Chemical Composition, Extraction Methods and Uses of *Zanthoxylum rhetsa* (Roxb.) DC.: A Review

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Summary

Zanthoxylum rhetsa (Roxb.) DC. is a spice plant in the *Rutaceae* family distributed throughout the tropical regions of the world, found mainly in India, Myanmar, Thailand, Laos and Vietnam. In Vietnam, the Son La province in the northwest accounts for 71% of the total output. *Z. rhetsa* is mainly used as a famous spice of specialties in the northwest mountains. Slightly different from Vietnam, in Northern Thailand, and in India, *Z. rhetsa* leaf is the main ingredient as an edible vegetable in daily meals. In addition to being a spice, fruit and seed powder of *Z. rhetsa* are also applied to preserve meat. *Z. rhetsa* is also used as a traditional medicine in the treatment of diseases of the teeth, intestinal tract, and as an anti-inflammatory. It has outstanding biological activities such as antibacterial and antioxidant because this plant contains three major chemical compounds: alkaloids, phenolics and terpenoids. This paper reviews recent information on extraction methods of *Z. rhetsa* essential oil or extracts, its chemical composition and bioactivity of the chemical constituents, as well as potential uses in food technology and medicine.

Key words

antioxidant, drug, herb, medicine, *Zanthoxylum rhetsa* (Roxb.) DC.

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Received: August 14, 2022 | Accepted: July 11, 2023

Introduction

Zanthoxylum rhetsa (Roxb.) DC. is a woody plant with many conical spines that grow from the base to the top. The tree has a long stem that can range from 26 to 35 m. The pinnate leaves are 140 to 230 mm long, with 9 to 23 ovate or elliptical leaflets symmetrically on both sides. The flowers are yellow-green and bloom in clusters, and the flower season is usually between June and July. After flowering, it takes nearly 4 months to bear fruit, which is harvested in October or November. The fruit is originally green but turns dark brown to black when dry, exposing the seeds (Pham et al., 2021; Maduka and Ikpa, 2021; Aziz et al., 2022).

Zanthoxylum is a genus in the family *Rutaceae* - this family contains about 160 genera and 1600 different species. The genus *Zanthoxylum* contains about 250 species that have been studied and distributed mainly in tropical and temperate regions of North America, South America, Africa, Asia, and Australia (Guo et al., 2018; Okagu et al., 2021; Aziz et al., 2022).

Each region will have a different local name for *Z. rhetsa*, such as "bazna" in Bangladesh, "batangberduri" in Malaysia, "tirphal" in India (Maduka and Ikpa, 2021), "makhwaen" in Thailand, and "mac khen" in Vietnam.

In fact, this plant has been used for centuries as food and a traditional drug to treat some diseases due to its precious bioactive compounds. Moreover, until now, food preservation technology has evolved and plays an important role in preserving many types of food. In the early stages, people knew many methods to preserve food but did not know the cause of food spoilage. Then, according to the history of scientific and technological development, people used more and more modern methods to preserve food, typically using additive compounds. When using chemical additives, there are potential risks that can be harmful to health; instead, natural preservative compounds are increasingly researched, developed, and more widely used to replace these harmful additives. Chemical compounds from *Z. rhetsa* containing significant biological activity can be applied in the field of food preservation because of the safety they bring (Antony et al., 2019). They are also gaining the interest of scientists in the human health field.

Chemical Composition of *Z. rhetsa*

Z. rhetsa contains many mineral components; although they do not provide energy, the minerals and other organic compounds are widely used in medicine and play an important role in many activities of the body. Renthlei et al. (2016) and Kuladip and Varsha (2018) report that a large amount of major and trace minerals are found in *Z. rhetsa* leaves and ripened fruit. The data is displayed in Table 1.

Nutrition is an important aspect of human health where minerals play a key role for healthy growth. Nitrogen plays an important role in living organisms; *Z. rhetsa* fruit accounts for a small amount of 160 mg 100 g^{-1}. Calcium is also an essential element in the development process of humans and a considerable amount is available in *Z. rhetsa* (541.16 mg 100 g^{-1} for leaves and 1,000 mg 100 g^{-1} for fruit). Potassium content in the leaves is over 2,200 mg 100 g^{-1} and is nearly 7 times higher than that in ripened fruit. In addition, ripened fruit is also rich in magnesium (1,001 mg 100 g^{-1}) and sodium (860 mg 100 g^{-1}). Although *Z. rhetsa* contains only a small amount of iron (16.19 mg 100 g^{-1} in leaves and 2.2 mg 100 g^{-1} in ripened fruit), it is higher than that in other fruit such as melon and grapes (Cristina et al., 2014), which is similar to other trace minerals. In general, this material is loaded with a high amount of minerals. Although all of these minerals play many important roles in the living body, such as helping to synthesize hemoglobin, transporting oxygen in the blood to the muscles and organs, building bones and existing in enzymes, they may threaten health in long-term consumption.

