Research Article

The Chemical Composition and Biological Activities of Essential Oils from Zanthoxylum rhetsa Grown in Son La, Northwest Vietnam

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Received 8 March 2021; Accepted 29 June 2021; Published 12 July 2021

Academic Editor: Chunpeng Wan

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Essential oils (EOs) from the stem barks, leaf petioles, fruit petioles, fresh leaves, and fresh and dried fruits of Zanthoxylum rhetsa were extracted by hydrodistillation. The volatile compounds of the products were analyzed by gas chromatography (GC-FID) and gas chromatography/mass spectrometry (GC/MSD). Monoterpenes hydrocarbons formed the predominant fraction of all six EO samples, of which sabine is one of the major components (from 12.37% to 41.13%). For the leaf petiole EO, limonene (25.01%), sabinene (14.56%), and linalool (12.63%) are the major constituents, while the main constituents of fruit petiole EO were terpinolene (19.66%), terpinen-4-ol (19.07%), and sabine (17.83%). The major components of stem bark EO are terpinen-4-ol (18.23%), sabinine (12.37%), α-phellandrene (7.34%), β-phellandrene (6.32%), and γ-terpinene (6.12%), while sabine (38.35%), terpinen-4-ol (13.71%), γ-terpinene (6.47%), and limonene (6.02%) are the major constituents of fresh leaf EO. For the EOs of dried fruits and fresh fruits, sabine, terpinolene, limonene, and terpinen-4-ol are the major constituents. The essential oils were also tested for their cytotoxic and antimicrobial activities. The results revealed that six EOs at concentrations of 50 μg/mL exhibited inhibitory activity against at least one tested cancer cell line but were nontoxic on Vero normal cells. Most EOs showed moderate antimicrobial activity against F. oxysporum; however, there were no obvious activity against B. subtilis and S. aureus.

1. Introduction

Zanthoxylum rhetsa (Roxb.) DC (Z. rhetsa) is a flowering plant of the Rutaceae family found in India, Myanmar, Thailand, Lao, and Vietnam. The tree has a medium size (about 14–18 meter in height) with a straight body, thorny branches, and 10–15 cm lanceolate leaves. The Z. rhetsa flowering season is between June and July with clusters of gray-white flowers and fruiting in October and November [1, 2]. Z. rhetsa is an indigenous plant in the northwest of
Vietnam, where the Son La province accounted for 71% of the total production [3]. Fruit and seed powders of *Z. rhetsa* are used as spices for cooking or for meat preservation by ethnic minorities such as Thai and H’Mong. Moreover, the plant is also used as traditional treatment for toothache, abdominal and stomach pain, and improving digestion [3, 4].

The chemical composition of the essential oil of *Z. rhetsa* grown in India and Thailand has been reported. For instance, the seed EO of *Z. rhetsa* grown in Kerala (South India) contained mostly monoterpenes [5], while sesquiterpenes were predominant in the leaf EO, with the major components include caryophyllene oxide, $\beta$-caryophyllene, $\beta$-copaene, and spathulenol [6]. The phytochemical profile of the seed EO, i.e., the presence of sabinene, $\alpha$-pinene, $\alpha$-terpinene, $\beta$-pinene, $\gamma$-terpinene, myrcene, terpinolene, and limonene, was also varied according to the pH of environment [7]. Meanwhile, the seed coat of *Z. rhetsa* collected from Senapati (the northeast of India) mainly consisted of terpinen-4-ol (32.1%), $\alpha$-terpinol (8.2%), sabinene (8.1%), along with $\beta$-phellandrene and 2-undecanone at 7.4% and 7.1%, respectively [8]. However, in some areas of Thailand such as Nan and Chiang Rai, the dried and the fresh fruits of *Z. rhetsa* contained different levels of limonene (27.10%–59.68%), $\beta$-phellandrene (10.88%–19.40%), and sabinene (25.03%–31.21%) [9]. On the other hand, sabinene (22.51%) and terpinene-4-ol (32.33%) were the major components of the EO extracted from fresh fruits of *Z. rhetsa* collected from Phayao (Thailand) [10].

