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Phytochemical and gas chromatography-mass spectrometry profiling of two plant parts of *Sandoricum koetjape*

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Abstract. *Saadah S, Tulandi SM, Rohman RA. 2022. Phytochemical and gas chromatography-mass spectrometry profiling of two plant parts of* Sandoricum koetjape*. Biodiversitas 23: 6199-6207. Sandoricum koetjape* has been used in traditional Indonesian medicine for centuries. In Indonesia, the stem and leaves were used to treat helminthiasis, cough, stomachache, diarrhea, bloating, leucorrhoea, colic, and fever. To ascertain the phytochemical constituents of each plant part, and provide a sufficient basis for clinical application, so Gas Chromatography-Mass Spectrometry (GC/MS) analysis of stems and leaves was established. Phytochemical screening showed that stems and leaves contained alkaloids, flavonoids, quinone, triterpenoids, and tannin. Total phenolics in the leaves are higher than in the stem. Saponin and steroids were not detected. The GC/MS analysis indicated that the leaf extract contained more identified compounds (30) than the stem extract (28). Both *S. koetjape* samples contained 1H-Cycloprop[e]azulen-7-ol. The major compounds of the stem extract of *S. koetjape* are Fonenol (12.89%), 1H-Cyclopenta[1,3]cyclopropa[1,2]benzene (12.54%), and 1H-Cycloprop[e]azulen-7-ol (11.70%), while the major compounds in leaf methanol extract were 14,15-didehydro-Cyclodecacyclotetradecene (23.71%), 1H-Cycloprop[e]azulen-7-ol (17.04%), and Solanesol (8.34%). The two main components of the variable can account for 50.92% of the total variance, according to Principal Component Analysis (PCA) (PC1 is 21.19% and PC2 is 29.74%). These results indicate that the two components effectively categorize samples with distinct characteristics. The groups were divided based on the type of sample used, namely stem and leaf samples. According to the loading plot, 1H-Cyclopenta[1,3]cyclopropa[1,2]benzene and Fonenol are two components that are very effective in categorizing samples based on their type. Both metabolites are higher in the stem than in the leaf. However, the metabolites activities of *S. koetjape* stem and leaves extracts could be revealed by further studies using in silico and in vitro approaches.

Keywords: GC/MS profiling, phytochemistry, *Sandoricum koetjape*

INTRODUCTION

Medicinal plants have been used to maintain health and treat various diseases. Numerous plants in Southeast Asia have been known to have medicinal properties (Awang-Jamil et al. 2021). As a mega biodiversity country, Indonesia has diverse medicinal plants (Astiti and Ramona 2021). *Sandoricum koetjape*, one of the traditional medicinal plants used in Indonesia, belongs to the Meliaceae family (Blench 2008). It is known as Santol or Kecapi and has been traditionally used for treating helminthiasis, cough, stomachache, diarrhea, bloating, leucorrhoea, colic, and fever, and a tonic after childbirth (Blench 2008; Nassar et al. 2010). The tree is lush and large, reaching up to 30 m, although generally, it only reaches about 20 meters in the yard. The trunk is buttressed and branched close to the ground. Younger branches have dense brown hair (Nassar et al. 2010). The diameter of the stem can reach 90 cm. The leaves of the *S. koetjape* are alternately compound, stems up to 18 cm, pinnate with three leaflets, oblong to egg-shaped, rounded or slightly pointed at the base, tapering at the tip; glossy green above, dull green below. The leaflets are long-stemmed, much longer than the side leaves (Blench 2008).

Many scientific studies on medicinal plants have been performed to support and discover the medicinal effects and mechanism of action based on scientific evidence (Awang-Jamil et al. 2021). The bioactivities of *S. koetjape* have been previously reported. The total phenol content in the stems and leaves of *S. koetjape* was 1.4155 mg/g and 3.1469 mg/g, respectively (Saadah and Tulandi 2020). The seed extract of *S. koetjape* has inhibitory activity against P-388 leukemia cells (Bumi et al. 2019). The leaf of *S. koetjape* has xanthine oxidase inhibitory activity and antioxidant activity (Hamzah et al. 2020). *S. koetjape* fruit peel ethanol extract has anti-inflammation properties for gingivitis after scaling (Wirata et al. 2021). In vitro studies showed the pharmacological potential of *S. koetjape* extract, including antioxidant, antibacterial, anticancer, antitumor, and insecticide activities (Wijaya 2022). *S. koetjape* has anti-inflammatory activity against tetradecanoylphorbol acetate (TPA) (Ismail et al. 2003; Rasadah et al. 2012). *S. koetjape* stem extract has anti-fungi activity against *Candida albicans* (Warsinah et al. 2015).

Photosynthesis occurs in the leaf tissue, whereas transportation occurs in the stem tissue (Lemoine et al. 2013; Rohman et al. 2022). Photosynthesis is the process by which plants synthesize food (Rohman et al. 2022). The stem transports sugars from the leaves, water, and minerals absorbed from the roots (Lemoine et al. 2013). In recent years, GC-MS has consolidated its position as a key technological platform for metabolite profiling in plant and non-plant species (Kanthal et al. 2014**.** Thus, this study aimed to determine the phytochemicals compounds in the stems and leaves methanol extract of *S. koetjape* using Gas Chromatography-mass Spectrometry (GC/MS).

MATERIALS AND METHODS

Plant materials

The stems and leaves of *Sandoricum koetjape* were bought in Bogor, Indonesia, in February 2020. Dr. Atik Retnowati completed taxonomical ID and verification at the Herbarium Bogoriense, Research Center for Biology, Indonesian Institute of Sciences.

Preparation of extracts

Fresh leaves and stems of *S. koetjape* leaves and stems were selected, washed, cut into pieces, dried by aerating, and then ground or crushed to powder. Fine powder was used for extraction. Eight hundred g was macerated with 6 L of methanol for 5 days, then further with 2 L of methanol for 2 days, stirring frequently. Next, the filtrates were filtered with a Buchner funnel lined with filter paper and evaporated with a vacuum rotary evaporator at a temperature of 50ºC to obtain the concentrated extract. The concentration extract is stored at 4ºC until used. The maceration method was chosen for this study because it is a simple method that requires only soaking the sample in a solvent (Malik and Ahmad 2014).