In addition to the above minerals, the crude protein content is determined to be quite high in the leaves of *Z. rhetsa* at 13.75% (Seal and Chaudhuri, 2015) compared with some other species of the same genus. Typically, *Zanthoxylum macrophylla* leaf protein only accounts for 5.95% (Ilodibia et al., 2017) or 1.11% present in leaves of *Zanthoxylum ovalifolium* (Pavani and Naika, 2021).

For ripened fruit, the moisture content is 49.2%, whereas other components have a smaller content, such as crude protein (1%), crude lipids (4%), and crude fiber (4.8%) (Kuladip and Varsha, 2018); however, the dried fruit possesses a high essential oil content (approximate 5%) (Bubpawan et al., 2015) compared to other materials (citrus peels, etc.) (Tan et al., 2011).

From the nutritional point of view, *Z. rhetsa* leaves are a rich source of protein; this is also an interesting property of *Z. rhetsa* compared to other species. In addition, the chemical components of *Z. rhetsa* are quite diverse, with all parts of the plant having different contents. Depending on the purpose of exploitation, various isolation methods with suitable materials can be used.

Extraction Methods of Bioactive Compounds from *Z. rhetsa*

As we know, many reports reveal that *Z. rhetsa* possesses some bioactive compounds, such as phenolic compounds, essential oil and alkaloids. They have many benefits for human health, so extracting them from the initial material is quite necessary. At present, there are quite a few extraction methods of *Z. rhetsa* depending on the scale of application. Each method is applied with its own extraction parameters, with materials in each locality affecting the yield and extraction capacity.

Maceration

Maceration was a widely used method before the invention of modern methods because of its simplicity and low cost. After the plant material is sun-dried or dried by hot air, it is separated into pods, fruits, and seeds and ground into a coarse powder. This method was used to extract non-volatile and volatile compounds (polyphenols, alkaloids, essential oil, etc.) from raw material with organic solvents. According to study of Imphat et al. (2021), the authors divided the powder of *Z. rhetsa* seeds into two groups that were soaked in hexane and ethanolic solvent (2:1 solvent to powder ratio) for three days. Then, the extract was filtered through Whatman filter paper and subjected to rotation to evaporate the solvent and obtain the crude extract. The results also showed that the seed powder had the highest yield when extracted with hexane and 95% ethanol. Terpinen-4-ol was the main compound extracted (35.13%), followed by *p*-cymene (10.95%), terpinenyl acetate (6.65%), cuminol (5.60%), and limonene (5.48%).

Table 1. Mineral components of *Z. rhetsa*

Minerals	Content (mg 100 g^{-1})	
Major mineral elements	Leaves (Renthlei et al., 2016)	Ripened fruit (Kuladip and Varsha, 2018)
Nitrogen (N)	-	160 ± 0.02
Phosphorus (P)	304.81 ± 1.89	100 ± 0.02
Potassium (K)	2214.34 ± 24.77	330 ± 0.01
Sodium (Na)	-	860 ± 0.02
Calcium (Ca)	541.16 ± 23.33	1000 ± 0.11
Magnesium (Mg)	-	1001 ± 0.05
Sulfur (S)	262.6 ± 4.63	100 ± 0.2
Trace mineral elements	Leaves (Renthlei et al., 2016)	Ripened fruit (Kuladip and Varsha, 2018)
Copper (Cu)	1.34 ± 0.07	1.2 ± 0.2
Ferrous (Fe)	16.19 ± 1.03	2.2 ± 0.06
Manganese (Mn)	28.59 ± 1.87	3.1 ± 0.3
Zinc (Zn)	2.84 ± 0.1	2 ± 0.04

Note: "-": not tested

Terpinen-4-ol has been shown to possess antibacterial, antifungal, antioxidant, antitumor, and anti-inflammatory activities. Shapira et al. (2016) also stated that terpinen-4-ol strongly improved the effect of several chemotherapeutic and biological agents.