Numerous studies have reported the interesting biological activities of *Z. rhetsa* EOs. The fresh fruit EO of *Z. rhetsa* grown in Phayao, Thailand, has showed anti-proliferative activity against breast cancer cells, and thus it was proposed as a potential food preservative and anticancer drug [10]. Meanwhile, terpinen-4-ol, which is the main constituent of pericarp EO, has the ability to inhibit the stress and diseases related to stomach and intestines [11].

In this paper, the EOs obtained from the different parts of *Z. rhetsa* (e.g., stem bark, leaf petiole, fruit petiole, fresh leaves, and fresh and dried fruit) grown in Son La, Northwest Vietnam, were extracted by hydrodistillation and its chemical composition was analyzed by GC/MS. In addition, these EOs have been evaluated for their biological activities, which included antibacterial and antiproliferative activities.

### 2. Materials and Methods

#### 2.1. Materials

The stem bark, leaf petiole, fruit petiole, leaves, and fruits of *Z. rhetsa* were collected from the Thuan Chau district, Son La province, Vietnam. Plant identification was performed by Dr. Nguyen Quoc Binh, the Vietnam Museum of Nature (VMN), Vietnam Academy of Science and Technology (VAST). All the plant parts were washed with tap water three times, air-dried at room temperature, and then stored in a refrigerator. 500 g of each fresh sample of stem bark, leaf petiole, fruit petiole, and leaves was chopped into pieces, and 200 g of fresh fruits was crushed as samples for EO isolation. 500 g of fresh fruits was dried at room temperature and then were ground as samples for EO isolation.

#### 2.2. Isolation of Essential Oils

The oil extraction was performed by hydrodistillation in the Clevenger-type apparatus for 3 h at normal pressure. The collected EOs were dehydrated with anhydrous sodium sulfate, weighted, and refrigerated until analysis. The samples were labeled as SB: stem bark; LP: leaf petiole; FP: fruit petiole; FL: fresh leaves; DF: dried fruit; and FF: fresh fruit.

#### 2.3. GC-MS and GC-FID Analysis

The chemical compositions of EOs were analyzed by Agilent 7890A gas chromatography (GC) equipped with an MSD Agilent 5975C detector and a HP-5MS column (60 m × 0.25 mm, 0.25 μm film thickness) (Agilent Technologies, CA, USA). Other conditions were set as follows: 250°C as injector temperature, helium as the carrier gas, 1 mL·min⁻¹ as flow rate, and temperature program from 60°C to 240°C (4°C/min). The split ratio was 100:1, and the injection volume of EO was 1 μL. The MSD full-scan mode was applied under 70 eV of ionization voltage, 40 mA of emission current, and 35–450 amu of acquisition scan mass range.

The constituents were identified by comparing their mass spectrum with the W09N08 libraries and NIST Chemistry WebBook (http://webbook.nist.gov/chemistry/) database. The retention indices (RIs) of EO components were calculated by MassFinder 4.0 software base on homologous n-alkanes with same conditions. The relative content of each phytochemical component was estimated based on the GC-FID peak area with same conditions.

#### 2.4. Antimicrobial Assays

The antimicrobial assays were performed by using four bacterial and two fungal strains purchased from American Type Culture Collection (ATCC, Manassas, VA, USA), including *Escherichia coli* ATCC 8739, *Bacillus subtilis* ATCC 27212, *Pseudomonas aeruginosa* ATCC 25923, *Staphylococcus aureus* ATCC 12222, *Aspergillus niger* ATCC 9763, and *Fusarium oxysporum* ATCC 48112. The culture of the microorganisms with an inoculum size of about $10^5$ colony-forming units (CFU) per mL was prepared and loaded into 96-well microplates. Samples at different concentrations (50–200 μg/mL) were prepared by dissolving in 5% DMSO, then loaded into the plates, and incubated at 37°C for 24 h. Gentamycin (16 IU/mg, 8 IU/mg, and 4 IU/mg), doxycycline (0.4 IU/mg, 0.2 IU/mg, and 0.1 IU/mg), and nystatin (12 IU/mg, 6 IU/mg, and 3 IU/mg) (Merck KGAa, Darmstadt, Germany) were used as positive references. 5% DMSO was used as the negative control [12].