Phytochemical screening

Alkaloids

Five milligrams of stems and leaves of *S. koetjape* were placed into 2 different test tubes, and then 5 mL of 2M hydrochloric acid (HCl) was added; pH was maintained at 2-2.5, stirred, and then cooled down to reach room temperature. Next, the cold sample was added with Dragendorff's reagent, stirred, and filtered. The red precipitate indicates the presence of alkaloids.

Two mg samples of *S. koetjape* stems and leaves extracts were placed in two separate test tubes and added with 3 drops of concentrated HCl and 5 drops of Mayer's reagent. The presence of alkaloids is indicated by a white precipitate (Sreevidya and Mehrotra 2003).

Flavonoids

Two-milligram samples of stems and leaves extract were placed into 2 different test tubes and then heated for approximately 5 minutes. After being heated, each 0.1 g of Magnesium (Mg) and 5 drops of concentrated HCl were added to the different test tubes containing the respective samples. A red to orange color indicates flavone, while the presence of flavonols or flavanones was indicated by dark red. The presence of aglycones or glycosides was indicated by green to blue (Malik and Ahmad 2014).

Quinone

Leaf and stem methanol extract of *S. koetjape* were mixed with 5% H_2O_2 and 0.5 M Potassium Hydroxide and then heated at 95ºC for ±10 minutes. The mixture was filtered through filter paper to benzene, and acetic acid was added. First, the upper layer is removed using a separating funnel, and then ammonia is added. If the benzene layer solution is colorless, it indicates a positive sample containing quinone (MoH 2020).

Saponin

About 2 mL of leaf and stem methanol extract of *S. koetjape* were dissolved using 2 mL of hot distilled water, heated at 95ºC for ± 5 minutes, and then filtered. Then the filtrate was put in a test tube and then shaken. A 1 cm foam formation indicates the presence of Saponin (MoH 2020).

Steroid and triterpenoids

Methanol extracts of leaves and stems of *S. koetjape* were mixed with ether and then separated using a separating funnel. The upper layer was mixed with H_2SO_4 and anhydrous acetic acid. If the sample contains steroids, a green color will be formed, whereas a red to purple color will be formed if the sample contains triterpenoids (MoH 2020).

Tannin

10% of iron (III) chloride solution was added to 1 mg of the leaves and stems methanol extract of the *S. koetjape* sample. If the sample contains tannins, a dark blue or greenish-black color will be formed (MoH 2020).

Total phenolic

0.1 mL of extracts and 2.5 mL of distilled water were added to a test tube, followed by 0.1 mL of Folin-Ciocalteu reagent. The solution was mixed well and stood for 6 minutes before adding 0.5 mL Na2CO3 20% solution. The color was developed for 30 minutes at room temperature, and the absorbance was measured at 760 nm. The measurement was compared to a calibration curve of gallic acid solutions (Kaškonienė et al. 2009)

Gas Chromatography-Mass Spectrometry analysis

In Brief, a gas chromatograph Agilent Technologies 7890B (GC) was used in conjunction with a mass spectrometer Agilent Technologies 5977B equipped with an HP-5MS UI column. In split mode [12:1 (v/v)], the derivatized samples (2 µL) were injected. The injector temperature was set to 290°C, and the data were analyzed randomly. The column temperature was held at 50°C for 5 minutes before increasing by 10°C/min to 280°C and remaining there for 15 minutes. At a flow rate of 1mL/min, helium was used as the carrier gas. At 70 eV, electron ionization produced ions. Over the mass range of m/z 50-300, mass spectra were recorded at 20 scans per second. The system control and data acquisition were carried out using Agilent MassHunter Qualitative Navigator B.08.00.

Data analysis

The commercial software Minitab 16 was used to perform principal component analysis (PCA). The significantly different metabolites ($p<0.05$) among parts of *S. koetjape* were tested using one-way ANOVA on Minitab 16. In addition, independent t-tests using Minitab 16 were used to detect differences in the total phenolics test.

RESULTS AND DISCUSSION

Phytochemical screening

The qualitative test results revealed that stem and leaves methanol extracts of *S. koetjape* contained alkaloids, flavonoids, quinone, triterpenoids, and tannin. Saponin and steroids were not detected (Table 1).

Total phenolics

In addition, the results revealed differences between the total phenolics of the leaf and stem of *S. koetjape*. Total phenolics in the leaf are higher than in the stem (Figure 1). The total phenol content in the stems and leaves of *S. koetjape* was 1.4155 mg/g and 3.1469 mg/g, respectively.

GC-MS profiling of stem and leaves of *Sandoricum koetjape*

Sandoricum koetjape is a common medicinal plant used as a therapeutic aid for alleviating human ailments in Indonesia. The chemical compounds of *S. koetjape* were analyzed using GC-MS. Figure 2 shows the results of the GC-MS analysis of *S. koetjape* leaves and stems extract.

The GC-MS analysis of *S. koetjape* methanol leaf extract revealed the presence of 3 major compounds identified as follows: 14,15-didehydro-Cyclodecacyclo-tetradecene (23.71%), 1H-Cycloprop[e]azulen-7-ol (17.04%), and Solanesol (8.34%). Table 2 displays the identified chemical compounds and their retention time (RT) and area (%).

Meanwhile, the GC-MS chromatogram of stem methanol extract of *S. koetjape* revealed the presence of Fonenol (12.89%), 1H-Cyclopenta[1,3]cyclopropa [1,2]benzene (12.54%), and 1H-Cycloprop[e]azulen-7-ol (11.70%) as the 3 major compounds. Table 3 shows the identified chemical compounds and their retention time (RT) and area (%).

PCA showed that they were separated along 50.92% of the total variance (PC1 is 21.19% and PC2 is 29.74%) based on the type of sample used. *S. koetjape* stem and leaf samples (Figure 3A). Furthermore, the loading plot of PCA showed that 1H-Cyclopenta[1,3]cyclopropa [1,2]benzene and Fonenol are two components that are important for the separation between the stem and leaf of *S. koetjape* (Figure 3B). The PCA loading plots show how single metabolites contribute to the global separation of samples. The plots show that a high concentration of metabolites primarily causes the differences.