Distillation

Among the extraction methods, steam distillation is the most common and is carried out in the laboratory. For lab scale, the Clevenger apparatus is usually used to distill essential oil (volatile compounds) from this material. After 6 distillation hours, the essential oil (EO) obtained is dried with anhydrous sodium sulfate (Na_2SO_4) and stored tightly closed in a dark container at -20 °C before chemical and biological analysis. The obtained results show that EO of fresh fruit of *Z. rhetsa* from Thailand contains 30 chemical components. Terpinen-4-ol and sabinene are the main extracted components (32.33% and 22.51%, respectively), followed by *γ*-terpinene, decyl aldehyde, and octanal (7.97%, 5.97%, and 5.35%, respectively) (Wongkattiya et al., 2018). EO of the fresh fruit of *Z. rhetsa* from Vietnam possesses sabinene (41.13%), terpinolene (27.05%), and limonene (7.84%) as major components (Pham et al., 2021). This difference could be explained due to the various distillation conditions and source of materials. In addition, we can exploit EO from many parts of this plant (stem bark, leaf petiole, fruit petiole, leaves, and fruit). Therefore, the quality of the obtained EO from these parts is different.

Soxhlet

This method is popular and often used by authors from India. The study of Kumar et al. (2019) used fresh fruit as the main ingredient collected from the state of Maharashtra. After that, the raw materials were pre-treated to separate the fruits, seeds, and seed coats and dried at room temperature to reduce the size of the materials. Next, all were separately homogenized into a fine powder. Similary to maceration, the Soxhlet method also used organic solvent with a reflux system to extract bioactive compounds. Kumar et al. (2019) isolated phenolic compounds from the seed pods and the whole fruit of *Z. rhetsa* with hexane, carbon tetrachloride, acetone and methanol. The results showed that phenolic content in extracts of the seed pods and the whole fruit were 0.033 mg gallic acid equivalent (GAE) mL^{-1} and 0.0392 mg GAE mL^{-1}, respectively. In addition, in order to further investigate the antioxidant activity of these extracts, the authors tested the inhibitory activity of DPPH (2,2-diphenyl-1-picrylhydrazyl) and the results showed that the antioxidant capacity of these two parts also accounted for the highest proportion of these extracts (96% of DPPH inhibition and 95% of DPPH inhibition, respectively).

In fact, the maceration and soxhlet methods take an extended period of time for extraction and are not friendly to the environment due to the use of a large volume of organic solvents. Fortunately, there are now some green solutions to overcome these weak points with modern extraction methods, such as microwave-assisted extraction, ultrasonic-assisted extraction, enzyme-assisted extraction, supercritical carbon dioxide extraction, and others. In my opinion, these are important gaps that future studies should focus on filling. For *Z. rhetsa*, there are still many interesting things to discover.

Bioactive Compounds of *Z. rhetsa*

In general, plants possess many biologically active compounds, so *Z. rhetsa* is no exception. Some previous literature reported that *Z. rhetsa* had three types of bioactive compounds, including alkaloids, phenolics and terpenoids, as well as other compounds, such as vitamins and saponins (Kumar et al., 2019; Thejashwini et al., 2020). In fact, there are many scientific studies that have isolated these substances from *Z. rhetsa*.

Alkaloid Compounds

The definition of the term alkaloid, to this day, is still a controversial term in many different fields. Through decades-long definitions, alkaloids can be defined as organic, N-containing compounds that are often heterocyclic and of plant or animal origin. Alkaloids are usually produced by several amino acids and have strong pharmacological effects. The small amounts of alkaloids can cause bioactivity, so they are widely used in medicine (Aniszewski, 2007).

Alkaloid found in *Z. rhetsa* has about 29 substances, but the same genus and each species will have different alkaloid compositions. The found alkaloid compounds in *Z. rhetsa* are more abundant than in species of the genus *Zanthoxylum*. To demonstrate this difference, alkaloid components of three representative species of the genus *Zanthoxylum* (*Z. rhetsa*, *Z. armatum*, and *Z. nitidum*) are shown in Table 2. In general, these compounds exist in all parts of the plant such as stem bark, bark, spines on the bark, root bark, roots, and bark.

In Table 2, there are clear differences between different species in the same genus. Compounds such as columbamine, skimmianine, dictamnine and zanthodioline occur in two species, *Z. rhetsa* and *Z. armatum*, but not in *Z. nitidum*. In addition, other substances appear only in one of the three mentioned plant species, which further demonstrates the difference in phytochemical composition between species. Depending on the purpose of the study, we can choose the most suitable method to isolate these compounds and apply them in the medical field and pharmaceutical technology.

Among the above alkaloids, columbamine is a tetrahydroisoquinoline alkaloid that plays an important role in medicine, especially its activity against various types of cancer. According to the study of Lei et al. (2019) on the biological effects of columbamine in colon cancer - one of the most common malignancies of the gastrointestinal tract, the results of this study demonstrated columbamine's ability to significantly inhibit proliferation, metastasis, and colon malignancy growth. In fact, the medicinal properties of alkaloids in *Z. rhetsa* are still being studied clearly.