#### 2.5. Cell Proliferation Assays

Five human cancer cell lines (e.g., HeLa, Hep-G2, A-549, MCF-7, and HGC-27) and a normal cell line Vero were obtained from ATCC and maintained in suitable media (RPMI 1640, MEM, DMEM; Sigma Aldrich Inc., Saint. Louis, MO, USA) at 37°C in 5% CO₂. MTT assay was performed to investigate the viability of cancer cells [13, 14]. Dilution was performed in a 96-well microplate to obtain a density of 5 × 10⁴ cells per well. The samples (0.63–50 μg/mL), DMSO as the negative control (Merck KGAa) and ellipticine as the positive control (Merck
of the EO, respectively. This result was different from the study of Jirovetz et al., where sesquiterpenes and monoterpenes were presented with the quantities of 38.6% and 2.2%, respectively [6].

3.1.5. Fresh Fruit and Dried Fruit EOs. A total of 23 components from fresh fruit EO (FF) and 26 components from dried fruit EO (DF) were identified, accounting for 99.99% (Figures 1(e) and 1(f)). The monoterpane hydrocarbon fractions were enriched in the two EOs (83.71% and 84.28%, respectively), with sabinene (41.13% and 32.88%, respectively), terpinolene (27.05% and 30.37%, respectively), and limonene (7.84% and 8.29%, respectively). Next, the oxygenated monoterpane fractions were 15.04% and 14.74% for FF and DF, respectively. The major components of this fraction were \( \alpha \)-terpineol (6.08%, 3.27%) and terpinen-4-ol (5.35%, 7.73%), respectively. In comparison with another result of chemical constituents of fresh fruit EO collected from the Mai Chau district of the Hoa Binh province in Vietnam, there were 24 components found, in which benzene, benzaldehyde-4-methoxy, 1-methoxy-4(1-propenyl), 1-butanon, 1-(4-hydroxyphenyl), benzene-methanol, and alpha-ethyl-4-methoxy were the main components [18].

There are nineteen common compounds present in all six essential oil samples, including sabinene, limonene, terpinolene, terpinen-4-ol, \( \alpha \)-terpineol, \( \gamma \)-terpinene, \( \alpha \)-terpinene, \( \alpha \)-pinene, linalool, trans-\( \beta \)-ocimene, myrcene, \( \alpha \)-pinene, \( \beta \)-phellandrene, \( \alpha \)-thujene, trans-sabinene hydrate, cis-sabinene hydrate, trans-p-menth-2-en-1-ol, cis-p-menth-2-en-1-ol, geranyl acetate, and germacrene D. In these common compounds, sabinene is present in high content in all six EOs (from 12.37% to 41.13%) followed by terpinen-4-ol (from 5.35% to 19.07%) and limonene (from 4.18% to 25.01%). Meanwhile, there are some compounds present in all six EO samples, but all in low content (less than 5%), such as \( \alpha \)-terpineol, \( \alpha \)-thujene, myrcene, \( \alpha \)-terpinene, trans-\( \beta \)-ocimene, cis-sabinene hydrate, trans-sabinene hydrate, cis-p-menth-2-en-1-ol, trans-p-menth-2-en-1-ol, geranyl acetate, and germacrene D. However, there is a large difference in the content of some compounds in six EO samples, such as terpinolene is present in high content in dried fruits, fresh fruits, fruit petioles, and leaf petioles (30.37%, 27.05%, 19.66%, and 6.86%, respectively) but with low content in fresh leaves and stem barks (1.91% and 1.57%, respectively); linalool is present in relatively high content in leaf petioles and fruit petioles (12.63% and 11.64%, respectively), but it is only present in low content in fresh leaves, fresh fruits, stem barks, and dried fruits (1.80%, 1.71%, 1.61%, and 0.84%, respectively); \( \alpha \)-pinene presents with 7.00% in leaf petioles and 5.62% in fresh leaves, but it has only trace content in the samples of dried fruits (0.67%) and fresh fruits (0.54%). These differences are displayed in Figure 2.