Discussion

Alkaloids are naturally occurring organic nitrogen-containing metabolites that are secondary metabolites derived from a specific group of amino acids. Alkaloids are formed from l-lysine, l-ornithine, l-tyrosine, l-tryptophan, l-histidine, l-phenylalanine, nicotinic acid, anthranilic, or acetic acid. The differences in alkaloid chemical structure cause significant clinical use as medicines for many diseases (Badal and Delgoda 2017). Alkaloids have properties in the health sector, namely triggering the nervous system, antipsychotic, anxiolytic, increasing blood pressure, and relieving pain, so they are used as sedatives, drugs for heart disease, and antimicrobial properties (Elisabetsky and Costa-Campos 2006). The seed of *S. koetjape* contains a high amount of alkaloids that showed inhibition zones toward *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Bacillus subtilis* (Azziz et al. 2015)

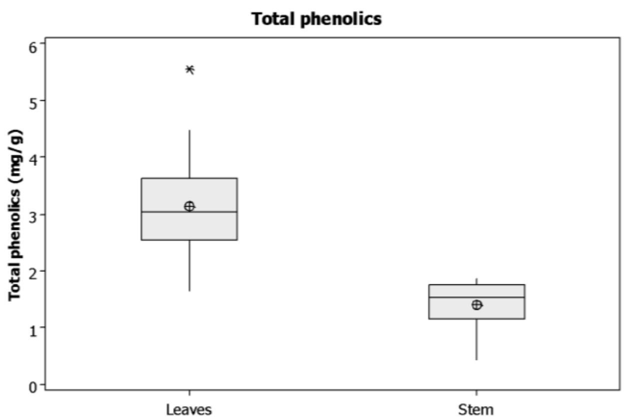

Figure 1. Bar graphs of total phenolics of two plant parts of *Sandoricum koetjape*

Table 1. Phytochemical screening of *Sandoricum koetjape* stem and leaf methanol extract

Samples	Secondary metabolites							
	Alkaloids		Flavonoids	Quinone	Saponin	Steroids	Triterpenoids	Tanin
	D	M						
Stem	+	+	+	+	-	-	+	+
Leaves	+	+	+	+	-	-	+	+

Note: D: Dragendorff; M: Meyer

Flavonoids are natural compounds with varied phenolic structures found in the bark of stems and roots, flowers, fruits, vegetables, grains, teas, and grapes. Flavonoids are considered essential ingredients in various dietary supplements, pharmaceuticals, and cosmetics applications. It is due to its antioxidant, anti-inflammatory, antimutagenic, and anticancer properties, coupled with its capacity to regulate the function of important cellular enzymes. Flavonoids can inhibit several enzymes, including xanthine oxidase (XO), cyclo-oxygenase (COX), lipoxygenase, and phosphoinositide 3-kinase (Panche et al. 2016). *S. koetjape* contains various flavonoids such as sandoricin and sandoripin derivatives with antioxidant, antibacterial, and insecticidal properties (Bailly 2022)

Quinones are chemical compounds that have two carbonyl groups conjugated with a carbon-carbon double bond. Quinones are divided into several groups, namely naphthoquinones, benzoquinones, isoprenoid quinones, and anthraquinones. Quinones are compounds that have a wide range of beneficial properties. Quinones are electron carriers involved in photosynthesis. They are a type of molecule that, as vitamins, can help prevent and treat diseases such as osteoporosis and cardiovascular disease. In addition, the antioxidant activity of quinone improves overall health. Many cancer drugs that have been approved or are currently being tested are quinone-related compounds. Unfortunately, quinones are toxicologically active because they are photoproducts of air pollutants (El-Najjar et al. 2011).

