Chemical Constituents and Evaluation of Cytotoxic Activities of Curcuma zedoaria (Christm.) Roscoe Oils from Malaysia and Indonesia

Devi Rosmy Syamsir, Yasodha Sivasothy, Hazrina Hazni, Sri Nurestri Abdul Malek, Noor Hasima Nagoor, Halijah Ibrahim & Khalijah Awang

To cite this article: Devi Rosmy Syamsir, Yasodha Sivasothy, Hazrina Hazni, Sri Nurestri Abdul Malek, Noor Hasima Nagoor, Halijah Ibrahim & Khalijah Awang (2017): Chemical Constituents and Evaluation of Cytotoxic Activities of Curcuma zedoaria (Christm.) Roscoe Oils from Malaysia and Indonesia, Journal of Essential Oil Bearing Plants, DOI: 10.1080/0972060X.2017.1362997

To link to this article: http://dx.doi.org/10.1080/0972060X.2017.1362997

Published online: 29 Aug 2017.

Submit your article to this journal

Article views: 1

View related articles

View Crossmark data
Chemical Constituents and Evaluation of Cytotoxic Activities of Curcuma zedoaria (Christm.) Roscoe Oils from Malaysia and Indonesia

Devi Rosmy Syamsir 1, Yasodha Sivasothy 1, Hazrina Hazri 2, Sri Nurestri Abdul Malek 3, Noor Hasima Nagoor 3, 4, Halijah Ibrahim 3, Khalijah Awang 1, 2 *

1 Department of Chemistry, Faculty of Science, University of Malaya, 50603, Kuala Lumpur, Malaysia
2 Center of Natural Products & Drug Discovery (CENAR), Department of Chemistry, Faculty of Science, University of Malaya, 50603, Kuala Lumpur, Malaysia
3 Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603, Kuala Lumpur, Malaysia
4 Centre for Research in Biotechnology for Agriculture (CEBAR), University of Malaya, 50603 Kuala Lumpur, Malaysia

Received 13 July 2016; accepted in revised form 20 March 2017

Abstract: The essential oils obtained by hydrodistillation of the rhizomes of Curcuma zedoaria (Christm.) Roscoe collected from Malaysia and Indonesia were analyzed by capillary GC and GC-MS. Both the oils were principally sesquiterpenic in nature and were characterized by zerumbone (17.14 % and 12.07 %, respectively). Camphor (17.56 % and 19.69 %, respectively) was also abundant in both oils. The cytotoxic effects of both the oils on human breast (MCF-7 and MDA-MB 231), lung (A549 and SK-LU-1) and cervical (HeLa S3 and SiHa) cancer cell lines were examined using the MTT assay. The Malaysian C. zedoaria rhizome oil was found to be cytotoxic against the MCF-7, SK-LU-1, HeLa S3 and SiHa cell lines, with IC_{50} values being less than 10 μg/mL. Our findings support the use of the Malaysian C. zedoaria rhizome oil as a potential chemopreventive agent towards a wide spectrum of cancer in particular cervical cancer.

Key words: Curcuma zedoaria (Christm.) Roscoe, essential oil, cytotoxic effects, MTT assay.

Introduction

During the past few decades, cancer has emerged as one of the most alarming diseases throughout the world. It is a multifactorial syndrome characterized by uncontrolled cellular growth, local tissue invasion and distant metastasis of abnormal cells 1. An increasing resistance of mammalian tumour cells to chemotherapy and the severe side effects of this conservative medication have potentiated the search for new, alternative anticancer agents from natural sources which are relatively less toxic and ingestive in nature. In the last few decades, the use of medicinal plants as alternative therapy for many types of cancer in urban areas has been increasing worldwide 1-2. The pursuit for new drugs that display activity against several types of cancer has become one of the most interesting subjects in the field of natural product research 3. Plant derived compounds such as vincristine, vinblastine, paclitaxel, doxorubicin, toposcian, irinotecan, flavopiridol, acracycline, brucenatian and thalicarpin have been successfully employed in the treatment of cancer 4.
Essential oils (EO) are reputed for their ethnomedical, culinary and cosmeceutical applications. EOs have been known to demonstrate pharmacological effects such as antiviral, insecticidal, anti-mycotic, anti-parasitic, anti-leishmanial, anti-inflammatory, antioxidant, cytotoxic and they are biocides against a broad range of organisms such as bacteria, fungi, viruses and protozoas. The lipophilic nature of EOs enables them to cross the cell membrane and reach the cell interior. Therefore, extensive research is being conducted to explore their anticancer role. Several studies have reported the anticancer potential of EOs against breast, brain, colon, lung, liver, mouth and prostate cancers. Free radical scavenging, the induction of apoptosis, cell cycle arrest and the inhibition of tumour metastasis are among the few mechanisms proposed to be responsible for the anticancer activities of EOs. Furthermore, these agents have shown synergistic effects when combined with each other or with standard chemotherapy.