Some compounds are only present in a certain EO and therefore are assumed to have properties specific to a certain EO: \( \delta \)-3-carene, 2-undecanone, \( \alpha \)-cubebene, \( \beta \)-cubebene, \( \alpha \)-copaene, cis-\( \beta \)-elemene, \( \beta \)-selinene, elemol, spathulenol, 1-epi-cubepol, epi-\( \alpha \)-cadinol, \( \alpha \)-muurolol, and neo-
Table 1: Phytochemical profile of EOs from the different parts of Z. rhetsa.

| Compound name                  | RI<sup>1</sup> | RI | SB | LP | FP | FL | DF | FF |
|--------------------------------|----------------|----|----|----|----|----|----|----|
| (Z)-Hex-3-en-1-ol              | 854            | 851 |    |    |    |    | 0.45 |    |
| (Z)-Hex-2-en-1-ol              | 855            | 860 |    |    |    |    | 1.06 |    |
| n-Hexanol                      | 871            | 862 |    |    |    |    | 0.41 |    |
| α-Thujene                      | 930            | 930 | 0.75 | 0.42 | 0.27 | 1.14 | 0.61 | 0.35 |
| α-Pinene                       | 939            | 939 | 2.09 | 7.00 | 1.07 | 5.62 | 0.67 | 0.54 |
| Sabinene                       | 975            | 978 | 12.37 | 14.56 | 17.83 | 38.35 | 33.71 | 41.13 |
| β-Pinene                       | 979            | 984 | 0.14 | 0.26 |    | 1.12 |    |    |
| Myrcene                        | 991            | 991 | 1.89 | 1.87 | 1.17 | 2.00 | 2.02 | 1.76 |
| n-Octanol                      | 999            | 1003 |    |    |    |    |    | 0.26 |
| α-Phellandrene                 | 1003           | 1010 | 7.34 | 2.74 | 0.10 | 2.11 | 0.11 |    |
| δ-3-Carene                     | 1011           | 1016 | 0.15 |    |    |    |    |    |
| α-Terpineol                    | 1017           | 1021 | 3.63 | 1.90 | 2.23 | 3.68 | 2.03 | 1.12 |
| α-Cymene                       | 1026           | 1029 | 0.71 | 0.42 | 0.39 | 0.66 | 0.23 |    |
| Limonene                       | 1029           | 1034 | 4.18 | 25.01 | 4.44 | 6.02 | 8.29 | 7.30 |
| β-Phellandrene                 | 1030           | 1035 | 6.32 | 2.08 | 0.26 | 2.53 | 0.35 | 0.26 |
| cis-β-Ocimene                  | 1037           | 1037 | 0.89 | 0.51 | 0.12 | 0.20 |    |    |
| trans-β-Ocimene                | 1050           | 1048 | 4.02 | 5.05 | 2.69 | 2.83 | 2.55 | 2.37 |
| γ-Terpineol                    | 1060           | 1063 | 6.12 | 3.16 | 4.43 | 6.47 | 3.34 | 1.83 |
| n-Octanol                      | 1068           | 1068 |    |    |    |    |    | 0.13 |
| cis-Sabinene hydrate           | 1070           | 1072 | 0.38 | 0.24 | 0.79 | 0.49 | 0.65 | 0.54 |
| Terpinolene                    | 1089           | 1094 | 1.57 | 6.86 | 19.66 | 1.91 | 30.37 | 27.05 |
| Linalool                       | 1097           | 1101 | 1.61 | 12.63 | 11.64 | 1.80 | 0.84 | 1.71 |
| trans-Sabinene hydrate         | 1098           | 1104 | 0.35 | 0.25 | 0.43 | 0.44 | 0.30 |    |
| trans-4,8-Dimethyl-1,3,7-triene | 1103           | 1117 |    |    | 0.18 |    |    |    |
| cis-p-Menth-2-en-1-ol           | 1122           | 1128 | 1.08 | 0.49 | 1.14 | 0.75 | 0.42 | 0.33 |
| trans-p-Menth-2-en-1-ol         | 1141           | 1145 | 0.73 | 0.34 | 0.83 | 0.53 | 0.31 | 0.02 |
| Terpinen-4-ol                  | 1177           | 1186 | 18.23 | 7.78 | 19.07 | 13.71 | 7.73 | 5.35 |
| p-Cymen-8-ol                   | 1183           | 1190 |    |    | 0.17 |    | 0.32 |    |
| α-Terpineol                    | 1189           | 1197 | 0.89 | 1.55 | 5.35 | 0.70 | 3.27 | 6.08 |