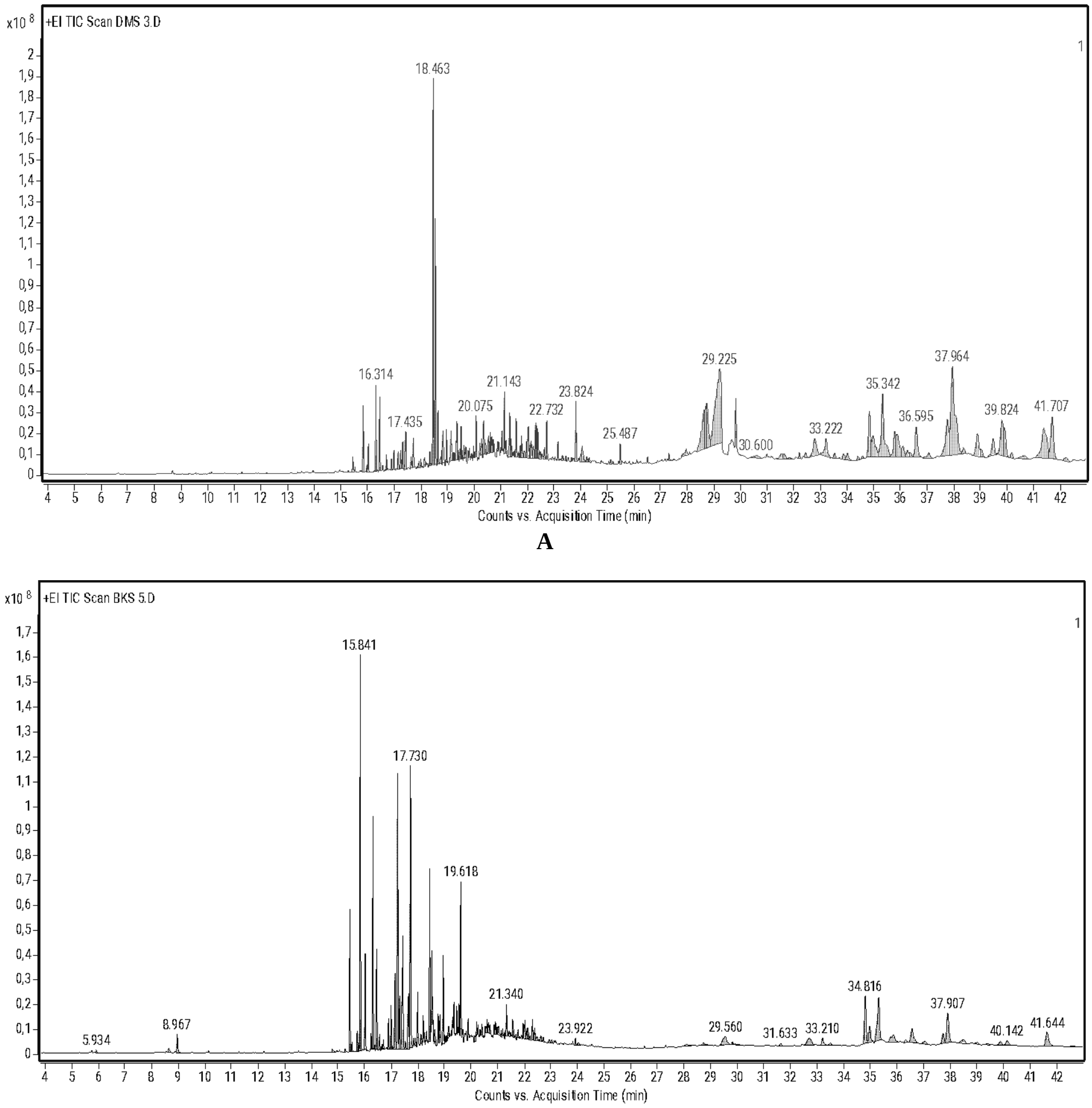

Figure 2. GC-MS chromatogram of *Sandoricum koetjape*. A. Leaf. B. Stem

Table 2. Identified chemical compounds by GC-MS analysis in the methanol leaf extract of *Sandoricum koetjape*

No.	RT (min)	Area (%)	Chemical name
1	15,448	0.84	1H-Cyclopenta[1,3]cyclopropa[1,2]benzene
2	16,314	3.31	Naphthalene,decahydro-1,6-dimethyl-4-(1-methylethyl)
3	16,898	0.51	1,4-Methanocycloocta[d]pyridazine
4	16,996	0.87	Neoalloocimene
5	18,446	17.04	1H-Cycloprop[e]azulen-7-ol
6	18,532	10.86	beta-Cedrene oxide
7	18,833	1.49	(7R,8S)-cis-anti-cis-7,8-Epoxytricyclo[7.3.0.0(2,6)]dodecane
8	18,966	1.11	Fonenol
9	19,353	1.83	4-mesityl-4-Phosphacyclopentene
10	19,468	0.50	(1R,4S)-4-Isopropyl-1,6-dimethyl-1,2,3,4-tetrahydronaphthalen-1-ol
11	19,503	1.24	[4-(Methoxymethoxy)-5-hexynylidene]cyclohexane
12	19,774	0.52	1-[3-(2,6,6-Trimethyl-cyclohex-2-enyl)-4,5-dihydro-3H-pyrazol-4-yl]-ethanone
13	20,213	0.75	1,4-Methanoazulen-9-one
14	20,537	1.15	Methyl commate E
15	20,612	1.11	Duvatriendiol
16	21,143	2.47	3,7,11-Trimethyl-2,6,10-dodecatrien-1-ol
17	21,346	2.61	Isoaromadendrene epoxide
18	21,53	0.40	1,7,7,7b-Tetramethyldecahydrocyclopropa[5,6]naphtho[1,8a-b]oxirene
19	21,565	2.11	1,4a,7,7-Tetramethyldecahydrocyclopropa[7,8]azuleno[3a,4-b]oxirene
20	21,733	0.54	4a,7-Methano-4aH-naphth[1,8a-b]oxirene
21	22,345	1.56	10-Methoxy-nb-alpha-methylcorynantheol
22	22,484	0.55	Nerolidol-epoxyacetate
23	23,148	0.85	19-di-torulosol
24	25,129	0.53	5-Oxatricyclo[8.2.0.04,6]dodecane
25	27,318	0.38	2-Methyl-4-(2,6,6-trimethylcyclohex-1-enyl)but-2-en-1-ol
26	29,103	23.71	Cyclodecacyclotetradecene,14,15-didehydro
27	33,21	3.64	Geranyl linalool isomer
28	34,816	8.34	Solanesol
29	35,873	3.82	Androstenediol
30	41,667	5.35	3-Ketoestra-6,13-dimethyl-4-ene-17-ol

Table 3. Identified chemical compounds in the stem methanol extract of *Sandoricum koetjape* by GC-MS analysis

No.	RT (min)	Area (%)	Chemical name
1	8,643	0.42	Octamethyl-cyclotetrasiloxane
2	8,961	1.39	1-Amino-3-(5',8'-dihydronaphth-1'-yloxy)propan-2-ol
3	14,795	0.07	4-Methylbenzoyl isothiocyanate
4	15,448	12.54	1H-Cyclopenta[1,3]cyclopropa[1,2]benzene
5	15,783	0.88	4,11-diyneOxacyclotetradeca
6	16,245	0.62	1,8-Cyclotetradecadiyne
7	16,314	10.79	Naphthalene, decahydro-1,6-dimethyl-4-(1-methylethyl)
8	16,898	2.19	1,4-Methanocycloocta[d]pyridazine
9	16,996	3.60	Neoalloocimene
10	18,446	11.70	1H-Cycloprop[e]azulen-7-ol
11	18,532	8.05	beta-Cedrene oxide
12	18,966	12.89	Fonenol
13	19,503	1.21	[4-(Methoxymethoxy)-5-hexynylidene]cyclohexane
14	19,89	2.15	N-Oxide benzo[b]-1,4-diazabicyclo[2.2.2]octene
15	20,537	2.71	Methyl commate E
16	20,612	2.01	Duvatriendiol
17	21,189	2.37	1-[3-(2,6,6-Trimethyl-cyclohex-2-enyl)-4,5-dihydro-3H-pyrazol-4-yl]-ethanone
18	21,346	3.95	Isoaromadendrene epoxide
19	21,444	1.10	5R,8R,9S,10R)-2-Formyl-3-hydroxy-5-isopropenyl-8-8-methyl-(3a10)-octahydronaphthO
20	21,565	3.09	1,4a,7,7-Tetramethyldecahydrocyclopropa[7,8]azuleno[3a,4-b]oxirene
21	21,733	0.78	4a,7-Methano-4aH-naphth[1,8a-b]oxirene
22	22,096	1.13	9-Isopropyl-1-methyl-2-methylene-5-oxatricyclo[5.4.0.0(3,8)]undecane
23	22,339	2.10	Tetraneurin - A - diol
24	22,345	1.03	10-Methoxy-nb-alpha-methylcorynantheol
25	22,484	1.16	Nerolidol-epoxyacetate
26	34,816	6.80	Solanesol
27	37,733	2.80	5-(7a-Isopropenyl-4,5-dimethyl-octahydroinden-4-yl)-3-methyl-pent-2-enal
28	42,597	0.46	Tris(tert-butyldimethylsilyloxy)arsane