Curcuma zedoaria (Christm.) Roscoe (Zingiberaceae), locally known as temu putih (white turmeric) in Malaysia and Indonesia, is widely used as an indigenous medicine in South East Asia, China, Vietnam and India. The rhizome is used to treat menstrual disorder, vomiting, dyspepsia, cancer, expectorant, carminative, cold, cough, fever and many other ailments. In addition to this, temu putih is also used in the preparation of Malay traditional medicine, consumed either on its own or as a mixture with other herbs to improve health as well as during postpartum confinement. C. zedoaria has been reported to have antibacterial activity due to the claim that the rhizomes have been used for the treatment of bacterial and fungal infections. Moreover, studies have also been carried out to determine the bioactivities of C. zedoaria oil such as antioxidant, anticancer activity against non-small lung carcinoma cell, anti-angiogenesis effects and others. The volatile constituents of C. zedoaria from India, China, Japan, Taiwan and Indonesia have been the subject of several previous studies. However, there are no reports on the oil composition of this species cultivated in Malaysia. The objectives of the present study were to examine in detail, the constituents of the rhizome oils of C. zedoaria collected from Malaysia and Indonesia, and to compare the results obtained for the Indonesian C. zedoaria oil with those reported for the same herb by Retnowati et al. The cytotoxicity effect of these oils against breast, lung and cervical cancer cell lines were also evaluated.

Materials and methods

Plant material

Fresh rhizomes of C. zedoaria were collected from two different countries; Temerloh, Pahang, Malaysia (N 3° 16’ 12.00", E 102° 15’ 0.0") and Tawangmangu, Solo Province, Indonesia (S 7° 36’ 58.9", E 111° 02’ 58’). Both samples were identified by Prof. Dr. Halijah Ibrahim and the voucher specimens (KLU 49446 and KLU 49447, respectively) have been deposited at the Herbarium of Rimba Ilmu Botanical Garden, University of Malaya, Kuala Lumpur.

Extraction and the yield of essential oil

Dried and powdered rhizomes of Malaysian (200 g) and Indonesian (200 g) C. zedoaria were separately hydrodistilled for 4 h in an all glass apparatus similar to that described in the British Pharmacopoeia, using pentane as the collecting solvent. The solvent was carefully removed using a gentle stream of nitrogen gas, yielding yellow aromatic oils in each case. Each C. zedoaria sample was extracted in three independent experiments. Determination of the EO yield was based on the mean values ± SD calculated for each C. zedoaria sample. The oil yields (w/w) were 0.14 ± 0.13 % (Malaysian C. zedoaria) and 0.39 ± 0.16 % (Indonesian C. zedoaria), all on dry weight basis.

Gas chromatography and Gas chromatography/Mass spectrometry (GC-MS) analysis

GC analysis was carried out using an Agilent 7890A GC System (Agilent Technologies, Santa Clara, CA, USA) equipped with a FID and an Agilent 7683B Series auto-injector. A HP-5MS UI (30 m x 0.25 mm id, film thickness 0.25 μm) fused-silica capillary column (J.W. Scientific) was employed. Analysis was performed in triplicates.
using the following operating conditions: initial oven temperature, 70°C for 10 minutes, then to 250°C at 4°C minutes and held for 15 minutes; injector and detector temperatures, 275°C; carrier gas, 1.0 mL/minutes N₂; injection volume, 0.2 μL; split ratio 20:1. The quantitative data were obtained electronically from FID area percent without the use of correction factors.

GC-MS analysis was performed using an Agilent 6890N Network GC System equipped with an Agilent 7683B Series auto-injector, coupled to a 5975 Inert Mass Selective Detector and the same capillary GC conditions as described above. The carrier gas used was He at 1.0 mL minutes. The significant MS operating parameters were ionisation voltage, 70 eV; ion source temperature 230°C; mass range 40-600 u.

