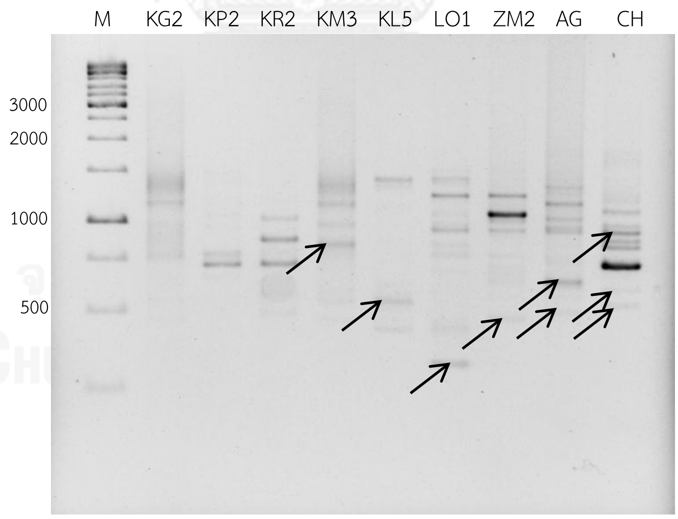


Figure 24. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the OPT-05 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

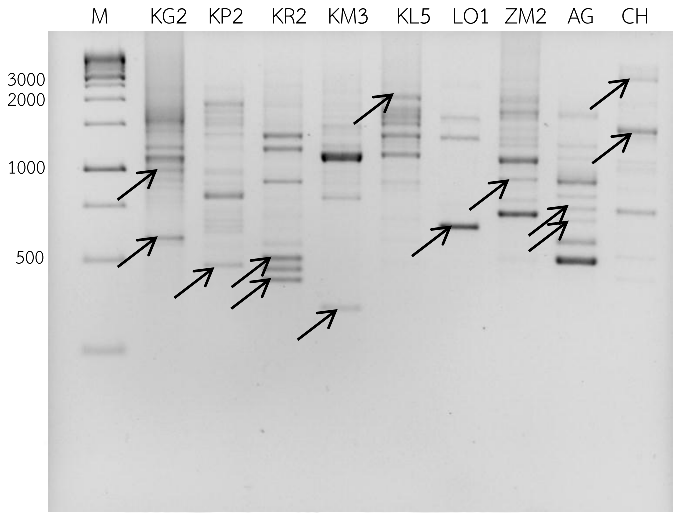


Figure 25. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the OPY-05 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

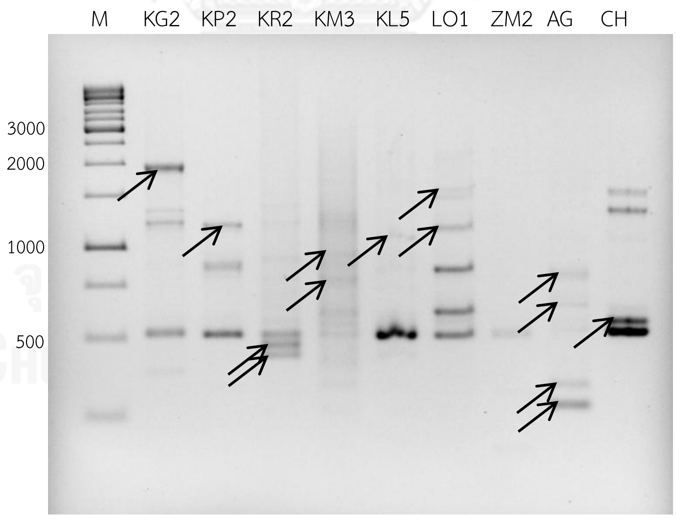


Figure 26. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the OPY-15 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

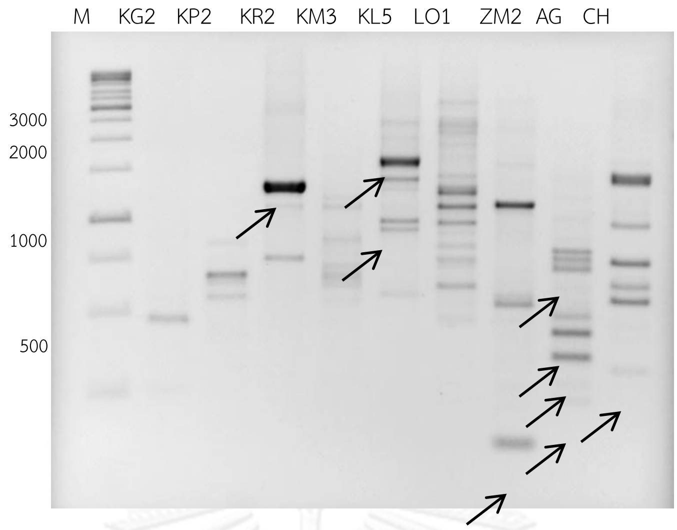


Figure 27. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the OPY-20 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

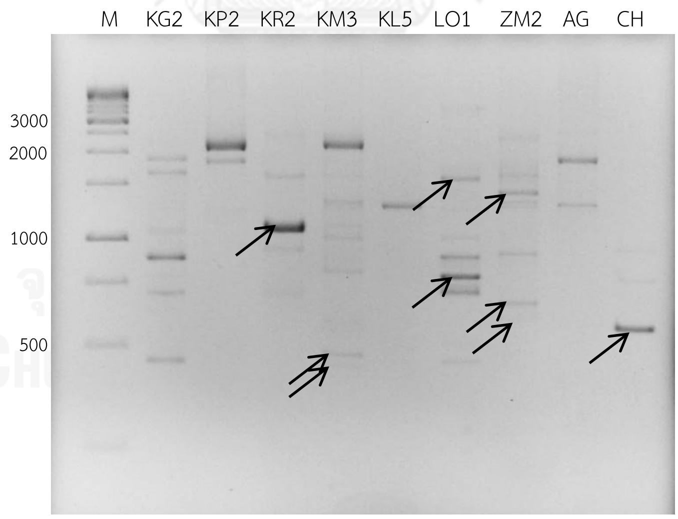


Figure 28. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the RAPD-05 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

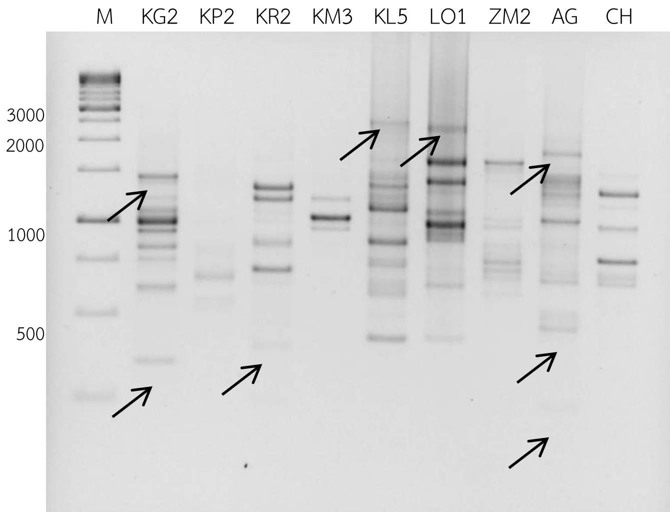


Figure 29. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the RAPD-18 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

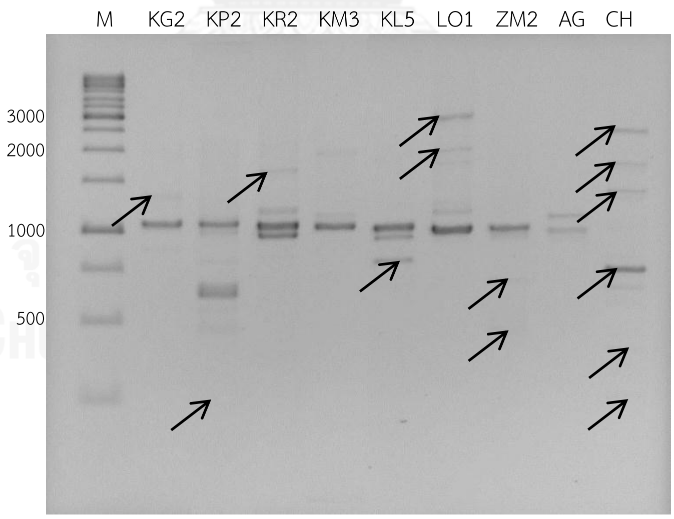


Figure 30. RAPD fingerprint of 5 *Kaempferia* and outgroup plants obtained from the RAPD-F 29 primer.

Abbreviations of the plant samples are according to the codes used in Table 10. M: GeneRuler 1 kb (size shown in bp).

The unique bands of each plant sample are indicated with arrows.