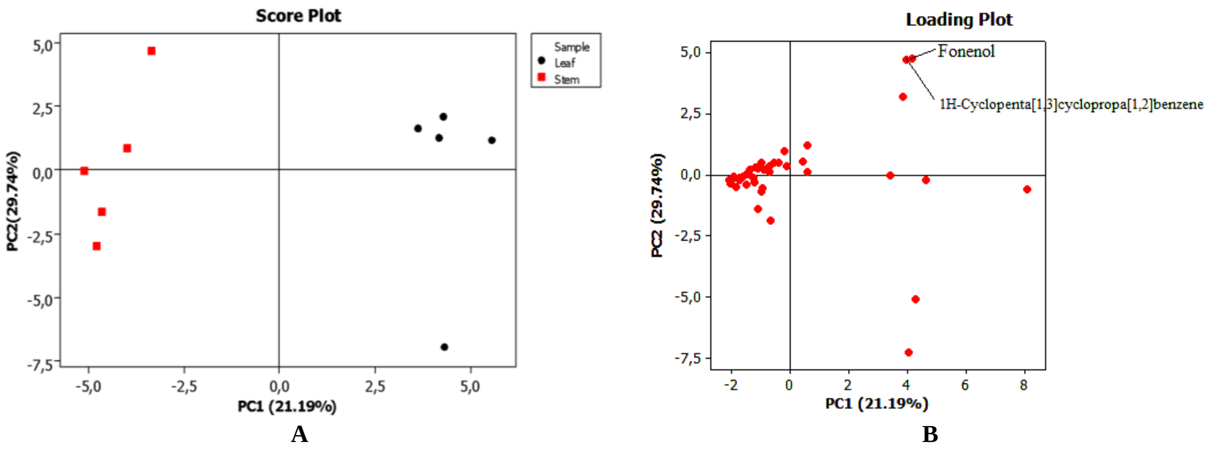

Figure 3. Bar graphs of the metabolites lettered in the loading plot. A. 1-H-Cyclopenta[1,3]cyclopropa[1,2]benzene. B Fonenol

Triterpenoids are included in the terpenoid group with a 30-carbon chain (Harborne 1980). Several triterpenoids have been isolated from *S. koetjape* fruit hulls and stem bark, such as bryononic acid, koetjapic acid, bryonolic acid, and indicic acid (Nassar et al. 2010). Koetjapic and katonic acid have been investigated against ten cancer cell lines (Nassar et al. 2010). Triterpenoids have been identified from *S. koetjape*, such as secotriterpene, oleane-type triterpene, limonoids, hydroxymultiflorane triterpene, and secomultiflorane-type triterpene (Wijaya 2022). Triterpenoids from *S. koetjape* have ichthyotoxyc and anticarcinogenic effects (Ismail et al. 2003). Koetjapic acid and tetracyclic triterpenoids from *S. koetjape* have antiangiogenic and antimetastatic effects (Bailly 2022). Triterpenoid compounds have various pharmacological activities. Triterpenoid compounds have various pharmacological activities, such as antibacterial against *S. aureus* and *E. coli*. In addition, triterpenoids compounds have several biological activities, such as anti-inflammatory, anticarcinogenic, or antitumor (Zhang et al. 2013), immunomodulatory, cytotoxic, and hemolytic properties (Top et al. 2017). Triterpene is a component of the cell membrane (Yan et al. 2017)

Tannins are astringent polyphenols found in plants that can bind and precipitate proteins. Because tannins exhibit strong protein-clotting activity, they are used to clarify and preserve white wine in Japan (Andersen and Jordheim 2010). In addition, tannins have antibacterial, antioxidant, and antidiarrheal activities. Tannins have also been shown to inhibit tumor growth because they can inhibit the DNA topoisomerase enzyme and reverse transcriptase and antifungal activity (Brighenti et al. 2021), antibacterial, antifungal, and insecticide (Wijaya 2022). Tannins were detected in *S. koetjape*.

Figure 1 shows the total phenolics are significantly higher in the leaves than in the stem of *S. koetjape*. Phenolic compounds are derivative compounds of benzoic acid and cinnamic acid. These compounds have high antioxidant activity in vitro, which benefits human health. Phenolic compounds can act as antioxidants by scavenging hydroxyl radicals, superoxide radical anions, some organic radicals, peroxyl radicals, peroxynitrite, and singlet oxygen. In addition, phenolics act as chain-breaking antioxidants and reducing agents. Phenolic compounds are also important in changing cell signaling pathways (Panche et al. 2016).

A previous study showed that *S. koetjape* methanol extract has many bioactivities. *S. koetjape* leaf of methanol extract has antioxidant and xanthine oxidase inhibitory activities (Hamzah et al. 2020). Methanol extract of *S. koetjape* has anti-inflammatory activity against TPA - the induced mouse ear inflammation model (Rasadah et al. 2012). Methanol extract from the *S. koetjape* stem has anti-fungi activity against *C. albicans* (Warsinah et al. 2015). *S. koetjape* methanol extract is antibacterial against *S. aureus* and *Bacillus* spp. and has antioxidant activity (Mesén-Mora et al. 2019) and antimicrobial activities against *B. subtilis*, *P. aeruginosa*, and *S. aureus* (Azziz et al. 2015).

The result of GC-MS analysis showed that the major compounds in the leaves of *S. koetjape* are Cyclodecacyclotetradecene,14,15-didehydro (23.71%), 1H-Cycloprop[e]azulen-7-ol (17.04%), and Solanesol (8.34%). However, the major constituents in stems are Fonenol (12.89%), 1H-Cyclopenta[1,3]cyclopropa[1,2]benzene (12.54%), and 1H-Cycloprop[e]azulen-7-ol (11.70%). In metabolomic analysis, PCA has been widely used to identify underlying factors that distinguish two or more groups (Tanabe et al. 2021). The non-targeted approach is used in this study to obtain a wide range of metabolites to differentiate the type of sample used. PCA demonstrated data separation based on sample type, the stem, and the leaf of *S. koetjape*. According to the loading plot, 1H-Cyclopenta[1,3]cyclopropa[1,2]benzene and fonenol are two components that are very effective in categorizing samples based on their type.