The constituents were identified by comparison of their mass spectra with those of authentic compounds or with reference spectra in the computer library (NIST 05), and confirmed by comparison of retention indices which were determined in relation to a homologous series of n-alkanes (C₆-C₃₀) with those of authentic compounds, or data in the literature 7, 20-21.

**MTT cell viability assay**

The Malaysian and Indonesian C. zedoaria oils were evaluated for their cytotoxic effects against human cancer cell lines; breast (MCF-7 and MDA-MB 231), lung (A549 and SK-LU-1) and cervical (Hela S3 and SiHa) by measuring the 3-[(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) dye metabolism. In order to compare the cytotoxic effects and the selectivity obtained on cancer cells after the treatment with the essential oils, treatment on normal human lung fibroblast cells (MRC-5) was also carried out. All samples were dissolved in DMSO (stock concentration of 10 mg/mL). Initially, 1 x 10⁶ cells per 100 μL / well were seeded in a 96’s well plate. The cells were plated in triplicates. After 24 hours of incubation, the cells were treated with the respective essential oils at various concentrations (10, 20, 30, 40, 50 and 60 μg/mL) and incubated at 37°C for another 24 hours. Doxorubicin was used as the positive control.

30 μL of the MTT reagent (5 mg/mL) was added into each well and incubated for 45 minutes. After incubation, the reagent was removed and 200 μL of DMSO was added to dissolve the purple formazan precipitates and a microtiter plate reader (Tecan Sunrise®, Switzerland) was used to detect the absorbance / reference at 570 nm and 650 nm. The percentage of cell viability of the test samples was calculated according to the given formula whereby NC (refers to the number of cells):

\[
\% \text{ Cell viability} = \frac{\text{NC}_\text{untreated} - \left[\left(\text{NC}_\text{DMSO} - \text{NC}_\text{sample}\right) / \text{NC}_\text{untreated}\right]}{\times 100}
\]

The potency of the essential oils in inhibiting the growth of the cancer cells at 50 % was expressed as IC₅₀ (inhibition concentration at 50 %). The selectivity indices (SI) is the ratio between the IC₅₀ values of the essential oil when tested against normal cell line to the IC₅₀ values of the essential oil when tested against cancerous cell line. SI values indicate the selectivity of the oil to the cell lines tested. The samples with SI values greater than three are considered to have a high selectivity towards the cancer cells 22-23.

**Statistical analysis**

Each experiment was performed in triplicate. Data from all of the experiments are presented as mean ± S.D. One-way ANOVA, p-value, paired student t-test, were used to determine the statistical significance of results with \( p \leq 0.05 \) and \( p \leq 0.01 \).

**Results and discussion**

**Composition of the essential oils**

Table 1 and Figure 1 lists the constituents identified in the rhizome oils of the Malaysian and Indonesian Curcuma zedoaria, the relative GC peak areas of these constituents and their experimental retention indices on the HP-5MS UI column. Figure 2 showed the gas chromatograms of Malaysian and Indonesian C. zedoaria oils.

Twenty-one compounds were identified in the rhizome oil of Malaysian C. zedoaria. The thirteen sesquiterpenoids clearly dominated the volatile profile, contributing 68.0 %. This figure was largely due to zerumbone (17.2 % ± 0.12), curzerenone (10.2 % ± 0.06), isovelleral (6.6 % ± 0.52), ar-turmerone (6.1 % ± 0.51) and β-
Table 1. Constituents identified in the rhizome oils of the Malaysian and Indonesian *C. zedoaria*