Table 20. The sequence of the oligonucleotide primers used for the RAPD analysis and the number of PCR products obtained from *Kaempferia* species and outgroup plants

Primer	Nucleotide sequence (5′ to 3′)	No. of bands	Size of bands	No. of polymorphic bands	Polymorphism (%)
OPA-15	TTCCGAACCC	26	2928-380	12	46.15
OPB-07	GGTGACGCAG	27	2719-255	11	40.74
OPL-18	ACCACCCACC	25	2708-263	12	48.00
OPT-05	GGGTTTGGCA	21	1399-310	9	42.86
OPY-05	GGCTGCGACA	29	2866-348	13	44.83
OPY 15	AGTCGCCCTT	21	1888-252	14	66.67
OPY 20	AGCCGTGGAA	30	3418-159	9	30.00
RAPD-05	TTCCGGGTGC	19	2154-442	10	52.63
RAPD-18	CCACGGTAGC	28	2409-231	8	28.57
RAPD-F 29	GCCGCTAATATG	22	3000-253	14	66.64

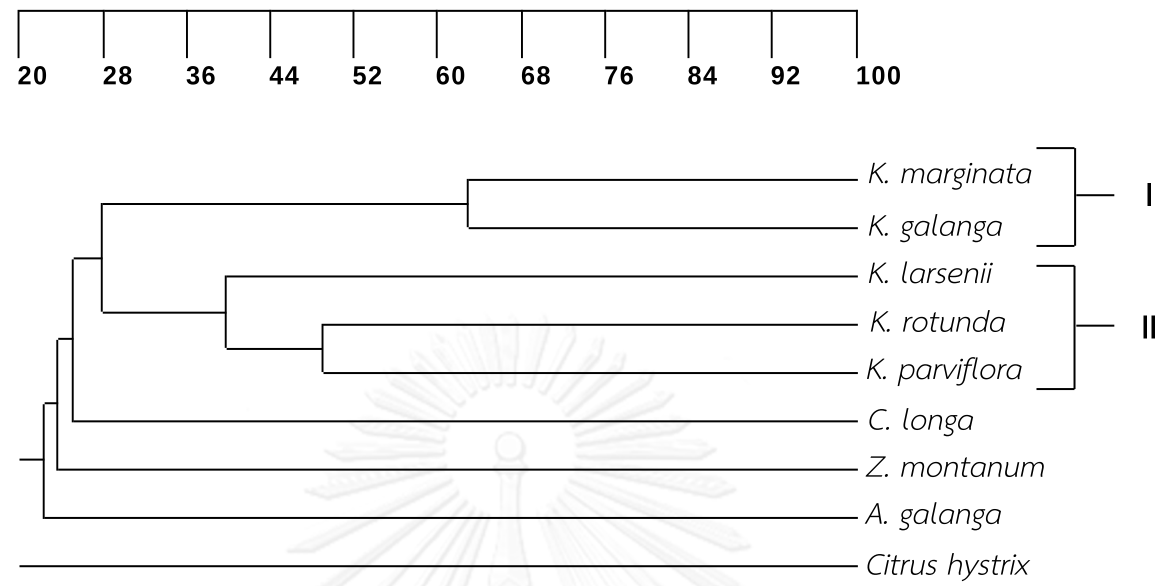


Figure 31. Dendrogram produced by UPGMA cluster analysis of RAPD data showing the genetic relationship among 5 *Kaempferia* plants and outgroup plants.

Table 21. Similarity matrix *of Kaempferia* and outgroup plants generated using Dice similarity coefficient.

Species	*K. marginata*	*K. galanga*	*K. larsenii*	*K. rotunda*	*K. parviflora*	*C. longa*	*Z. montanum*	*A. galanga*	*Citrus hystrix*
K. marginata	1.0000								
K. galanga	0.6284	1.0000							
K. larsenii	0.2076	0.2064	1.0000						
K. rotunda	0.3275	0.3295	0.3603	1.0000					
K. parviflora	0.2992	0.2981	0.4337	0.4897	1.0000				
C. longa	0.1854	0.2941	0.2741	0.2261	0.2734	1.0000			
Z. montanum	0.2396	0.2683	0.2287	0.2363	0.2287	0.2133	1.0000		
A. galanga	0.2166	0.2005	0.1961	0.2787	0.2161	0.2196	0.2297	1.0000	
Citrus hystrix	0.2499	0.1903	0.1846	0.1536	0.2611	0.2218	0.1336	0.1981	1.0000

4.2.3 The relation of essential oil compositions and RAPD profiles with morphological characteristics

The UPGMA dendrogram based on essential oil compositions and RAPD profiles showed that 5 *Kaempferia* plants were divided into two clusters (Figure 19 and 31). The results showed the relation of essential oil compositions and RAPD fingerprints. *K. galanga* and *K. marginata* were clustered in the same group and *K. parviflora*, *K. rotunda* and *K. larsenii* were clustered together.

The *Kaempferia* species grouped in the same cluster were found to be morphologically related. *K. marginata* and *K. galanga* have horizontal, orbicular, unequal-side and sessile leaves. The upper surface of the leaves is glabrous while the lower surface is hairy. The inflorescence is totally enclosed in the two leaf-sheaths with white flowers. The anther-crest is deeply divided and the ovary is glabrous (Picheansoonthon & Koonterm, 2008; Sirirugsa, 1992). Furthermore, Picheansoonthon and Koonterm (2008) noted that *K. marginata* may be conspecific to *K. galanga*.

K. parviflora, *K. rotunda* and *K. larsenii* which clustered in the same group, have 6-30 cm. tall pseudostems. The leaves are erect, ovate-elliptic, with triangular ligule. *K. rotunda* and *K. parviflora* have the leaves which are hairy in lower surface. Their petiole and peduncle are long. In contrast, *K. larsenii* has the leaves which are glabrous on both leave surfaces and sessile petiole and peduncle (Picheansoonthon & Koonterm, 2008; Sirirugsa, 1992).

The important morphological characters of each plant are summarized in Table 22.

Table 22. The important morphological characters of five *Kaempferia* species

Morphological characters	*K. galanga*	*K. marginata*	*K. parviflora*	*K. rotunda*	*K. larsenii*
Height	2-5 cm	3-5 cm	6-10 cm	12-30 cm	8-10 cm
Colour of rhizome	Pale yellow	Pale yellow	Dark purple	Pale yellow	Pale yellow
Leaf position	Horizontal, near the ground	Horizontal, near the ground	Erect	Erect	Erect
Leaf shape	Ovate to suborbicular, unequal sided	Elliptic or orbicular, unequal sided	Ovate or elliptic, slightly unequal sided	Elliptic or lanceolate-oblong	Elliptic-linear
Leaf apex	Mucronate or acute	Acute	Acute or mucronate	Acute	Acute, hooded
Leaf base	Rounded-cuneate	Cuneate	Subcordate	Cuneate	Cuneate
Colour of leaf margin	White	Purple	Red	Green	Green
Indumentum	Upper surface glabrous, lower surface hairy	Upper surface glabrous, lower surface hairy	Upper surface glabrous, lower surface hairy	Upper surface glabrous, lower surface hairy	Glabrous on both surfaces
Ligule shape	Triangular, membranous	Triangular	Triangular, broad	Triangular, broad	Triangular, broad

Table 22. The important morphological characters of five *Kaempferia* species

Morphological characters	*K. galanga*	*K. marginata*	*K. parviflora*	*K. rotunda*	*K. larsenii*
Petiole length	Sessile	Sessile	3 cm	1-2 cm	Sessile
Position of Inflorescence	Enclose by the two leaf-sheaths	Enclose by the two leaf-sheaths	Enclose by the two innermost leaf-sheaths	From the rhizome	Rising between the two innermost leaves,
Peduncle length	Sessile	1 cm	5-6 cm	Shortly	Sessile
Colour of labellum	Purple	Purple	Purple	Purple	Purple
Labellum shape	Obovate, divided to the base	Obovate deeply divided	Ovate, shallowly divided	Elliptic, deeply divided	Obovate, divided to the base
Bract shape	Lanceolate	Lanceolate	Oblong	Lanceolate	Linear
Filament length	2 mm	1 mm	1 mm	3 mm	Sessile
Anther-crest shape	Round, deeply divided	Quadrate, deeply divided	Suborbicular, entire	Oblong, entire	Obovate, entire
Ovary	Glabrous	Glabrous	Hairy	Hairy	Glabrous
Stylodial gland shape	Filiform	Filiform	Filiform	Linear	Filiform

CHAPTER V
CONCLUSION

Twenty-two *Curcuma* species and five *Kaempferia* species in Thailand were investigated for essential oil constituents in the rhizome by Gas Chromatography - Mass Spectroscopy (GC-MS) analysis and for genetic markers by RAPD fingerprinting. The obtained data were used in studying phylogenetic relationships among species belonging to each of two genera.

According to the essential oil profiles, the *Curcuma* plants were divided into five clusters. Cluster I was characterized by the presence of *Z*-asarone, cluster II was characterized by the presence of curlone and (*Z*)-γ-atlantone, cluster IV was characterized by the presence of selina-6-en-4-ol and cluster V was characterized by the presence of sylvestrene and α-copanene. For *Kaempferia* plants, two clusters were given. Cluster I was characterized by the presence of α-cadinol and cluster II by the presence of δ-3-carene and cyperene.

According to the RAPD profiles, the *Curcuma* and *Kaempferia* plants were divided into five and two cluster, respectively. RAPD profiles showed that the RAPD-F-29 primer generated characteristic band of Zingiberaceous plants whereas the OPS-12 primer generated characteristic band of *Curcuma* plants. Therefore, the RAPD-F-29 and OPS-12 primer could be further developed to authenticate Zingiberaceous plants and *Curcuma* plants, respectively. Furthermore, sequence characterized amplified regions (SCARs) could be further developed to differentiate plants that have similar morphological characteristics.

The classification of the plants based on essential oil constituents was found to be in agreement with that based on RAPD profiles. Furthermore, both of the classifications were found to relate with morphological characters of the plants. Based on all the information on essential oil compositions, RAPD profiles and morphological characters, the unidentified *Curcuma* species, *Curcuma* sp. 1, *Curcuma* sp. 2, *Curcuma* sp. 3, *Curcuma* sp. 4, *Curcuma* sp. 5, *Curcuma* sp. 6, *Curcuma* sp. 7 and *Curcuma* sp. 8 should be members of the Longa group while *Curcuma* sp. 9 should be member of Alismatifolia group.