The highest compound in the leaves of *S. koetjape* is Cyclodecacyclotetradecene, 14,15-didehydro. Cyclodecacyclotetradecene is a fatty acid found in *Wraburgia ugandensis* Sprague with antimicrobial activity against *S. aureus*, *C. albicans*, and *Escherichia coli* (Otieno 2016). It is also obtained in the cactus plant *Saussurea lappa*, which has antibacterial activity against *S. aureus* and *Salmonella* sp. (Omer et al. 2019). Cyclodecacyclotetradecene is the chemical composition of the n-hexane fraction of *Sonneratia apetala* seeds. It has antibacterial, anti-diarrhoeal, analgesic, and cytotoxic activities (Hossain et al. 2017). The hydrocarbon also forms in olefin metathesized products by the reaction between two 9,12,15-octadecatrienoic acid methyl esters and 9,12-octadecanoic acid methyl esters as intermediate (Vyshnavi et al. 2014).

Leaves and stems contain 1H-Cycloprop[e]azulen-7-ol. 1H-Cycloprop[e]azulen-7-ol is a volatile metabolite that effectively differentiates between the stem and leaves of *S. koetjape*. The area (%) of 1H-Cycloprop[e]azulen-7-ol in the stem is higher than in the leaf samples. It is also found in black pepper (*Piper ningrum* L.), which has antibacterial activities against *Escherichia coli* and *S. aureus* (Chen W et al. 2018). 1H-Cycloprop[e]azulen-7-ol found in *Solanum melongena* has pesticide activity (Umaru et al. 2019).

Solanesol is the third most abundant compound in the leaves of *S. koetjape*. Solanesol is terpene alcohol composed of nine isoprene units that accumulate primarily in plants. Solanes in 33.21-36.28% affect the environment, such as temperature increase, drought, and pathogen infection. Solanesol is also an important intermediate in the pharmaceutical synthesis of coenzyme Q10, SDB, and vitamin K2. Solanesol and its derivatives have a high level of bioactivity, including neuroprotective, antitumor, antiulcer, antimicrobial, and anti-inflammatory activities (Yan et al. 2017). In addition, solanesol scavenges free radicals; therefore, it has antioxidant properties. Medicinal values of solanesol are pharmaceutical intermediate, for delivery of the hydrophobic drug, for multimerization of bioactive peptide, and for mediating vesicle fusion (Yan et al. 2019).

The highest compound in the leaves of *S. koetjape* is fonenol. Fonenol is also the metabolite that effectively differentiates the stem and leaf of *S. koetjape*. The area (%) of fonenol in the stem is higher than in leaf samples. Fonenol is sesquiterpene alcohol which is an essential oil. Sesquiterpene alcohol is terpene consisting of three isoprene units with the addition of alcohol. It has a diverse range of biological and pharmacological activities such as antibacterial, antifungal, insecticidal, anti-inflammatory, anticancer or antitumor, anti-trypanosomal, anti-leishmanial, anti-schistosomal, anti-malarial, antiulcer activities (Chan et al. 2016). Fonenol is found in *Araucaria bidiwili* shoot, which has anti-inflammatory and antipyretic potentialities (Abdelhameed et al. 2021). It is the main constituent of the volatile compounds of *Piper longum* L leaf (Hieu et al. 2018) and an aroma compound found in *Asteriscus maritimus* (L.) Less. flowers from Spain and *Xylopia phloiodora* (Serhati 2010; Pala-Paul et al. 2014)

The second most abundant compound in the leaves of *S. koetjape* is 1H-Cyclopenta[1,3]cyclopropa[1,2]benzene. It is also known as β-cubebene (Groot and Schmidt 2016). It is an essential oil found in medicinal plants *Premna tomentosa* (Priyadarshini et al. 2017), in the leaves and fruits of *Piper aduncum* (Wibawa et al. 2019), *Artemesia lavandulaefolia* (Yuan et al. 2010), *Cunninghamia lanceolata* biomass (Qing-Zhia et al. 2012), a bioactive phytochemical compound of *Cyperus aucheri* Jaub. (Abu-Serag et al. 2019), and in Chinese ginger (*Zingiber officinale* Roscoe) rhizomes (Ding et al. 2012; Choudhari and Kareppa 2013).

In summary, the phytochemical analysis of both leaf and stem extracts of *S. koetjape* revealed the presence of alkaloids, flavonoids, quinone, triterpenoids, and tannin. Total phenolics are higher in the leaves than in the stem. Saponin and steroids were not detected. The GC/MS analysis indicates that the leaf extract has more identified compounds (30) than the stem extracts (28). The major compounds from GC-MS analysis of the stem of *S. koetjape* were fonenol (12.89%), 1H-Cyclopenta[1,3] cyclopropa[1,2]benzene (12.54%), and 1H-Cycloprop[e] azulen-7-ol (11.70%), while, the major compounds of the leaf of *S. koetjape* were 14,15-didehydro-Cyclodeca-cyclotetradecene (23.71%), 1H-Cycloprop[e]azulen-7-ol (17.04%), and Solanesol (8.34%). According to PCA, the two main components of the variable can account for 50.92% of the total variance (PC1 is 21.19% and PC2 is 29.74%). These results indicate that the two components effectively categorize samples with distinct characteristics. The groups were divided based on the type of sample used: *S. koetjape* stem and leaf samples. According to the loading plot, 1H-Cyclopenta[1,3] cyclopropa[1,2]benzene and fonenol are two components that are very effective in categorizing samples based on their type. Both metabolites are higher in the stem than in the leaf.

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REFERENCES

Abdelhameed MF, Asaad GF, Ragab TIM, Ahmed RF, El Gendy AENG, Abd El-Rahman SS, Elshamy AI. 2021. Oral and topical anti-inflammatory and antipyretic potentialities of *Araucaria bidiwillii* shoot essential oil and its nanoemulsion in relation to chemical composition. Molecules 26: 5833. DOI: 10.3390/molecules26195833.

Abu-Serag NA, Al-Garaawi NI, Ali AM, Alsirrag MA. 2019. Analysis of bioactive phytochemical compound of (*Cyperus aucheri* Jaub.) by using Gas Chromatography-Mass Spectrometry. IOP Conf Ser Earth Environ Sci 388: 012063. DOI: 10.1088/1755-1315/388/1/012063.

Andersen ØM, Jordheim M. 2010. Chemistry of flavonoid-based colors in plants. Comprehensive Natural Products II: Chemistry and Biology. DOI: 10.1016/b978-008045382-8.00086-1.