<table>
<thead>
<tr>
<th>Compounds</th>
<th>RI</th>
<th>Malaysian C. zedoaria oil</th>
<th>Area (%) (^{ab})</th>
<th>Indonesian C. zedoaria oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camphene</td>
<td>960</td>
<td>1.0 ± 0.07</td>
<td>2.5 ± 0.33</td>
<td></td>
</tr>
<tr>
<td>β-Pinene</td>
<td>989</td>
<td>t</td>
<td>0.6 ± 0.41</td>
<td></td>
</tr>
<tr>
<td>1,8-Cineole</td>
<td>1044</td>
<td>1.1 ± 0.08</td>
<td>8.4 ± 1.20</td>
<td></td>
</tr>
<tr>
<td>Camphor</td>
<td>1155</td>
<td>17.6 ± 0.19</td>
<td>19.7 ± 3.05</td>
<td></td>
</tr>
<tr>
<td>Isoborneol</td>
<td>1167</td>
<td>5.1 ± 0.03</td>
<td>5.1 ± 0.69</td>
<td></td>
</tr>
<tr>
<td>Bornol</td>
<td>1176</td>
<td>2.0 ± 0.01</td>
<td>2.5 ± 0.49</td>
<td></td>
</tr>
<tr>
<td>α-Terpineol</td>
<td>1204</td>
<td>t</td>
<td>1.3 ± 0.24</td>
<td></td>
</tr>
<tr>
<td>β-Elemene</td>
<td>1402</td>
<td>3.9 ± 0.01</td>
<td>t</td>
<td></td>
</tr>
<tr>
<td>α-Curcumene</td>
<td>1494</td>
<td>3.7 ± 0.55</td>
<td>3.9 ± 1.10</td>
<td></td>
</tr>
<tr>
<td>α-Selene</td>
<td>1501</td>
<td>t</td>
<td>1.5 ± 0.27</td>
<td></td>
</tr>
<tr>
<td>Curzerene</td>
<td>1509</td>
<td>1.7 ± 0.17</td>
<td>t</td>
<td></td>
</tr>
<tr>
<td>β-Caryophyllene oxide</td>
<td>1599</td>
<td>t</td>
<td>2.3 ± 0.33</td>
<td></td>
</tr>
<tr>
<td>Curzerenone</td>
<td>1620</td>
<td>10.2 ± 0.06</td>
<td>7.4 ± 1.25</td>
<td></td>
</tr>
<tr>
<td>Spathulenol</td>
<td>1645</td>
<td>1.8 ± 0.28</td>
<td>5.0 ± 0.65</td>
<td></td>
</tr>
<tr>
<td>β-Eudesmol</td>
<td>1668</td>
<td>5.4 ± 0.03</td>
<td>5.6 ± 1.12</td>
<td></td>
</tr>
<tr>
<td>ar-Turmerone</td>
<td>1686</td>
<td>6.1 ± 0.51</td>
<td>2.0 ± 0.40</td>
<td></td>
</tr>
<tr>
<td>Germanacre</td>
<td>1713</td>
<td>3.0 ± 0.09</td>
<td>4.4 ± 0.08</td>
<td></td>
</tr>
<tr>
<td>Zerumbone</td>
<td>1752</td>
<td>17.2 ± 0.12</td>
<td>12.1 ± 1.28</td>
<td></td>
</tr>
<tr>
<td>α-Cuparenol</td>
<td>1765</td>
<td>4.1 ± 0.75</td>
<td>8.9 ± 1.53</td>
<td></td>
</tr>
<tr>
<td>Benzyl benzoate</td>
<td>1780</td>
<td>4.3 ± 0.09</td>
<td>t</td>
<td></td>
</tr>
<tr>
<td>Isovelleral</td>
<td>1810</td>
<td>6.6 ± 0.52</td>
<td>2.5 ± 0.74</td>
<td></td>
</tr>
<tr>
<td>Monoterpene hydrocarbons</td>
<td></td>
<td>1.0 %</td>
<td>3.1 %</td>
<td></td>
</tr>
<tr>
<td>Oxygenated monoterpenes</td>
<td></td>
<td>25.8 %</td>
<td>37.0 %</td>
<td></td>
</tr>
<tr>
<td>Sesquiterpene hydrocarbons</td>
<td></td>
<td>7.6 %</td>
<td>5.4 %</td>
<td></td>
</tr>
<tr>
<td>Oxygenated sesquiterpenes</td>
<td></td>
<td>56.1 %</td>
<td>50.2 %</td>
<td></td>
</tr>
<tr>
<td>Non-terpenes</td>
<td></td>
<td>4.3 %</td>
<td>t</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>94.8 %</td>
<td>95.7 %</td>
<td></td>
</tr>
</tbody>
</table>

\(^{a}\) Percentage of total FID area obtained on HP-5MS UI column.
\(^{b}\) Expressed as the average of three independent experiments ± S. D. (\(n = 3\)).

\(t\) refers to trace compounds which are present at a composition less than 0.05 %.

eudesmol (5.4 ± 0.03), the first being the most abundant component in the oil. Seven monoterpenoids (26.8 %) were identified, among which only camphor (17.6 ± 0.19) and isoborneol (5.0 % ± 0.03) were detected at notable concentrations.