| cis-Piperitol                  | 1196           | 1203 | 0.26 | 0.13 | 0.28 | 0.18 |    |    |
| Decanal                        | 1202           | 1206 |    |    |    |    | 0.34 | 0.40 |
| Octyl acetate                  | 1214           | 1210 |    |    |    |    | 0.23 | 0.22 |
| trans-Piperitol                | 1208           | 1214 | 0.41 | 0.17 | 0.46 | 0.28 | 0.13 |    |
| Nerol                          | 1230           | 1231 | 0.12 |    | 0.25 |    |    |    |
| Geraniol                       | 1253           | 1255 | 0.19 | 0.22 | 0.58 |    |    |    |
| 2-Undecanone                   | 1294           | 1294 | 2.77 |    |    |    |    |    |
| α-Cubebeone                    | 1351           | 1360 | 0.16 |    |    |    |    |    |
| Geranyl acetate                | 1381           | 1383 | 0.16 | 0.27 | 0.34 | 0.14 | 0.63 | 0.51 |
| β-Copaene                      | 1377           | 1389 | 0.36 |    |    |    |    |    |
| β-Cubebeone                    | 1388           | 1401 | 0.21 |    |    |    |    |    |
| cis-β-Elemene                  | 1391           | 1403 | 0.21 |    |    |    |    |    |
| (E)-Caryophyllene              | 1419           | 1437 | 3.42 | 1.23 | 1.01 | 1.53 | 0.11 |   |
| (β)-Caryophyllene              | 1449           | 1471 | 0.67 | 0.21 | 0.19 | 0.25 |    |   |
| α-Humulene                     | 1455           | 1471 |    |    |    |    |    |    |
| β-Chamigrene                   | 1478           | 1489 | 0.38 |    |    |    |    |    |
| Germacrone D                   | 1485           | 1498 | 3.46 | 0.65 | 0.76 | 0.88 | 0.27 | 0.24 |
| β-Selinene                     | 1490           | 1503 | 0.38 |    |    |    |    |    |
| (E,E)-α-Farnesene              | 1506           | 1512 |    |    |    |    | 0.51 |    |
| Bicyclogermacrone              | 1500           | 1513 | 2.28 | 0.40 | 0.32 | 0.36 |    |    |
| γ-Cadinene                     | 1514           | 1530 | 0.11 |    |    |    |    |    |
| δ-Cadinene                     | 1523           | 1536 | 0.97 | 0.21 | 0.12 | 0.19 |    |    |
| Elemol                         | 1550           | 1562 | 0.58 |    |    |    |    |    |
| Spathulenol                    | 1578           | 1595 | 0.38 |    |    |    |    |    |
| Viridiflorol                   | 1593           | 1603 | 0.45 | 0.15 |    |    |    |    |
| Guaiol (=champacol)            | 1601           | 1613 | 0.55 | 0.23 | 0.31 |    |    |    |
| 1-epi-Cubenol                  | 1629           | 1645 | 0.17 |    |    |    |    |    |
| epi-α-Cadinol (=tau-cadinol)   | 1640           | 1657 | 0.26 |    |    |    |    |    |
| epi-α-Muurolol (=tau-muurolol) | 1642           | 1658 | 0.96 | 0.22 |    | 0.11 |    |    |
| α-Murolol (=δ-cadinol)         | 1646           | 1661 | 0.29 |    |    |    |    |    |
| α-Cadinol                     | 1654           | 1671 | 1.12 | 0.40 | 0.28 | 0.18 |    |    |
| Compound name    | R$I^{a/b}$ | RI  | Percentage |
|------------------|------------|-----|------------|
| Neointermenedol  | 1660       | 1674| 1.93       |
| Bulnesol        | 1672       | 1685| 0.24       |
| Total           | 98.85      | 99.69| 99.69      |
| Monoterpene hydrocarbons | 52.17 | 71.84| 54.66      |
| Oxygenated monoterpenes | 24.41 | 24.07| 41.64      |
| Sesquiterpene hydrocarbons | 12.61 | 2.7 | 2.71       |
| Oxygenated sesquiterpenes | 6.93 | 1.11| 0.51       |
| Aliphatic ketones | 2.77      |     | 0.18       |
| Others          |           |     | 1.92       |