Astiti NPA, Ramona Y. 2021. GC-MS analysis of active and applicable compounds in methanol extract of sweet star fruit (*Averrhoa carambola* L.) leaves. Hayati J Biosci 28 (1): 12-22. DOI: 10.4308/hjb.28.1.12.

Awang-Jamil Z, Aminuddin MF, Zaidi BQ, Basri AM, Ahmad NHT. 2021. Phytochemicals and antimicrobial analysis of selected medicinal plants from Brunei Darussalam. Biodiversitas 22 (2): 601-606. DOI: 10.13057/biodiv/d220211.

Azziz SSSA, Alimon H, Sani AA, Daud NNN. 2015. Phytochemical screening and antimicrobial activities of seed extracts from *Sandoricum koetjape*. Proceedings ICNP 4 (1): 104-104. DOI: 10.2174/2210289201304010104.

Badal S, Delgoda R. 2017. Pharmacognosy: Fundamentals, Applications and Strategies. Chennai: Mica Haley.

Bailly C. 2022. The health benefits of santol fruits and bioactive products isolated from *Sandoricum koetjape* Merr.: A scoping review. J Food Biochem 46 (7): 10-12. DOI: 10.1111/jfbc.14152.

Blench R. 2008. A history of fruits on the Southeast Asian mainland. Occasional Paper 4: 115-137.

Brighenti V, Iseppi R, Pinzi L, Mincuzzi A, Ippolito A, Messi P, Pellati F. 2021. Antifungal activity and DNA topoisomerase inhibition of hydrolysable tannins from *Punica granatum* L. Intl J Mol Sci 22 (8): 4175. DOI: 10.3390/ijms22084175.

Bumi MB, Heliawaty L, Hermawati E, Syah YM. 2019. Four limonoids from the seeds extract of *Sandoricum koetjape*. J Nat Med 73 (3): 641-647. DOI: 10.1007/s11418-019-01303-w.

Chan WK, Tan LTH, Chan KG, Lee LH, Goh BH. 2016. Nerolidol: A sesquiterpene alcohol with multi-faceted pharmacological and biological activities. Molecules 21 (5): 529. DOI: 10.3390/molecules21050529.

Chen W, Zou L, Chen W, Hu YCH. 2018. Effects of black pepper (*Piper nigrum* L.) chloroform extract on the enzymatic activity and metabolism of *Escherichia coli* and *Staphylococcus aureus*. J Food Qual 30 (1): 1-9. DOI: 10.1155/2018/9635184.

Choudhari SS, Kareppa BM. 2013. Identification of bioactive compounds of *Zingiber officinale* Roscoe rhizomes through Gas Chromatography and Mass Spectrometry. Intl J Pharm Res Develop 5 (2): 16-20.

Ding SH, An KJ, Zhao CP, Li Y, Guo YH, Wang ZF. 2012. Effect of drying methods on volatiles of Chinese ginger (*Zingiber officinale* Roscoe). Food Bioprod Proc 90 (3): 515-524. DOI: 10.1016/j.fbp.2011.10.003.

El-Najjar N, Gali-Muhtasib H, Ketola RA, Vuorela P, Urtti A, Vuorela H. 2011. The chemical and biological activities of quinones: Overview and implications in analytical detection. Phytochem Rev 10 (3): 353-370. DOI: 10.1007/s11101-011-9209-1.

Elisabetsky E, Costa-Campos L. 2006. The alkaloid alstonine: A review of its pharmacological properties. Evid Based Complement Alternat Med 3 (1): 39-48. DOI: 10.1093/ecam/nek011.

Groot AC, Schmidt E. 2016. Essential Oils. In História, Ciências, Saúde-Manguinhos. DOI: 10.1590/s0104-59702001000400018.

Hamzah FN, Subandi, Sujarwo W, Septama AW, Mozef T. 2020. Antioxidant and Xanthine oxidase inhibitory activities of kecapi (*Sandoricum koetjape* (Burm. f) Merr.) leaf extract. IOP Conf Ser Mater Sci Eng 833: 012012. DOI: 10.1088/1757-899X/833/1/012012.

Harborne JB. 1980. Phytochemical Methods: A guide to modern techniques qf plant analysis. London: Chapman and Hall.

Hieu LD, Hoi TM, Thang TD, Eresanya OI, Ogunwande IA. 2018. Fonenol, the main constituent of the essential oil of the leaf of *Piper longum* L. Am J Essential Oil Nat Prod 6 (1): 16-19.

Hossain SJ, Islam MR, Pervin T, Iftekharuzzaman M, Hamdi OAA, Mubassara S, Shilpi JA. 2017. Antibacterial, anti-diarrhoeal, analgesic, cytotoxic activities, and GC-MS profiling of *Sonneratia apetala* (Buch.-Ham.) seed. Prev Nutr Food Sci 22 (3): 157-165. DOI: 10.3746/pnf.2017.22.3.157.

Ismail IS, Ito H, Mukainaka T, Higashihara H, Enjo F, Tokuda H, Yoshida T. 2003. Ichthyotoxic and anticarcinogenic effects of triterpenoids from *Sandoricum koetjape* bark. BiolPharm Bull 26 (9): 1351-1353. DOI: 10.1248/bpb.26.1351.

Kanthal LK, Dey A, Satyavathi K, Bhojaraju P. 2014. GC-MS analysis of bio-active compounds in methanolic extract of *Lactuca runcinata* DC. Pharmacognosy Res 6 (1): 58-61. DOI: 10.4103/0974-8490.122919.

Kaškonienė V, Maruška A, Kornyšova O, Charczun N, Ligor M, Buszewski B. 2009. Quantitative and qualitative determination of phenolic compounds in honey. Cheminė Technologija 52 (3): 74-80.

Lemoine R, Camera SL, Atanassova R, Dédaldéchamp F, Allario T, Pourtau N, Durand M. 2013. Source-to-sink transport of sugar and regulation by environmental factors. Front Plant Sci 4 (7): 272. DOI: 10.3389/fpls.2013.00272.

Malik A, Ahmad AR. 2014. Determination of phenolic and flavonoid contents of ethanolic extract of Kanunang leaves (*Cordia myxa* L.). Intl J PharmTech Res 7 (2): 243-246.

Mesén-Mora LD, Carvajal-Miranda Y, Álvarez-Valverde V, Rodríguez-Rodríguez G. 2019. Bioprospecting study, antibiotic and antioxidant activity of the santol's fruit (*Sandoricum koetjape*). Uniciencia 33 (1): 75-82. DOI: 10.15359/ru.33-1.6.