Analysis of the Indonesian *C. zedoaria* oil resulted in the identification of twenty-one constituents. The oil was characterized by thirteen sesquiterpenoids (55.6 %) and seven monoterpenoids (40.1 %). Quantitatively significant constituents included camphor (19.7 % ± 3.05), zerumbone (12.1 % ± 1.28), α-cuparenol (8.9 % ± 1.53), 1,8-cineole (8.4 % ± 1.20), curzerenone (7.4 % ± 1.25), β-eudesmol (5.6 % ± 1.12), isoborneol (5.1 % ± 0.69) and spathulenol (5.0 % ± 0.65). A previous investigation of the Indonesian *C. zedoaria* rhizome oil in 2014 revealed a high content of monoterpenoids (73.9 %) \(^{19}\). Retnowati and co-workers reported camphor (49.1 %) and iso-
Fig. 1. Chemical structure of constituents in the rhizome oils of Malaysian and Indonesian *Curcuma zedoaria*
Fig 2. Gas chromatograms of Malaysian and Indonesian *C. zedoaria* oils
borneol (12.7 %) as the major components. They did not detect zerumbone, curzerenone, α-cuparenol, spathulenol and β-eudesmol but found furanodienone (3.5 %) and furanodiene (3.6 %). With regard to 1,8-cineole, one of the constituents that characterized the oil in the present study was only detected at a concentration of 3.4 % in the previous investigation. These marked differences in the composition of the rhizome oil determined by Retnowati, et. al., 2014 from that of the current study could be attributed to the source, cultivation, vegetative stage and growing season of the plant under investigation 7, 20.

The major component(s) which characterized the rhizome oils of C. zedoaria native to a number of phytogeographical locations in Asia showed variation. Curzerenone, epi-curzerenone or 1,8-cineole have been reported to characterize the rhizomes of Indian C. zedoaria 15-17 while epi-curzerenone or furanogeremonone were determined to be the chemical markers of the species native to China 12,18. Curcumenol and dehydrocurdione on the other hand were the major oil components of Taiwanese and Japanese C. zedoaria 18.

Cytotoxic assay

Table 2 summarizes the IC_{50} values for the cancer and normal cell lines treated with the Malaysian and Indonesian C. zedoaria oils. Results indicated that the IC_{50} values for the treated cancer cell lines were in the range of 6.4 μg/mL - 22 μg/mL and 11.5 μg/mL - 21.6 μg/mL for the Malaysian and Indonesian C. zedoaria oils, respectively. As for the normal cell lines MRC-5, the IC_{50} values were 25.7 μg/mL and 27.0 μg/mL, respectively. Both the Malaysian and Indonesian C. zedoaria oils exerted significant cytotoxic effects against the MCF-7 (8.7 μg/mL and 16.5 μg/mL, respectively), MDA-MB 231 (22 μg/mL and 20.4 μg/mL, respectively) and SK-LU-1 (9.9 μg/mL and 14 μg/mL, respectively) cell lines as their IC_{50} values were lower than those recorded for doxorubicin. Overall, both the oils constitute promising anticancer agents for drug development since their IC_{50} values were lower than 30 μg/mL against all experimental cancer cell lines tested in the current study according to the American National Centre Institute 3.

Table 2 also provides the selectivity indices of the essential oils tested against the cancer and normal cell lines. Selectivity indices is considered interesting for values greater than three. In certain cases, values greater than or equal to 2.0 are interesting selectivity indices 3. Treatment of the cancer cell lines with the Malaysian C. zedoaria oil which recorded selectivity indices ranging from 1.2 - 4.0 demonstrated that the Malaysian C. zedoaria oil is a promising natural product for the development of anticancer agents.