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APPENDIX

APPENDIX A

Essential oil components and colour of the oils obtained from *Curcuma* and outgroup plants

Table 23. Essential oil components of *Kaempferia* and outgroup plants

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
1	Tricyclene	MH	926	0.86	0.10	0.14	-	0.20
2	α-Thujene	MH	930	-	-	-	-	-
3	α-Pinene	MH	939	4.14	0.67	2.63	0.85	8.84
4	Camphene	MH	954	14.50	1.20	10.03	2.56	11.61
5	Sabinene	MH	975	-	-	-	-	-
6	β-Pinene	MH	979	0.56	0.46	1.60	0.39	15.22
7	Myrcene	MH	990	1.96	0.48	0.43	0.27	0.58
8	α-Phellandrene	MH	1002	-	-	-	-	-
9	δ-3-Carene	MH	1011	13.18	4.06	-	2.00	-
10	α-Terpinene	MH	1017	-	-	-	-	-
11	*o*-Cymene	MH	1026	1.65	0.25	-	-	-
12	Limonene	MH	1029	-	-	1.94	-	1.73
13	1,8-Cineole	OM	1031	9.20	1.50	1.57	0.88	0.73
14	(*E*)-β-Ocimene	MH	1050	-	-	-	-	-
15	γ-Terpinene	MH	1059	-	-	-	-	-
16	*cis*-Linalool oxide	OM	1072	-	-	-	-	-
17	*trans*-Linalool oxide	OM	1086	-	-	-	-	-
18	Terpinolene	MH	1088	-	-	-	-	-
19	Linalool	OM	1096	-	-	0.31	-	2.66
20	*trans*-Sabinine hydrate	OM	1098	-	-	-	-	-
21	Camphor	OM	1146	1.19	-	4.97	-	-
22	*neo*-Isopulegol	OM	1148	-	-	-	-	-
23	Citronellal	OM	1153	-	-	-	-	-
24	Borneol	OM	1169	11.73	0.67	1.37	2.08	4.54
25	Terpinen-4-ol	OM	1177	-	-	-	-	-
26	α-Terpineol	OM	1188	-	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
1	Tricyclene	MH	926	1.24	0.92	-	-
2	α-Thujene	MH	930	-	-	-	-
3	α-Pinene	MH	939	5.89	6.89	0.21	0.05
4	Camphene	MH	954	23.94	14.96	-	-
5	Sabinene	MH	975	-	-	-	-
6	β-Pinene	MH	979	1.02	8.88	-	-
7	Myrcene	MH	990	0.42	0.09	-	-
8	α-Phellandrene	MH	1002	-	-	4.45	0.84
9	δ-3-Carene	MH	1011	-	-	-	-
10	α-Terpinene	MH	1017	-	-	-	-
11	*o*-Cymene	MH	1026	-	-	1.42	-
12	Limonene	MH	1029	0.44	0.12	-	-
13	1,8-Cineole	OM	1031	1.29	1.13	1.79	0.35
14	(*E*)-β-Ocimene	MH	1050	-	-	-	-
15	γ-Terpinene	MH	1059	-	-	-	-
16	*cis*-Linalool oxide	OM	1072	-	-	-	-
17	*trans*-Linalool oxide	OM	1086	-	-	-	-
18	Terpinolene	MH	1088	-	-	4.45	1.01
19	Linalool	OM	1096	0.55	0.92	-	-
20	*trans*-Sabinine hydrate	OM	1098	-	-	-	-
21	Camphor	OM	1146	7.34	5.41	-	-
22	*neo*-Isopulegol	OM	1148	-	-	-	-
23	Citronellal	OM	1153	-	-	-	-
24	Borneol	OM	1169	0.52	0.91	-	-
25	Terpinen-4-ol	OM	1177	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
1	Tricyclene	MH	926	-	-	-	-
2	α-Thujene	MH	930	0.19	0.41	-	-
3	α-Pinene	MH	939	0.46	1.02	1.19	0.21
4	Camphene	MH	954	-	-	-	-
5	Sabinene	MH	975	17.04	24.40	0.23	3.02
6	β-Pinene	MH	979	-	-	0.33	0.24
7	Myrcene	MH	990	0.64	0.74	0.29	1.16
8	α-Phellandrene	MH	1002	-	-	-	-
9	δ-3-Carene	MH	1011	-	-	-	-
10	α-Terpinene	MH	1017	1.07	1.58	0.17	0.07
11	*o*-Cymene	MH	1026	-	0.43	-	-
12	Limonene	MH	1029	-	0.63	1.02	0.25
13	1,8-Cineole	OM	1031	-	-	14.33	-
14	(*E*)-β-Ocimene	MH	1050	-	-	-	0.59
15	γ-Terpinene	MH	1059	1.99	3.13	-	-
16	*cis*-Linalool oxide	OM	1072	-	-	-	0.56
17	*trans*-Linalool oxide	OM	1086	-	-	-	0.31
18	Terpinolene	MH	1088	0.36	0.55	-	-
19	Linalool	OM	1096	-	-	-	3.56
20	*trans*-Sabinine hydrate	OM	1098	0.55	0.14	-	-
21	Camphor	OM	1146	-	-	-	-
22	*neo*-Isopulegol	OM	1148	-	-	-	1.06
23	Citronellal	OM	1153	-	-	-	63.70
24	Borneol	OM	1169	-	-	-	-
25	Terpinen-4-ol	OM	1177	11.83	11.28	0.67	-
26	α-Terpineol	OM	1188	-	0.24	0.39	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
27	Citronellol	OM	1225	-	-	-	-	-
28	Geraniol	OM	1252	-	-	-	-	-
29	Isobornyl acetate	OM	1285	-	-	-	-	-
30	Bornyl acetate	OM	1288	1.91	-	0.08	-	0.37
31	α-Terpinyl acetate	OM	1349	-	-	-	-	-
32	Citronellyl acetate	OM	1352	-	-	-	-	-
33	Eugenol	OM	1359	-	-	-	-	-
34	α-Ylangene	SH	1375	-	-	-	-	-
35	α-Copaene	SH	1376	-	-	0.08	-	5.32
36	Geranyl acetate	OM	1381	-	-	-	-	-
37	β-Elemene	SH	1390	-	-	0.09	-	1.85
38	Cyperene	SH	1398	1.08	0.26	-	0.47	-
39	α-Gurjunene	SH	1409	1.30	0.10	3.12	0.33	-
40	*E*-Caryophyllene	SH	1419	-	-	5.26	-	3.02
41	α-Guaiene	SH	1439	-	-	-	-	-
42	(*Z*)-β-Farnesene	SH	1442	-	-	-	-	-
43	α-Humulene	SH	1454	-	-	0.55	-	1.03
44	(*E*)-β-Farnesene	SH	1456	-	-	-	-	-
45	Ishwarane	SH	1466	-	-	-	-	-
46	*E*-Ethyl cinnamate	PP	1467	0.33	31.75	3.43	19.12	-
47	β-Chamigrene	SH	1477	-	-	-	-	-
48	*ar*-Curcumene	SH	1480	-	-	-	-	-
49	γ-Curcumene	SH	1482	-	-	-	-	-
50	Germacrene D	SH	1485	2.19	0.48	0.55	0.80	22.36
51	β-Selinene	SH	1490	-	-	-	-	-
52	Drim-8(12)-ene	SH	1491	-	-	0.56	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
27	Citronellol	OM	1225	-	-	-	-
28	Geraniol	OM	1252	-	-	-	-
29	Isobornyl acetate	OM	1285	-	-	-	-
30	Bornyl acetate	OM	1288	2.75	-	-	-
31	α-Terpinyl acetate	OM	1349	-	-	-	-
32	Citronellyl acetate	OM	1352	-	-	-	-
33	Eugenol	OM	1359	-	-	-	-
34	α-Ylangene	SH	1375	0.80	2.31	-	-
35	α-Copaene	SH	1376	-	-	-	-
36	Geranyl acetate	OM	1381	-	-	-	-
37	β-Elemene	SH	1390	0.08	0.44	-	-
38	Cyperene	SH	1398	-	-	-	-
39	α-Gurjunene	SH	1409	-	-	-	-
40	*E*-Caryophyllene	SH	1419	-	-	4.52	2.06
41	α-Guaiene	SH	1439	0.66	3.06	-	-
42	(*Z*)-β-Farnesene	SH	1442	-	-	1.09	0.29
43	α-Humulene	SH	1454	-	-	-	-
44	(*E*)-β-Farnesene	SH	1456	-	-	-	-
45	Ishwarane	SH	1466	0.50	1.51	-	-
46	*E*-Ethyl cinnamate	PP	1467	-	-	-	-
47	β-Chamigrene	SH	1477	-	-	-	-
48	*ar*-Curcumene	SH	1480	-	-	7.79	1.26
49	γ-Curcumene	SH	1482	0.27	-	-	-
50	Germacrene D	SH	1485	0.37	0.29	-	-
51	β-Selinene	SH	1490	0.27	1.16	-	-
52	Drim-8(12)-ene	SH	1491	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
27	Citronellol	OM	1225	-	-	-	15.43
28	Geraniol	OM	1252	-	-	-	0.59
29	Isobornyl acetate	OM	1285	-	-	0.18	-
30	Bornyl acetate	OM	1288	-	-	-	-
31	α-Terpinyl acetate	OM	1349	0.31	0.19	-	-
32	Citronellyl acetate	OM	1352	-	-	-	1.50
33	Eugenol	OM	1359	-	-	0.34	-
34	α-Ylangene	SH	1375	-	-	-	-
35	α-Copaene	SH	1376	-	-	-	0.53
36	Geranyl acetate	OM	1381	-	-	0.35	-
37	β-Elemene	SH	1390	-	-	0.60	-
38	Cyperene	SH	1398	-	-	-	-
39	α-Gurjunene	SH	1409	-	-	-	-
40	*E*-Caryophyllene	SH	1419	-	-	9.03	2.91
41	α-Guaiene	SH	1439	-	-	-	-
42	(*Z*)-β-Farnesene	SH	1442	-	-	-	-
43	α-Humulene	SH	1454	-	-	-	-
44	(*E*)-β-Farnesene	SH	1456	-	-	10.57	-
45	Ishwarane	SH	1466	-	-	-	-
46	*E*-Ethyl cinnamate	PP	1467	-	-	-	-
47	β-Chamigrene	SH	1477	-	-	0.39	-
48	*ar*-Curcumene	SH	1480	-	-	-	-
49	γ-Curcumene	SH	1482	-	-	-	-
50	Germacrene D	SH	1485	-	-	-	-
51	β-Selinene	SH	1490	-	-	8.31	
52	Drim-8(12)-ene	SH	1491	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
53	α-Zingiberene	SH	1493	-	-	-	-	-
54	Valencene	SH	1496	-	-	-	-	-
55	α-Selinene	SH	1498	-	-	-	-	-
56	Pentadecane	SH	1500	0.96	8.13	-	9.64	-
57	Bicyclogermacrene	SH	1500	-	-	0.65	-	3.31
58	β-Bisabolene	SH	1505	-	-	-	-	-
59	*E*-*E*-α-Farnesene	SH	1505	-	-	-	-	-
60	γ-Cadinene	SH	1513	1.04	0.37	0.63	0.35	0.77
61	β-Curcumeme	SH	1515	-	-	-	-	-
62	7-*epi*-α-Selinene	SH	1520	-	-	-	-	-
63	β-Sesquiphellandrene	SH	1522	-	-	-	-	-
64	δ-Cadinene	SH	1523	0.94	0.26	1.05	-	3.02
65	*E*-γ- Bisabolene	SH	1531	-	-	-	-	-
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	0.51	0.23	-	-	-
67	Germacrene B	SH	1561	0.44	0.39	1.16	0.55	0.27
68	*E*-Nerolidol	OS	1563	-	-	-	-	-
69	Caryophyllene oxide	OS	1583	1.10	-	13.06	0.11	1.11
70	*ar*-Tumerol	OS	1583	-	-	-	-	-
71	Carotol	OS	1594	-	-	-	-	-
72	Guaiol	OS	1600	2.16	-	-	-	-
73	Humulene epoxide II	OS	1608	1.39	-	1.78	-	-
74	Helifolen-12-al C (anti-syn-syn-)	OS	1620	-	-	-	-	-
75	1-*epi*-Cubenol	OS	1628	0.33	0.30	-	-	-
76	γ-Eudesmol	OS	1632	1.89	-	-	-	-
77	*epi*-α-Cadinol	OS	1640	-	-	-	-	1.78
78	*epi*-α-Murrolol	OS	1642	-	-	1.47	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
53	α-Zingiberene	SH	1493	-	-	6.61	3.17
54	Valencene	SH	1496	0.47	2.03	-	-
55	α-Selinene	SH	1498	-	-	-	-
56	Pentadecane	SH	1500	2.39	-	-	-
57	Bicyclogermacrene	SH	1500	-	-	-	-
58	β-Bisabolene	SH	1505	-	-	1.61	0.57
59	*E-E*-α-Farnesene	SH	1505	-	-	-	-
60	γ-Cadinene	SH	1513	1.45	0.43	-	-
61	β-Curcumeme	SH	1515	-	-	-	-
62	7-*epi*-α-Selinene	SH	1520	-	-	-	-
63	β-Sesquiphellandrene	SH	1522	-	-	11.14	3.68
64	δ-Cadinene	SH	1523	-	-	-	-
65	*E*-γ- Bisabolene	SH	1531	-	-	-	-
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	-	-	-	-
67	Germacrene B	SH	1561	0.06	0.14	-	-
68	*E*-Nerolidol	OS	1563	-	-	-	-
69	Caryophyllene oxide	OS	1583	-	-	-	-
70	*ar*-Tumerol	OS	1583	-	-	0.58	0.75
71	Carotol	OS	1594	-	-	0.20	1.56
72	Guaiol	OS	1600	-	-	-	-
73	Humulene epoxide II	OS	1608	-	-	-	-
74	Helifolen-12-al C (anti-syn-syn-)	OS	1620	-	-	1.42	1.64
75	1-*epi*-Cubenol	OS	1628	0.67	0.32	-	-
76	γ-Eudesmol	OS	1632	1.29	2.24	-	-
77	*epi*-α-Cadinol	OS	1640	-	-	-	-
78	*epi*-α-Murrolol	OS	1642	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
53	α-Zingiberene	SH	1493	-	-	-	-
54	Valencene	SH	1496	-	-	-	-
55	α-Selinene	SH	1498	-	-	8.11	-
56	Pentadecane	SH	1500	-	-	-	-
57	Bicyclogermacrene	SH	1500	-	-	-	1.45
58	β-Bisabolene	SH	1505	-	-	15.30	-
59	*E*-*E*-α-Farnesene	SH	1505	-	-	-	0.50
60	γ-Cadinene	SH	1513	-	-	-	-
61	β-Curcumeme	SH	1515	-	0.19	-	-
62	7-*epi*-α-Selinene	SH	1520	-	-	0.67	-
63	β-Sesquiphellandrene	SH	1522	2.46	1.45	1.85	-
64	δ-Cadinene	SH	1523	-	-	-	0.84
65	*E*-γ- Bisabolene	SH	1531	-	-	0.32	-
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	-	-	-	-
67	Germacrene B	SH	1561	-	0.11	7.39	-
68	*E*-Nerolidol	OS	1563	-	-	-	1.25
69	Caryophyllene oxide	OS	1583	-	-	-	-
70	*ar*-Tumerol	OS	1583	-	-	-	-
71	Carotol	OS	1594	-	-	-	-
72	Guaiol	OS	1600	-	-	-	-
73	Humulene epoxide II	OS	1608	-	-	-	-
74	Helifolen-12-al C (anti-syn-syn-)	OS	1620	-	-	-	-
75	1-*epi*-Cubenol	OS	1628	-	-	-	-
76	γ-Eudesmol	OS	1632	-	-	-	-
77	*epi*-α-Cadinol	OS	1640	-	-	-	-
78	*epi*-α-Murrolol	OS	1642	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
79	α-Muurolol	OS	1646	-	-	-	-	1.85
80	β-Eudesmol	OS	1650	8.18	-	-	0.18	-
81	α-Cadinol	OS	1654	-	-	2.04	-	2.91
82	Selin-11-en-4-α-ol	OS	1659	-	-	-	-	-
83	*neo*-Intermedeol	OS	1660	-	-	-	-	-
84	*ar*-Turmerone	OS	1669	-	-	-	-	-
85	Germacrone	OS	1693	-	-	4.85	-	-
86	(*Z*)-γ-Atlantone	OS	1694	-	-	-	-	-
87	Heptadecane	Other	1700	-	0.46	-	-	-
88	1,3,3-Trimethyl-2-oxabicyclo[2.2.2] octan-6-ol, acetate	OM	1700	-	-	-	-	-
89	*6R,7R*-Bisabolone	OS	1742	-	-	-	-	-
90	2*E*,6*E*-Farnesol	OS	1743	-	-	-	-	-
91	Benzyl benzoate	PP	1760	-	-	-	-	-
92	*E*-α-Atlantone	OS	1778	-	-	-	-	-
93	Octadecane	Other	1800	-	-	-	1.34	-
94	2*E*,6*E*-Farnesyl acetate	OS	1846	-	-	-	-	-
95	Benzyl salicylate	PP	1865	-	-	-	-	-
96	Pimaradiene	DH	1949	13.37	0.15	1.42	5.97	-
97	Sandaracopimara-8(14),15-diene	DH	1969	-	-	-	5.57	-
98	*epi*-13-Manool	OD	2060	-	-	22.63	-	0.48
99	Curlone	OS	-	-	-	-	-	-
100	Methyl 3,4-dimethoxycinnamate	PP	-	-	-	-	-	-
101	5-Cyclohexadecen-1-one	PP	-	-	1.14	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
79	α-Muurolol	OS	1646	-	-	-	-
80	β-Eudesmol	OS	1650	1.40	1.38	-	-
81	α-Cadinol	OS	1654	0.93	-	-	-
82	Selin-11-en-4-α-ol	OS	1659	-	2.82	-	-
83	*neo*-Intermedeol	OS	1660	-	-	-	-
84	*ar*-Turmerone	OS	1669	-	-	17.63	17.89
85	Germacrone	OS	1693	-	-	-	-
86	(*Z*)-γ-Atlantone	OS	1694	-	-	23.93	33.13
87	Heptadecane	Other	1700	-	-	-	-
88	1,3,3-Trimethyl-2-oxabicyclo[2.2.2] octan-6-ol, acetate	OM	1700	-	-	-	-
89	*6R,7R*-Bisabolone	OS	1742	-	-	0.26	1.13
90	2*E*,6*E*-Farnesol	OS	1743	-	-	-	-
91	Benzyl benzoate	PP	1760	39.41	35.96	-	-
92	*E*-α-Atlantone	OS	1778	-	-	0.30	3.84
93	Octadecane	Other	1800	-	-	-	-
94	2*E*,6*E*-Farnesyl acetate	OS	1846	-	-	-	-
95	Benzyl salicylate	PP	1865	2.07	4.01	-	-
96	Pimaradiene	DH	1949	0.42	1.66	-	-
97	Sandaracopimara-8(14),15-diene	DH	1969	-	-	-	-
98	*epi*-13-Manool	OD	2060	-	-	-	-
99	Curlone	OS	-	-	-	10.59	15.72
100	Methyl 3,4-dimethoxycinnamate	PP	-	-	-	-	-
101	5-Cyclohexadecen-1-one	PP	-	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
79	α-Muurolol	OS	1646	-	-	-	-
80	β-Eudesmol	OS	1650	-	-	-	-
81	α-Cadinol	OS	1654	-	-	-	-
82	Selin-11-en-4-α-ol	OS	1659	-	-	-	-
83	*neo*-Intermedeol	OS	1660	-	-	2.18	-
84	*ar*-Turmerone	OS	1669	-	-	-	-
85	Germacrone	OS	1693	-	-	-	-
86	(*Z*)-γ-Atlantone	OS	1694	-	-	-	-
87	Heptadecane	Other	1700	-	-	-	-
88	1,3,3-Trimethyl-2-oxabicyclo[2.2.2] octan-6-ol, acetate	OM	1700	-	-	0.95	-
89	*6R,7R*-Bisabolone	OS	1742	-	-	-	-
90	2*E*,6*E*-Farnesol	OS	1743	-	-	0.28	-
91	Benzyl benzoate	PP	1760	-	-	-	-
92	*E*-α-Atlantone	OS	1778	-	-	-	-
93	Octadecane	Other	1800	-	-	-	-
94	2*E*,6*E*-Farnesyl acetate	OS	1846	-	-	2.09	-
95	Benzyl salicylate	PP	1865	-	-	-	-
96	Pimaradiene	DH	1949	-	-	-	-
97	Sandaracopimara-8(14),15-diene	DH	1969	-	-	-	-
98	*epi*-13-Manool	OD	2060	-	-	-	-
99	Curlone	OS	-	-	-	-	-
100	Methyl 3,4-dimethoxycinnamate	PP	-	1.09	0.89	-	-
101	5-Cyclohexadecen-1-one	PP	-	-	-	-	-