RI$^{a/b}$: retention index compared between software predictions [15–17]; SB: stem bark; LP: leaf petiole; FP: fruit petiole; FL: fresh leave; DF: dried fruit; FF: fresh fruit.

Figure 1: Chromatography of EOs from (a) SB, (b) LP, (c) FP, (d) FL, (e) DF, and (f) FF.
intermedeolare represent only in stem bark EO; trans-4,8-dimethylnona-1,3,7-triene is present only in fruit petiole EO; (Z)-hex-3-en-1-ol, (Z)-hex-2-en-1-ol, n-hexanol, and (E,E)-\( \alpha \)-farnesene are present only in fresh leaf EO; and the two compounds decanal and octyl acetate are specific to fresh and dried fruit EOs.

3.2. Biological Activity of \( Z. \) rhetsa EOs

3.2.1. Cytotoxicity. Six EO samples extracted from different parts of \( Z. \) rhetsa collected from the Son La province in Vietnam were tested for their cytotoxicity effect against five cancer cell lines (MCF-7, HeLa, HGC-27, Hep-G2, and A-549) and a normal cell line Vero. Cytotoxic activities were expressed by IC\(_{50}\) values, which revealed that all EOs at maximum concentration slightly inhibited at least one tested cell line (IC\(_{50}\) ranges from 46.21 to 89.39 \( \mu \)g/mL; Table 2).

Particularly, the EO of fresh leaves (FL) exhibited stronger cytotoxicity against four tested cancer cell lines, while the EO of stem bark (SB) and of fresh fruit (FF) exhibited cytotoxicity against HGC-27 and A-549, respectively. Significantly, these EOs demonstrated no cytotoxicity against the normal Vero cell line at the final concentration of samples up to 100 \( \mu \)g/mL. Naik et al. suggested that the EO from \( Z. \) rhetsa fruits could inhibit the cell viability and proliferation of breast cancer [10]. It was found the EO obtained from dried fruits collected from Nan of Thailand exhibited inhibitory effect on the growth of human lung cancer cell line (H460) with an EC\(_{50}\) value of 1.79 \( \mu \)L/mL. Meanwhile, the dried \( Z. \) rhetsa fruits collected from some districts of Thailand (Nan, Phayao, and Chiang Rai) revealed a wide range of EC\(_{50}\) values from 2.03 \( \mu \)g/mL to 7.07 \( \mu \)g/mL against human lung cancer cells (MRC-5) [9].

3.2.2. Antimicrobial Activity. Six EO samples from different parts of \( Z. \) rhetsa collected from the Son La province in Vietnam were also tested for their antimicrobial activities (Table 3). The results demonstrated that most of the EOs showed moderate antimicrobial activity against \( F. \) oxysporum yet did not inhibited bacteria \( B. \) subtilis and \( S. \) aureus.

Vanden Bergher and Vlietinck also observed various degrees of inhibition of the fresh leaf EO of \( Z. \) rhetsa at different concentrations against the test fungal isolates. The obtained results have shown that the concentration of 12.5% exhibited the highest activity against \( A. \) niger, \( A. \) fumigatus, \( A. \) flavus, and \( P. \) italicum in agar dilution tests [19]. Pham et al. suggested that terpinen-4-ol that is the main active constituent in \( Z. \) rhetsa pericarp EOs had the ability to inhibit stomach and intestine diseases [11]. Some other studies have also shown that essential oils obtained from plants exhibited potential antibacterial and antifungal activities [20–22].