<table>
<thead>
<tr>
<th>Cell lines</th>
<th>Malaysian C. zedoaria oil</th>
<th>Indonesian C. zedoaria oil</th>
<th>Doxorubicin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast MCF-7</td>
<td>8.7 ± 1.5</td>
<td>16.5 ± 4.9</td>
<td>19.6 ± 6.6</td>
</tr>
<tr>
<td>MDA-MB 231</td>
<td>22 ± 2.8</td>
<td>20.4 ± 0.7</td>
<td>32.9 ± 11.9</td>
</tr>
<tr>
<td>Lung A549</td>
<td>13.9 ± 2.9</td>
<td>12.1 ± 4.9</td>
<td>9.3 ± 4.6</td>
</tr>
<tr>
<td>SK-LU-1</td>
<td>9.9 ± 0.4</td>
<td>14 ± 0.9</td>
<td>51.5 ± 2.1</td>
</tr>
<tr>
<td>Cervical HeLa S3</td>
<td>6.4 ± 0.8</td>
<td>21.6 ± 2.5</td>
<td>6.5 ± 0.3</td>
</tr>
<tr>
<td>SiHa</td>
<td>9.8 ± 0.3</td>
<td>11.5 ± 1.9</td>
<td>7.8 ± 0.8</td>
</tr>
<tr>
<td>Normal MRC-5</td>
<td>25.7 ± 3.8</td>
<td>27 ± 2.8</td>
<td>&gt; 60</td>
</tr>
</tbody>
</table>

*Values are expressed as the mean ± S.D. after deduction of DMSO solvent induced cytotoxicity of three independent experiments (n = 3).
SI = Selectivity index.
due to its selectivity indices being greater than 2.0. Figure 3 illustrates the cytotoxic effects of both the oils against selected cancer cell lines after 24 hours of treatment. In addition, treatment with 30 μg/mL of the oils resulted in a significant difference of $p < 0.01$ for the Malaysian C. zedoaria oil in percentage of cell viability on MCF-7 cells and a significant difference of $p < 0.05$ on A549 and SK-LU-1 cells when treated with Indonesian C. zedoaria oil as compared to MRC-5 cells (Figure 4).

The three major compounds; camphor, zerumbone and curzerenone, could have been responsible in evoking the cytotoxic activity in both the Malaysian and Indonesian C. zedoaria oils. In addition, isovelleral has been reported to demonstrate cytotoxic activity against BHK 21, L1210 and B16-F1 cells while $ar$-turmerone is known to exhibit apoptotic activity in the K562, L1210, U937 and RBL-2H3 cells. Therefore, the higher levels of isovelleral and $ar$-turmerone in the Malaysian oil as compared to the levels of the corre-

![Malaysian C. zedoaria oil](image1)

![Indonesian C. zedoaria oil](image2)

**Fig. 3.** Cytotoxic effects of Malaysian and Indonesian C. zedoaria oils against breast (MCF-7 and MDA-MB 231), lung (A549 and SK-LU-1) and cervical (HeLa S3 and SiHa) cancer cell lines along with normal human lung fibroblast cells (MRC-5) after 24 h of treatment. All MTT data are represented as mean ± SD of three independent experiments ($n = 3$).
sponding compounds in the Indonesian oil could have resulted in the higher cytotoxic potency of the Malaysian C. zedoaria oil (IC$_{50}$: 6.4 - 22 μg/mL).

The evaluation of the anti-tumour effects of C. zedoaria oil against non-small cell lung carcinoma cells (NSCLC) at various concentrations for 24, 48 and 72 hours have resulted in IC$_{50}$ values ranging from 80 to 170 μg/mL for H1299 cells, 80 to 250 μg/mL (A549) and 180 to 185 μg/mL (H23) 13. In addition, cytotoxicity studies on essential oils of other Curcuma species have shown that the rhizomes of C. purpurascens which contain high levels of oxygenated sesquiterpenes exhibited cytotoxic effects against HT29, CaSki, HCT116 and A549 cell lines at IC$_{50}$ values ranging from 4.9 to 46.3 μg/mL 26. The leaf oil of C. longa which was dominated by α-turmerone (63.4 %), α-turmerone (13.7 %) and β-turmerone (12.6 %) exhibited cytotoxicity against breast tumour (Hs578T) (98.86 % at 250 μg/mL) and prostate tumour (PC-3) (97.94 % at 100 μg/mL) 27.

In conclusion, the cell viability assay on the Malaysian and Indonesian essential oils of C. zedoaria which were dominated by camphor, zerumbone and curzerenone showed potent cytotoxic activities when tested against breast, lung, and cervical cancer cell lines with IC$_{50}$ values ranging from 6.4 to 22 μg/mL. This suggested that the rhizome oil of C. zedoaria has the potential to be a chemopreventive agent towards a wide spectrum of cancer in particular cervical cancer. However, it is commendable that further assays should be conducted.

Acknowledgements
This project was funded by University of Malaya Postgraduate Research Grant (PPP) (PV050/2012A) and University of Malaya Research Grant (UMRG) (RP001/2012A/B).

References