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
102	3-(4-Methoxyphenyl)-2-propenoic acid, ethyl ester	Other	-	1.91	46.59	4.90	45.92	0.64
103	8-Heptadecene	Other	-	-	-	-	-	-
104	Hydroxy-α-terpenyl acetate	Other	-	-	-	-	-	-
105	(*E*)-1-(3,4)-dimethoxy phenylbutadiene	Other	-	-	-	-	-	-
106	(*Z*)-9,17-Octadecadienal	Other	-	-	-	-	-	0.96
	Compound class							
	Terpenoids							
	- Monoterpene hyfrocarbons (MH)			36.85	7.22	16.77	6.07	38.18
	- Oxygenated monoterpenes (OM)			24.03	2.17	8.30	2.96	8.30
	- Sesquiterpene hydrocarbons (SH)			7.95	9.99	13.7	12.14	40.95
	- Oxygenated sesquiterpenes (OS)			15.56	0.53	23.20	0.29	7.65
	Phenylpropanoids			0.33	32.89	3.43	19.12	0.00
	Others			15.28	47.20	28.95	58.80	2.08
	Total identified			100.00	100.00	94.35	99.38	97.16
	% Yield (V/W)			0.24	0.32	0.13	0.24	0.28

[a] MH: Monoterpene hyfrocarbons; OM: Oxygenated monoterpenes; SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes; PP: Phenylpropanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

–: not detected

Abbreviations of the plant samples according to the codes used in Table 10.

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
102	3-(4-Methoxyphenyl)-2-propenoic acid, ethyl ester	Other	-	-	-	-	-
103	8-Heptadecene	Other	-	-	-	-	-
104	Hydroxy-α-terpenyl acetate	Other	-	-	-	-	-
105	(*E*)-1-(3,4)-dimethoxy phenylbutadiene	Other	-	-	-	-	-
106	(*Z*)-9,17-Octadecadienal	Other	-	-	-	-	-
	Compound class						
	Terpenoids						
	- Monoterpene hyfrocarbons (MH)			32.95	31.86	10.53	1.90
	- Oxygenated monoterpenes (OM)			12.45	8.37	1.79	0.35
	- Sesquiterpene hydrocarbons (SH)			7.32	11.37	32.76	11.03
	- Oxygenated sesquiterpenes (OS)			4.29	6.76	54.91	75.66
	Phenylpropanoids			41.48	39.97	0.00	0.00
	Others			0.42	1.66	0.00	0.00
	Total identified			98.91	99.99	99.99	88.94
	% Yield (V/W)			0.36	0.40	0.07	0.16

[a] MH: Monoterpene hyfrocarbons; OM: Oxygenated monoterpenes; SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes; PP: Phenylpropanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

–: not detected

Abbreviations of the plant samples according to the codes used in Table 10.

Table 23. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
102	3-(4-Methoxyphenyl)-2-propenoic acid, ethyl ester	Other	-	-	-	-	-
103	8-Heptadecene	Other	-	-	-	0.96	-
104	Hydroxy-α-terpenyl acetate	Other	-	-	-	11.48	-
105	(*E*)-1-(3,4)-dimethoxy phenylbutadiene	Other	-	52.38	45.97	-	-
106	(*Z*)-9,17-Octadecadienal	Other	-	-	-	-	-
	Compound class						
	Terpenoids						
	- Monoterpene hyfrocarbons (MH)			21.75	32.89	3.23	5.54
	- Oxygenated monoterpenes (OM)			12.69	11.85	17.21	86.71
	- Sesquiterpene hydrocarbons (SH)			2.46	1.75	62.54	6.23
	- Oxygenated sesquiterpenes (OS)			0.00	0.00	4.55	1.25
	Phenylpropanoids			1.09	0.89	0.00	0.00
	Others			52.38	45.97	12.44	0.00
	Total identified			90.37	93.35	99.97	99.73
	% Yield (V/W)			1.40	1.20	0.90	1.10

[a] MH: Monoterpene hyfrocarbons; OM: Oxygenated monoterpenes; SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes; PP: Phenylpropanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

–: not detected

Abbreviations of the plant samples according to the codes used in Table 10.

Table 24. Colour of the essential oils obtained from Curcuma species and outgroup plants

Species	Colour of the oils
C. aeruginosa (AE 1, AE 2, AE 3)	Pale yellow
C. albicoma (AL 1, AL 2, AL 3)	Dark purple
C. amada (AM 1, AM 3)	Pale yellow
C. angustifolia (AN 3)	Pale yellow
C. aromatica (AR 1, AR 2, AR 3)	Pale yellow
C. *comosa* (CO 1, CO 2, CO 3)	Pale yellow
C. longa (LO 1, LO 2)	Yellow
C. mangga (MA 1, MA 2, MA 3)	Pale yellow
C. parviflora (PA 1)	Pale yellow
C. petiolata (PE 3)	Pale yellow
C. rubrobracteata (RU 1)	Pale yellow
C. sessilis (SE 1)	Pale yellow
C. zedoaria (ZE 1, ZE 2)	Yellow

Table 24. Colour of the essential oils obtained from Curcuma species and outgroup plants

Species	Colour of the oils
Curcuma sp. 1 (SP 14)	Yellow
Curcuma sp. 2 (SP 21, SP 22)	Pale yellow
Curcuma sp. 3 (SP 31, SP 32, SP 33)	Greenish yellow
Curcuma sp. 4 (SP 41, SP 42)	Dark purple
Curcuma sp. 5 (SP 51, SP 53)	Pale yellow
Curcuma sp. 6 (SP 61, SP 63)	Greenish yellow
Curcuma sp. 7 (SP 71, SP 72)	Pale yellow
Curcuma sp. 8 (SP 81, SP 82, SP 83)	Dark purple
Curcuma sp. 9 (SP 92, SP 93)	Pale yellow
K. rotunda (KR 2, KR 3)	Pale yellow
Z. montanum (ZM 1, ZM 2)	Yellow
A. galanga (AG)	Pale yellow
Citrus hystrix (CH)	Pale yellow