**Figure 2:** The main constituents in six essential oil samples.

**Table 2:** Cytotoxic activity of essential oils.

| Samples | MCF-7 IC\(_{50}\), \( \mu \)g/mL | HeLa | HGC-27 | HepG-2 | A-549 | Vero |
|---------|-------------------------------|------|--------|--------|-------|------|
| SB      | >100                          | >100 | 83.48  | >100   | >100  | >100 |
| FL      | 75.19                         | >100 | 72.69  | 89.39  | 66.27 | >100 |
| LP      | 46.21                         | >100 | >100   | 54.67  | 56.8  | >100 |
| FP      | 72.93                         | >100 | >100   | >100   | >100  | >100 |
| FF      | >100                          | >100 | >100   | 74.82  | >100  | >100 |
| DF      | >100                          | >100 | >100   | 48.45  | 62.57 | >100 |
| Ellipticine | 0.42                      | 0.36 | 0.51   | 0.34   | 0.35  | 1.84 |

MCF-7: human breast adenocarcinoma cells; HeLa: cervical cancer cells; HGC-27: human stomach carcinoma cell; Hep-G2: hepatocellular carcinoma; A-549: human lung adenocarcinoma epithelial cells; Vero: kidney epithelial cells.
4. Conclusions

Six EO samples were obtained by hydrodistillation from different parts of *Z. rhesta* (e.g., stem barks, fresh leaves, leaf and fruit petioles, fresh and dried fruits) collected in the Son La province in Vietnam. Monoterpene hydrocarbons were found to be the predominant compound of all six EO samples, of which sabinene is one of the major components (from 12.37% to 41.13%) followed by limonene (from 4.18% to 25.01%). Oxygenated monoterpenes is present in quite high content in six EO samples, in which terpinen-4-ol was found to be the main compound of this fraction (from 5.35% to 19.07%). Sesquiterpene hydrocarbons and oxygenated sesquiterpenes were present at a relatively high concentration in stem bark EO (12.61% and 6.93%, respectively) but only in a trace amount in other samples. Especially, aliphatic ketones were found only in stem bark EO (2.77%) and completely absent in the remaining five EO samples. Some compounds were present in all six EO samples but at different concentrations, such as terpinolene is present in high content in dried fruits, fresh fruits, fruit petioles, and leaf petioles (30.37%, 27.05%, 19.66%, and 6.86%, respectively) but is in low content in fresh leaves and stem barks (1.91% and 1.57%, respectively); linalool is present in relatively high content in leaf petioles and fruit petioles (12.63% and 11.64%, respectively), but it is only present in trace amounts in fresh leaves, fresh fruits, stem barks, and dried fruits (1.80%, 1.71%, 1.61%, and 0.84%, respectively). The cytotoxicity results have shown that six EOs at a concentration of 50 μg/mL exhibited inhibitory activity against at least one tested cancer cell line but were nontoxic on Vero normal cells. For the antimicrobial activity, most EOs showed moderate inhibitory effect against *F. oxysporum*, yet no effects were observed against *B. subtilis* and *S. aureus*.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Table 3: Antimicrobial activities of essential oils.

| Samples | *E. coli* | *P. aeruginosa* | *B. subtilis* | *S. aureus* | *A. niger* | *F. oxysporum* |
|---------|-----------|-----------------|--------------|-------------|------------|---------------|
| SB      | >200      | >200            | >200         | >200        | >200       | >200          |
| FL      | >200      | >200            | >200         | >200        | >200       | 100           |
| LP      | >200      | 100             | >200         | >200        | >200       | 100           |
| FP      | 50        | >200            | >200         | >200        | >200       | 200           |
| FF      | 100       | 200             | >200         | >200        | >200       | 100           |
| DF      | >200      | >200            | >200         | >200        | >200       | 200           |

*The highest test concentration 200 μg/mL.*

Acknowledgments

This research was funded by the Vietnam Academy of Science and Technology (VAST) under grant number VAST04.06/20-21.

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