MoH. 2020. Farmakope Indonesia edisi VI. In Kementerian Kesehatan Republik Indonesia.

Nassar ZD, Aisha AA, Majid AMSA. 2010. The pharmacological properties of terpenoids from *Sandoricum koetjape*. WebMedCentral, 13 (11): 1-11.

Omer RE, Koua F, Abdelhag I, Ismail M. 2019. Gas Chromatography-mass Spectrometry profiling of the costus plant *Saussurea lappa* (Decne.) C.B. Clarke root extracts and their antibacterial activity. J App Pharm Sci 9 (5): 73-81. DOI: 10.7324/JAPS.2019.90509.

Otieno AJ. 2016. Antimicrobial activity and phytochemical profiles of *Warbugiau gandensis* Sprague (Canellaceae) extracts from different populations across the Kenyan rift valley. [Thesis]. Kenyatta University, Nairobi.

Pala-Paul J, Usano-Alemany J, Soria AC. 2014. Essential oil composition of *Asteriscus maritimus* (L.) Less. from Spain. J Plant Biol Soil Health 1 (2): 4-9. DOI: 10.13188/2331-8996.1000006.

Panche A, Diwan A, Chandra S. 2016. Flavonoids: An overview. J Nutr Sci 5: e47. DOI: 10.1017/jns.2016.41.

Priyadarshini G, Elizabeth AA, Anthony J, Rao MRK, Prabhu K, Ramesh AKV. 2017. The GC MS analysis of one medicinal plant, *Premna tomentosa*. J Pharm Sci Res 9 (9): 1595-1597.

Qing-zhia M, Dang-quan Z, Lu-yang X, Qi-mei L. 2012. Study on health function of *Cunninghamia lanceolata* biomass by TD-GC-MS. Mater Sci Forum 704: 577-580. DOI: 10.4028/www.scientific.net/MSF.704-705.577.

Rasadah MA, Khozirah S, Aznie AA, Nik MM. 2012. Anti-inflammatory agents from *Sandoricum koetjape* Merr. Indian Drugs 49 (4): 5-11. DOI: 10.53879/id.49.04.p0005.

Rohman R, Maryanto S, Sudania W, Utomo C, Liwang T. 2022. Nitrogen uptake efficiency induced fumarate hydratase activity in oil palm seedlings. J Prot Proteomics 13: 117-124. DOI: 10.1007/s42485-022-00087-0.

Saadah S, Tulandi SM. 2020. Phytochemical screening and total phenolics analysis of stem and leaf extracts of *Sandoricum koetjape*. Jurnal Agroindustri Halal 6 (2): 164-171. DOI: 10.30997/jah.v6i2.3156. [Indonesian]

Sreevidya N, Mehrotra S. 2003. Spectrophotometric method for estimation of alkaloids precipitable with Dragendorff's reagent in plant materials. J AOAC Intl 86 (6): 1124-1127.

Serhati TC. 2010. Chromatography of aroma compounds and fragrances. Springer. DOI: 10.1007/978-3-642-01656-1.

Tanabe K, Hayashi C, Katahira T, Sasaki K, Igami K. 2021. Multiblock metabolomics: An approach to elucidate whole-body metabolism with multiblock principal component analysis. Comput Struct Biotechnol J 19: 1956-1965. DOI: 10.1016/j.csbj.2021.04.015.

Top H, Sarikahya NB, Nalbantsoy A, Kirmizigul S. 2017. Immunomodulatory, hemolytic properties and cytotoxic activity potent of triterpenoid saponins from *Cephalaria balansae*. Phytochemistry 137: 139-147. DOI: 10.1016/j.phytochem.2017.02.015.

Umaru I, Umaru H, Omorinoye O. 2019. Phytochemical profiling and assessment of pesticides residues in *Solanum melongena* and its health implications. J Biochem Intl 6 (1): 49-55.

Vyshnavi Y, Prasad R, Karuna M. 2014. Synthesis of industrially important platform chemicals via olefin metathesis of Palash fatty acid methyl esters. Eur J Chem 5 (3): 532-535. DOI: 10.5155/eurjchem.5.3.532-535.1088.

Warsinah W, Kusumawati E, Sunarto S. 2015. Identification of compound antifungi of *Sandoricum koetjape* stem and activity to *Candida albicans*. Trad Med J 16 (3): 170-178. DOI: 10.22146/TRADMEDJ.8055.

Wibawa IPAH, Saraswaty V, Kuswantoro F, Andila PS, Wardhani PK, Tirta IG, Sujarwo W. 2019. A study of essential oil from an invasive *Piper aduncum* L. Jurnal Biologi Udayana 23 (2): 50. DOI: 10.24843/jbiounud.2019.v23.i02.p02.

Wijaya. 2022. Ethnomedicinal, phytochemicals, and pharmacological aspects of sentul (*Sandoricum koetjape*). Biol Med Nat Prod Chem 11 (1): 20-26.

Wirata IN, Agung AAG, Arini NW, Nuratni NK. 2021. Sentul fruit (*Sandoricum koetjape*) peel as anti-Inflammation for gingivitis after scaling. J Health Med Sci 4 (4): 27-36. DOI: 10.31014/aior.1994.04.04.190.

Yan N, Liu Y, Liu L, Du Y, Liu X, Zhang HZ. 2019. Bioactivities and medicinal value of Solanesol and its accumulation, extraction technology, and determination methods. Biomolecules 9 (8): 334. DOI: 10.3390/biom9080334.

Yan N, Liu Y, Zhang H, Du Y, Liu X, Zhang Z. 2017. Solanesol biosynthesis in plants. Molecules 22 (4): 510. DOI: 10.3390/molecules22040510.

Yuan H-B, Shang L-N, Wei C-Y, Ren B-Z. 2010. Comparison of constituents and insecticidal activities of essential oil from *Artemisia lavandulaefolia* by steam distillation and supercritical-CO_2 fluid extraction. Chem Res Chinese Univ 26 (6): 888-892.

Zhang Y, Ning Z, Lu C, Zhao S, Wang J, Liu B, Liu Y. 2013. Triterpenoid resinous metabolites from the genus *Boswellia*: Pharmacological activities and potential species-identifying properties. Chem Cent J 7: 153. DOI: 10.1186/1752-153X-7-153.