APPENDIX B

Essential oil components of *Kaempferia* and outgroup plants

Table 25. Essential oil components of *Kaempferia* and outgroup plants

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
1	Tricyclene	MH	926	0.86	0.10	0.14	-	0.20
2	α-Thujene	MH	930	-	-	-	-	-
3	α-Pinene	MH	939	4.14	0.67	2.63	0.85	8.84
4	Camphene	MH	954	14.50	1.20	10.03	2.56	11.61
5	Sabinene	MH	975	-	-	-	-	-
6	β-Pinene	MH	979	0.56	0.46	1.60	0.39	15.22
7	Myrcene	MH	990	1.96	0.48	0.43	0.27	0.58
8	α-Phellandrene	MH	1002	-	-	-	-	-
9	δ-3-Carene	MH	1011	13.18	4.06	-	2.00	-
10	α-Terpinene	MH	1017	-	-	-	-	-
11	*o*-Cymene	MH	1026	1.65	0.25	-	-	-
12	Limonene	MH	1029	-	-	1.94	-	1.73
13	1,8-Cineole	OM	1031	9.20	1.50	1.57	0.88	0.73
14	(*E*)-β-Ocimene	MH	1050	-	-	-	-	-
15	γ-Terpinene	MH	1059	-	-	-	-	-
16	*cis*-Linalool oxide	OM	1072	-	-	-	-	-
17	*trans*-Linalool oxide	OM	1086	-	-	-	-	-
18	Terpinolene	MH	1088	-	-	-	-	-
19	Linalool	OM	1096	-	-	0.31	-	2.66
20	*trans*-Sabinine hydrate	OM	1098	-	-	-	-	-
21	Camphor	OM	1146	1.19	-	4.97	-	-
22	*neo*-Isopulegol	OM	1148	-	-	-	-	-
23	Citronellal	OM	1153	-	-	-	-	-
24	Borneol	OM	1169	11.73	0.67	1.37	2.08	4.54
25	Terpinen-4-ol	OM	1177	-	-	-	-	-
26	α-Terpineol	OM	1188	-	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
1	Tricyclene	MH	926	1.24	0.92	-	-
2	α-Thujene	MH	930	-	-	-	-
3	α-Pinene	MH	939	5.89	6.89	0.21	0.05
4	Camphene	MH	954	23.94	14.96	-	-
5	Sabinene	MH	975	-	-	-	-
6	β-Pinene	MH	979	1.02	8.88	-	-
7	Myrcene	MH	990	0.42	0.09	-	-
8	α-Phellandrene	MH	1002	-	-	4.45	0.84
9	δ-3-Carene	MH	1011	-	-	-	-
10	α-Terpinene	MH	1017	-	-	-	-
11	*o*-Cymene	MH	1026	-	-	1.42	-
12	Limonene	MH	1029	0.44	0.12	-	-
13	1,8-Cineole	OM	1031	1.29	1.13	1.79	0.35
14	(*E*)-β-Ocimene	MH	1050	-	-	-	-
15	γ-Terpinene	MH	1059	-	-	-	-
16	*cis*-Linalool oxide	OM	1072	-	-	-	-
17	*trans*-Linalool oxide	OM	1086	-	-	-	-
18	Terpinolene	MH	1088	-	-	4.45	1.01
19	Linalool	OM	1096	0.55	0.92	-	-
20	*trans*-Sabinine hydrate	OM	1098	-	-	-	-
21	Camphor	OM	1146	7.34	5.41	-	-
22	*neo*-Isopulegol	OM	1148	-	-	-	-
23	Citronellal	OM	1153	-	-	-	-
24	Borneol	OM	1169	0.52	0.91	-	-
25	Terpinen-4-ol	OM	1177	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
1	Tricyclene	MH	926	-	-	-	-
2	α-Thujene	MH	930	0.19	0.41	-	-
3	α-Pinene	MH	939	0.46	1.02	1.19	0.21
4	Camphene	MH	954	-	-	-	-
5	Sabinene	MH	975	17.04	24.40	0.23	3.02
6	β-Pinene	MH	979	-	-	0.33	0.24
7	Myrcene	MH	990	0.64	0.74	0.29	1.16
8	α-Phellandrene	MH	1002	-	-	-	-
9	δ-3-Carene	MH	1011	-	-	-	-
10	α-Terpinene	MH	1017	1.07	1.58	0.17	0.07
11	*o*-Cymene	MH	1026	-	0.43	-	-
12	Limonene	MH	1029	-	0.63	1.02	0.25
13	1,8-Cineole	OM	1031	-	-	14.33	-
14	(*E*)-β-Ocimene	MH	1050	-	-	-	0.59
15	γ-Terpinene	MH	1059	1.99	3.13	-	-
16	*cis*-Linalool oxide	OM	1072	-	-	-	0.56
17	*trans*-Linalool oxide	OM	1086	-	-	-	0.31
18	Terpinolene	MH	1088	0.36	0.55	-	-
19	Linalool	OM	1096	-	-	-	3.56
20	*trans*-Sabinine hydrate	OM	1098	0.55	0.14	-	-
21	Camphor	OM	1146	-	-	-	-
22	*neo*-Isopulegol	OM	1148	-	-	-	1.06
23	Citronellal	OM	1153	-	-	-	63.70
24	Borneol	OM	1169	-	-	-	-
25	Terpinen-4-ol	OM	1177	11.83	11.28	0.67	-
26	α-Terpineol	OM	1188	-	0.24	0.39	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
27	Citronellol	OM	1225	-	-	-	-	-
28	Geraniol	OM	1252	-	-	-	-	-
29	Isobornyl acetate	OM	1285	-	-	-	-	-
30	Bornyl acetate	OM	1288	1.91	-	0.08	-	0.37
31	α-Terpinyl acetate	OM	1349	-	-	-	-	-
32	Citronellyl acetate	OM	1352	-	-	-	-	-
33	Eugenol	OM	1359	-	-	-	-	-
34	α-Ylangene	SH	1375	-	-	-	-	-
35	α-Copaene	SH	1376	-	-	0.08	-	5.32
36	Geranyl acetate	OM	1381	-	-	-	-	-
37	β-Elemene	SH	1390	-	-	0.09	-	1.85
38	Cyperene	SH	1398	1.08	0.26	-	0.47	-
39	α-Gurjunene	SH	1409	1.30	0.10	3.12	0.33	-
40	*E*-Caryophyllene	SH	1419	-	-	5.26	-	3.02
41	α-Guaiene	SH	1439	-	-	-	-	-
42	(*Z*)-β-Farnesene	SH	1442	-	-	-	-	-
43	α-Humulene	SH	1454	-	-	0.55	-	1.03
44	(*E*)-β-Farnesene	SH	1456	-	-	-	-	-
45	Ishwarane	SH	1466	-	-	-	-	-
46	*E*-Ethyl cinnamate	PP	1467	0.33	31.75	3.43	19.12	-
47	β-Chamigrene	SH	1477	-	-	-	-	-
48	*ar*-Curcumene	SH	1480	-	-	-	-	-
49	γ-Curcumene	SH	1482	-	-	-	-	-
50	Germacrene D	SH	1485	2.19	0.48	0.55	0.80	22.36
51	β-Selinene	SH	1490	-	-	-	-	-
52	Drim-8(12)-ene	SH	1491	-	-	0.56	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
27	Citronellol	OM	1225	-	-	-	-
28	Geraniol	OM	1252	-	-	-	-
29	Isobornyl acetate	OM	1285	-	-	-	-
30	Bornyl acetate	OM	1288	2.75	-	-	-
31	α-Terpinyl acetate	OM	1349	-	-	-	-
32	Citronellyl acetate	OM	1352	-	-	-	-
33	Eugenol	OM	1359	-	-	-	-
34	α-Ylangene	SH	1375	0.80	2.31	-	-
35	α-Copaene	SH	1376	-	-	-	-
36	Geranyl acetate	OM	1381	-	-	-	-
37	β-Elemene	SH	1390	0.08	0.44	-	-
38	Cyperene	SH	1398	-	-	-	-
39	α-Gurjunene	SH	1409	-	-	-	-
40	*E*-Caryophyllene	SH	1419	-	-	4.52	2.06
41	α-Guaiene	SH	1439	0.66	3.06	-	-
42	(*Z*)-β-Farnesene	SH	1442	-	-	1.09	0.29
43	α-Humulene	SH	1454	-	-	-	-
44	(*E*)-β-Farnesene	SH	1456	-	-	-	-
45	Ishwarane	SH	1466	0.50	1.51	-	-
46	*E*-Ethyl cinnamate	PP	1467	-	-	-	-
47	β-Chamigrene	SH	1477	-	-	-	-
48	*ar*-Curcumene	SH	1480	-	-	7.79	1.26
49	γ-Curcumene	SH	1482	0.27	-	-	-
50	Germacrene D	SH	1485	0.37	0.29	-	-
51	β-Selinene	SH	1490	0.27	1.16	-	-
52	Drim-8(12)-ene	SH	1491	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
27	Citronellol	OM	1225	-	-	-	15.43
28	Geraniol	OM	1252	-	-	-	0.59
29	Isobornyl acetate	OM	1285	-	-	0.18	-
30	Bornyl acetate	OM	1288	-	-	-	-
31	α-Terpinyl acetate	OM	1349	0.31	0.19	-	-
32	Citronellyl acetate	OM	1352	-	-	-	1.50
33	Eugenol	OM	1359	-	-	0.34	-
34	α-Ylangene	SH	1375	-	-	-	-
35	α-Copaene	SH	1376	-	-	-	0.53
36	Geranyl acetate	OM	1381	-	-	0.35	-
37	β-Elemene	SH	1390	-	-	0.60	-
38	Cyperene	SH	1398	-	-	-	-
39	α-Gurjunene	SH	1409	-	-	-	-
40	*E*-Caryophyllene	SH	1419	-	-	9.03	2.91
41	α-Guaiene	SH	1439	-	-	-	-
42	(*Z*)-β-Farnesene	SH	1442	-	-	-	-
43	α-Humulene	SH	1454	-	-	-	-
44	(*E*)-β-Farnesene	SH	1456	-	-	10.57	-
45	Ishwarane	SH	1466	-	-	-	-
46	*E*-Ethyl cinnamate	PP	1467	-	-	-	-
47	β-Chamigrene	SH	1477	-	-	0.39	-
48	*ar*-Curcumene	SH	1480	-	-	-	-
49	γ-Curcumene	SH	1482	-	-	-	-
50	Germacrene D	SH	1485	-	-	-	-
51	β-Selinene	SH	1490	-	-	8.31	
52	Drim-8(12)-ene	SH	1491	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
53	α-Zingiberene	SH	1493	-	-	-	-	-
54	Valencene	SH	1496	-	-	-	-	-
55	α-Selinene	SH	1498	-	-	-	-	-
56	Pentadecane	SH	1500	0.96	8.13	-	9.64	-
57	Bicyclogermacrene	SH	1500	-	-	0.65	-	3.31
58	β-Bisabolene	SH	1505	-	-	-	-	-
59	*E*-*E*-α-Farnesene	SH	1505	-	-	-	-	-
60	γ-Cadinene	SH	1513	1.04	0.37	0.63	0.35	0.77
61	β-Curcumeme	SH	1515	-	-	-	-	-
62	7-*epi*-α-Selinene	SH	1520	-	-	-	-	-
63	β-Sesquiphellandrene	SH	1522	-	-	-	-	-
64	δ-Cadinene	SH	1523	0.94	0.26	1.05	-	3.02
65	*E*-γ- Bisabolene	SH	1531	-	-	-	-	-
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	0.51	0.23	-	-	-
67	Germacrene B	SH	1561	0.44	0.39	1.16	0.55	0.27
68	*E*-Nerolidol	OS	1563	-	-	-	-	-
69	Caryophyllene oxide	OS	1583	1.10	-	13.06	0.11	1.11
70	*ar*-Tumerol	OS	1583	-	-	-	-	-
71	Carotol	OS	1594	-	-	-	-	-
72	Guaiol	OS	1600	2.16	-	-	-	-
73	Humulene epoxide II	OS	1608	1.39	-	1.78	-	-
74	Helifolen-12-al C (anti-syn-syn-)	OS	1620	-	-	-	-	-
75	1-*epi*-Cubenol	OS	1628	0.33	0.30	-	-	-
76	γ-Eudesmol	OS	1632	1.89	-	-	-	-
77	*epi*-α-Cadinol	OS	1640	-	-	-	-	1.78
78	*epi*-α-Murrolol	OS	1642	-	-	1.47	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
53	α-Zingiberene	SH	1493	-	-	6.61	3.17
54	Valencene	SH	1496	0.47	2.03	-	-
55	α-Selinene	SH	1498	-	-	-	-
56	Pentadecane	SH	1500	2.39	-	-	-
57	Bicyclogermacrene	SH	1500	-	-	-	-
58	β-Bisabolene	SH	1505	-	-	1.61	0.57
59	*E-E*-α-Farnesene	SH	1505	-	-	-	-
60	γ-Cadinene	SH	1513	1.45	0.43	-	-
61	β-Curcumeme	SH	1515	-	-	-	-
62	7-*epi*-α-Selinene	SH	1520	-	-	-	-
63	β-Sesquiphellandrene	SH	1522	-	-	11.14	3.68
64	δ-Cadinene	SH	1523	-	-	-	-
65	*E*-γ- Bisabolene	SH	1531	-	-	-	-
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	-	-	-	-
67	Germacrene B	SH	1561	0.06	0.14	-	-
68	*E*-Nerolidol	OS	1563	-	-	-	-
69	Caryophyllene oxide	OS	1583	-	-	-	-
70	*ar*-Tumerol	OS	1583	-	-	0.58	0.75
71	Carotol	OS	1594	-	-	0.20	1.56
72	Guaiol	OS	1600	-	-	-	-
73	Humulene epoxide II	OS	1608	-	-	-	-
74	Helifolen-12-al C (anti-syn-syn-)	OS	1620	-	-	1.42	1.64
75	1-*epi*-Cubenol	OS	1628	0.67	0.32	-	-
76	γ-Eudesmol	OS	1632	1.29	2.24	-	-
77	*epi*-α-Cadinol	OS	1640	-	-	-	-
78	*epi*-α-Murrolol	OS	1642	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
53	α-Zingiberene	SH	1493	-	-	-	-
54	Valencene	SH	1496	-	-	-	-
55	α-Selinene	SH	1498	-	-	8.11	-
56	Pentadecane	SH	1500	-	-	-	-
57	Bicyclogermacrene	SH	1500	-	-	-	1.45
58	β-Bisabolene	SH	1505	-	-	15.30	-
59	*E*-*E*-α-Farnesene	SH	1505	-	-	-	0.50
60	γ-Cadinene	SH	1513	-	-	-	-
61	β-Curcumeme	SH	1515	-	0.19	-	-
62	7-*epi*-α-Selinene	SH	1520	-	-	0.67	-
63	β-Sesquiphellandrene	SH	1522	2.46	1.45	1.85	-
64	δ-Cadinene	SH	1523	-	-	-	0.84
65	*E*-γ- Bisabolene	SH	1531	-	-	0.32	-
66	*cis*-Muurol-5-en-4-β-ol	OS	1551	-	-	-	-
67	Germacrene B	SH	1561	-	0.11	7.39	-
68	*E*-Nerolidol	OS	1563	-	-	-	1.25
69	Caryophyllene oxide	OS	1583	-	-	-	-
70	*ar*-Tumerol	OS	1583	-	-	-	-
71	Carotol	OS	1594	-	-	-	-
72	Guaiol	OS	1600	-	-	-	-
73	Humulene epoxide II	OS	1608	-	-	-	-
74	Helifolen-12-al C (anti-syn-syn-)	OS	1620	-	-	-	-
75	1-*epi*-Cubenol	OS	1628	-	-	-	-
76	γ-Eudesmol	OS	1632	-	-	-	-
77	*epi*-α-Cadinol	OS	1640	-	-	-	-
78	*epi*-α-Murrolol	OS	1642	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
79	α-Muurolol	OS	1646	-	-	-	-	1.85
80	β-Eudesmol	OS	1650	8.18	-	-	0.18	-
81	α-Cadinol	OS	1654	-	-	2.04	-	2.91
82	Selin-11-en-4-α-ol	OS	1659	-	-	-	-	-
83	*neo*-Intermedeol	OS	1660	-	-	-	-	-
84	*ar*-Turmerone	OS	1669	-	-	-	-	-
85	Germacrone	OS	1693	-	-	4.85	-	-
86	(*Z*)-γ-Atlantone	OS	1694	-	-	-	-	-
87	Heptadecane	Other	1700	-	0.46	-	-	-
88	1,3,3-Trimethyl-2-oxabicyclo[2.2.2] octan-6-ol, acetate	OM	1700	-	-	-	-	-
89	*6R,7R*-Bisabolone	OS	1742	-	-	-	-	-
90	2*E*,6*E*-Farnesol	OS	1743	-	-	-	-	-
91	Benzyl benzoate	PP	1760	-	-	-	-	-
92	*E*-α-Atlantone	OS	1778	-	-	-	-	-
93	Octadecane	Other	1800	-	-	-	1.34	-
94	2*E*,6*E*-Farnesyl acetate	OS	1846	-	-	-	-	-
95	Benzyl salicylate	PP	1865	-	-	-	-	-
96	Pimaradiene	DH	1949	13.37	0.15	1.42	5.97	-
97	Sandaracopimara-8(14),15-diene	DH	1969	-	-	-	5.57	-
98	*epi*-13-Manool	OD	2060	-	-	22.63	-	0.48
99	Curlone	OS	-	-	-	-	-	-
100	Methyl 3,4-dimethoxycinnamate	PP	-	-	-	-	-	-
101	5-Cyclohexadecen-1-one	PP	-	-	1.14	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
79	α-Muurolol	OS	1646	-	-	-	-
80	β-Eudesmol	OS	1650	1.40	1.38	-	-
81	α-Cadinol	OS	1654	0.93	-	-	-
82	Selin-11-en-4-α-ol	OS	1659	-	2.82	-	-
83	*neo*-Intermedeol	OS	1660	-	-	-	-
84	*ar*-Turmerone	OS	1669	-	-	17.63	17.89
85	Germacrone	OS	1693	-	-	-	-
86	(*Z*)-γ-Atlantone	OS	1694	-	-	23.93	33.13
87	Heptadecane	Other	1700	-	-	-	-
88	1,3,3-Trimethyl-2-oxabicyclo[2.2.2] octan-6-ol, acetate	OM	1700	-	-	-	-
89	*6R,7R*-Bisabolone	OS	1742	-	-	0.26	1.13
90	2*E*,6*E*-Farnesol	OS	1743	-	-	-	-
91	Benzyl benzoate	PP	1760	39.41	35.96	-	-
92	*E*-α-Atlantone	OS	1778	-	-	0.30	3.84
93	Octadecane	Other	1800	-	-	-	-
94	2*E*,6*E*-Farnesyl acetate	OS	1846	-	-	-	-
95	Benzyl salicylate	PP	1865	2.07	4.01	-	-
96	Pimaradiene	DH	1949	0.42	1.66	-	-
97	Sandaracopimara-8(14),15-diene	DH	1969	-	-	-	-
98	*epi*-13-Manool	OD	2060	-	-	-	-
99	Curlone	OS	-	-	-	10.59	15.72
100	Methyl 3,4-dimethoxycinnamate	PP	-	-	-	-	-
101	5-Cyclohexadecen-1-one	PP	-	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
79	α-Muurolol	OS	1646	-	-	-	-
80	β-Eudesmol	OS	1650	-	-	-	-
81	α-Cadinol	OS	1654	-	-	-	-
82	Selin-11-en-4-α-ol	OS	1659	-	-	-	-
83	*neo*-Intermedeol	OS	1660	-	-	2.18	-
84	*ar*-Turmerone	OS	1669	-	-	-	-
85	Germacrone	OS	1693	-	-	-	-
86	(*Z*)-γ-Atlantone	OS	1694	-	-	-	-
87	Heptadecane	Other	1700	-	-	-	-
88	1,3,3-Trimethyl-2-oxabicyclo[2.2.2] octan-6-ol, acetate	OM	1700	-	-	0.95	-
89	*6R,7R*-Bisabolone	OS	1742	-	-	-	-
90	2*E*,6*E*-Farnesol	OS	1743	-	-	0.28	-
91	Benzyl benzoate	PP	1760	-	-	-	-
92	*E*-α-Atlantone	OS	1778	-	-	-	-
93	Octadecane	Other	1800	-	-	-	-
94	2*E*,6*E*-Farnesyl acetate	OS	1846	-	-	2.09	-
95	Benzyl salicylate	PP	1865	-	-	-	-
96	Pimaradiene	DH	1949	-	-	-	-
97	Sandaracopimara-8(14),15-diene	DH	1969	-	-	-	-
98	*epi*-13-Manool	OD	2060	-	-	-	-
99	Curlone	OS	-	-	-	-	-
100	Methyl 3,4-dimethoxycinnamate	PP	-	1.09	0.89	-	-
101	5-Cyclohexadecen-1-one	PP	-	-	-	-	-

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)				
				KG 1	KG 2	KL 5	KM 3	KP 2
102	3-(4-Methoxyphenyl)-2-propenoic acid, ethyl ester	Other	-	1.91	46.59	4.90	45.92	0.64
103	8-Heptadecene	Other	-	-	-	-	-	-
104	Hydroxy-α-terpenyl acetate	Other	-	-	-	-	-	-
105	(*E*)-1-(3,4)-dimethoxy phenylbutadiene	Other	-	-	-	-	-	-
106	(*Z*)-9,17-Octadecadienal	Other	-	-	-	-	-	0.96
	Compound class							
	Terpenoids							
	- Monoterpene hyfrocarbons (MH)			36.85	7.22	16.77	6.07	38.18
	- Oxygenated monoterpenes (OM)			24.03	2.17	8.30	2.96	8.30
	- Sesquiterpene hydrocarbons (SH)			7.95	9.99	13.7	12.14	40.95
	- Oxygenated sesquiterpenes (OS)			15.56	0.53	23.20	0.29	7.65
	Phenylpropanoids			0.33	32.89	3.43	19.12	0.00
	Others			15.28	47.20	28.95	58.80	2.08
	Total identified			100.00	100.00	94.35	99.38	97.16
	% Yield (V/W)			0.24	0.32	0.13	0.24	0.28

[a] MH: Monoterpene hyfrocarbons; OM: Oxygenated monoterpenes; SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes; PP: Phenylpropanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

–: not detected

Abbreviations of the plant samples according to the codes used in Table 10.

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				KR 2	KR 3	LO 1	LO 2
102	3-(4-Methoxyphenyl)-2-propenoic acid, ethyl ester	Other	-	-	-	-	-
103	8-Heptadecene	Other	-	-	-	-	-
104	Hydroxy-α-terpenyl acetate	Other	-	-	-	-	-
105	(*E*)-1-(3,4)-dimethoxy phenylbutadiene	Other	-	-	-	-	-
106	(*Z*)-9,17-Octadecadienal	Other	-	-	-	-	-
	Compound class						
	Terpenoids						
	- Monoterpene hyfrocarbons (MH)			32.95	31.86	10.53	1.90
	- Oxygenated monoterpenes (OM)			12.45	8.37	1.79	0.35
	- Sesquiterpene hydrocarbons (SH)			7.32	11.37	32.76	11.03
	- Oxygenated sesquiterpenes (OS)			4.29	6.76	54.91	75.66
	Phenylpropanoids			41.48	39.97	0.00	0.00
	Others			0.42	1.66	0.00	0.00
	Total identified			98.91	99.99	99.99	88.94
	% Yield (V/W)			0.36	0.40	0.07	0.16

[a] MH: Monoterpene hyfrocarbons; OM: Oxygenated monoterpenes; SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes; PP: Phenylpropanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

–: not detected

Abbreviations of the plant samples according to the codes used in Table 10.

Table 25. Essential oil components of *Kaempferia* and outgroup plants (cont.)

No.	Compound	Class[a]	KI[b]	Content (%)			
				ZM 1	ZM 2	AG	CH
102	3-(4-Methoxyphenyl)-2-propenoic acid, ethyl ester	Other	-	-	-	-	-
103	8-Heptadecene	Other	-	-	-	0.96	-
104	Hydroxy-α-terpenyl acetate	Other	-	-	-	11.48	-
105	(*E*)-1-(3,4)-dimethoxy phenylbutadiene	Other	-	52.38	45.97	-	-
106	(*Z*)-9,17-Octadecadienal	Other	-	-	-	-	-
	Compound class						
	Terpenoids						
	- Monoterpene hyfrocarbons (MH)			21.75	32.89	3.23	5.54
	- Oxygenated monoterpenes (OM)			12.69	11.85	17.21	86.71
	- Sesquiterpene hydrocarbons (SH)			2.46	1.75	62.54	6.23
	- Oxygenated sesquiterpenes (OS)			0.00	0.00	4.55	1.25
	Phenylpropanoids			1.09	0.89	0.00	0.00
	Others			52.38	45.97	12.44	0.00
	Total identified			90.37	93.35	99.97	99.73
	% Yield (V/W)			1.40	1.20	0.90	1.10

[a] MH: Monoterpene hyfrocarbons; OM: Oxygenated monoterpenes;
SH: Sesquiterpene hydrocarbons; OS: Oxygenated sesquiterpenes;
PP: Phenylpropanoids

[b] KI: Retention indices determined relative to n-alkanes (C6–C24) on a ZP-5 GC column.

–: not detected

Abbreviations of the plant samples according to the codes used in Table 10.

APPENDIX C

Morphological characters of *Curcuma* spp.

Figure 32. Morphological characteristics of *C. aeruginosa* Roxb.

Figure 33. Morphological characteristics of *C. albicoma* S.Q. Tong

Figure 34. Morphological characteristics of *C. amada* Roscoe

Figure 35. Morphological characteristics of *C. angustifolia* Roxb.

Figure 36. Morphological characteristics of *C. aromatica* Salisb.

Figure 37. Morphological characteristics of *C. comosa* Roxb.

Figure 38. Morphological characteristics of *C. longa* L.

Figure 39. Morphological characteristics of *C. mangga* Valeton & Zijp

Figure 40. Morphological characteristics of *C. parviflora* Wall.

Figure 41. Morphological characteristics of *C. petiolata* Roxb.

Figure 42. Morphological characteristics of *C. rubrobracteata* Skornickova

Figure 43. Morphological characteristics of *C. sessilis* Gage

Figure 44. Morphological characteristics of *C. zedoaria* (Berg) Roscoe

Figure 45. Morphological characteristics of *Curcuma* sp. 1 (ว่านม้าห้อมัง)

Figure 46. Morphological characteristics of *Curcuma* sp. 2 (ว่านคัณฑมาลา)

Figure 47. Morphological characteristics of *Curcuma* sp. 3 (ว่านขมิ้นดำ) (ณรงค์ศักดิ์ ค้านอธรรม, 2551)

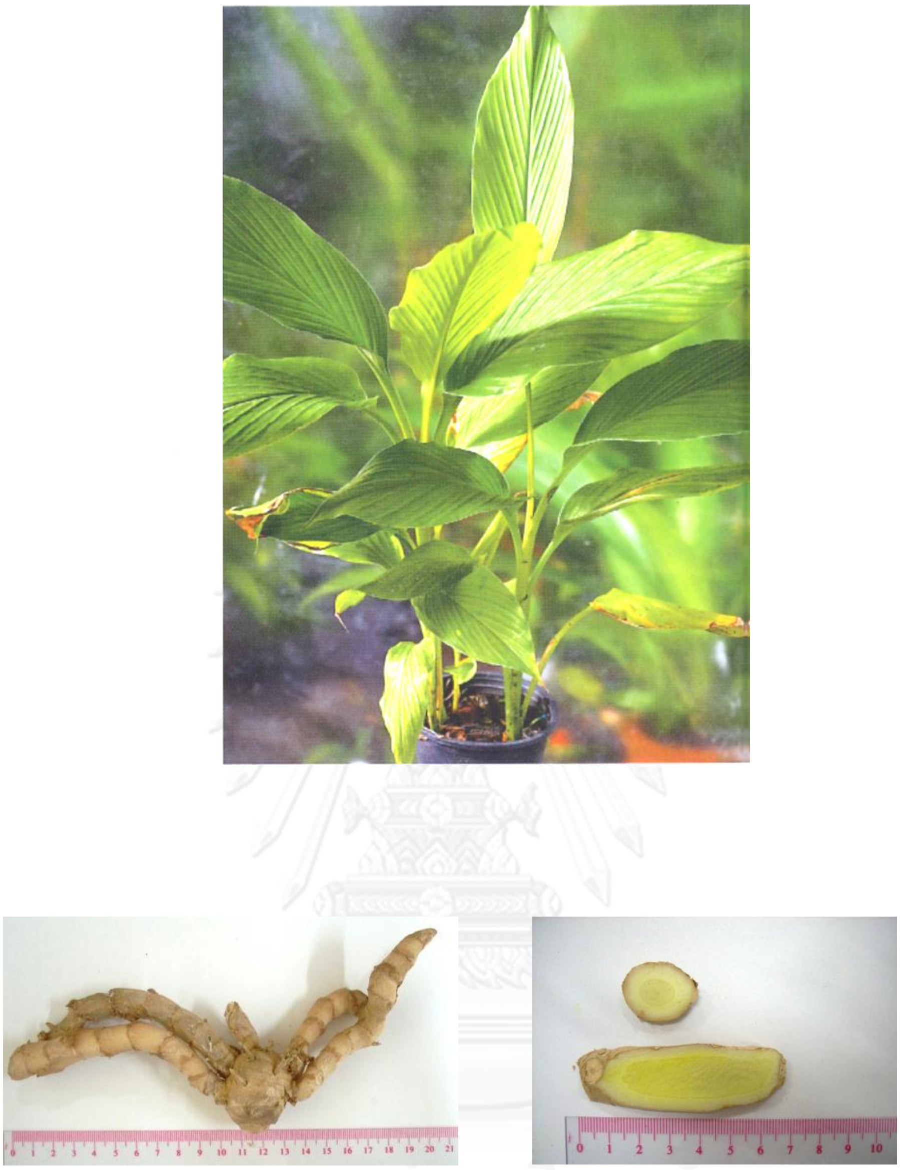

Figure 48. Morphological characteristics of *Curcuma* sp. 4 (ว่านม้าขาว) (ณรงค์ศักดิ์ ค้านอธรรม, 2551)

Figure 49. Morphological characteristics of *Curcuma* sp. 5 (ว่านม้าเหลือง)

Figure 50. Morphological characteristics of *Curcuma* sp. 6 (ว่านเอ็นเหลือง)

Figure 51. Morphological characteristics of *Curcuma* sp. 7 (ว่านมหาจักรพรรดิ)

Figure 52. Morphological characteristics of *Curcuma* sp. 8 (ว่านม้าห้อ)

Figure 53. Morphological characteristics of *Curcuma* sp. 9 (ว่านมหาอุดม)

APPENDIX D

Morphological characters of *Kaempferia* spp.

Figure 54. Morphological characteristics of *Kaempferia galanga* L.

Figure 55. Morphological characteristics of *K. larsenii* Sirirugsa

Figure 56. Morphological characteristics of *K. marginata* Carey

Figure 57. Morphological characteristics of *K. rotunda* L.

Figure 58. Morphological characteristics of *K. parviflora* Wall. ex Baker

VITA

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Publication

Theanphong, O., Thanakijcharoenpath, W., Ruangrungsi, N., Palanuvej, C and Rungsihirunrat, K. 2013. Phylogenetic relationship of selected Kaempferia plants in Thailand based on RAPD marker. Res. J. Pharm., Biol. Chem. Sci. 4: 1362-1369.

Poster presentation

Theanphong O., Palanuvej, C., Ruangrungsi, N., Rungsihirunrat, K. and Thanakijcharoenpath, W. 20134. Essential oil Compositions of Kaempferia larsenii Sirirugsa and Kaempferia marginata Carey Rhizomes from Thailand. Pure and Applied Chemistry International Conference 2014 (PACCON 2014), January, 8-10, 2014,Khon Kaen, Thailand.