Phenolic Compounds

The second largest group of compounds in this plant are phenolic compounds, a group of small molecules characterized by their structure having at least one phenol functional group. These compounds have been investigated for their antioxidant activity involving hydroxyl groups and phenolic rings (Al Mamari, 2021). All of the phenolic compounds present mainly in the bark belong to the subgroups of flavonoids, lignans, and coumarins (Santhanam et al., 2013; Maduka and Ikpa, 2021). According to the report of Santhanam et al. (2013), total phenol content with ethyl acetate and butanol fractions of *Z. rhetsa* bark extract is 20.47 and 14.14 mg GAE g^{-1} of the dry weight (DW), respectively. These results are similar to those for ginger (*Zingiber officinale* Rosc.) in the study of Quoc (2020) (22.79 mg GAE g^{-1} DW) and higher than that of galangal (*Alpinia galanga* (L.) Willd., 7.49 mg GAE g^{-1} DW) (Quoc, 2021).

To date, some specific phenolic compounds have been extracted because of their pharmaceutical properties; for instance, a flavanone named hesperetin has been isolated from the ethyl acetate extract of the bark of *Z. rhetsa*. In addition, yangambin and kobusin belong to the group of phenolic lignans; they were also identified and isolated in this material (Santhanam et al., 2016). Many precious phenolic compounds have also been found in other parts of the plant; for instance, Karanjalker et al. (2022) revealed that many specific phenolic compounds existed in the fruit pericarp of *Z. rhetsa*, such as ferulic, caffeic, sinapic, *p*-coumaric, *t*-cinnamic, and gentisic acid. Out of 18 identified compounds, ferulic and caffeic acid accounted for 64.27% and 12.38%, respectively. Therefore, we can say that this is a potential material that is enriched in phenolic compounds and has high antioxidant activity.

There are many solvents that can be used to extract phenolic compounds, such as methanol, hexane, chloroform, ethyl acetate, and butanol. Sesamin, yagambin, kobusin, eudesmin and mangnolin, common phenolic constituents extracted in *Z. rhetsa* appeared in four of the five extracts (except butanol) and most abundantly in the chloroform extract. Phenolic substances will be highly dependent on the extraction solvent. From the comparative data of phenolic components based on extraction solvent, it can be assumed that chloroform is the typical solvent in extracting phenolic components in *Z. rhetsa* to give the results with the best efficiency (Santhanam et al., 2016).

Among them, sesamin is widely used in the medical field; however, sesamin in *Z. rhetsa* has not been studied, while *Zanthoxylum riedelianum*, a plant from the same genus as *Z. rhetsa*, was studied by Lima et al. (2007). Its extract also possessed sesamin. Sesamin in this study displays significant anti-inflammatory activity. In addition, another study has suggested that sesamin acts as an anti-carcinogen, reduces blood pressure and serum lipids, and inhibits cholesterol absorption and synthesis in rats (Kumar and Singh, 2015). Thus, the presence of sesamin in *Z. rhetsa* is an advantage to exploit and apply it in medicine compared to other materials.

Terpenoid Compounds

Terpenoids, also known as isoprenoids, are a large, diverse group of natural compounds and are abundant in essential oils commonly found in the fruits, seeds, leaves, seed coat, and whole plant of *Z. rhetsa* (most abundant in the fruit). To date, 80 terpenoids have been isolated by many authors from almost all parts of *Z. rhetsa* (Aziz et al., 2022). All plants in general and individual *Z. rhetsa* plants, in particular, will have different values for the chemical composition of EOs, especially terpenoid compounds. The main compositions of essential oils extracted from *Z. rhetsa* was illustrated in Table 3 (Jirovetz et al., 1998;

Table 2. Alkaloid composition of the genus *Zanthoxylum*

No.	Alkaloids	*Z. rhetsa* (Aziz et al., 2022)	*Z. armatum* (Phuyal et al., 2019)	*Z. nitidum* (Liang et al., 2006)
1	2'-Episimulanoquinoline	x	-	-
2	2,11-Didemethoxyvepridimerine B	x	-	-
3	8-Methoxy-N-methylflindersine	x	-	-
4	Berberine	-	x	-
5	Rhetsine	x	-	-
6	Zanthonitrile	-	x	-
7	Chelerythrine	x	x	x
8	Columbamine	x	x	-
9	Dictamnine	x	x	-
10	Dihyochelerythrine	-	-	x
11	Hydroxy evodiamine	x	-	-
12	8-Methoxydictamnine	-	x	-
13	Liriodenine	-	-	x
14	Magnoflorine	-	x	-
15	Nevadensin	-	x	-
16	Nitidine	-	-	x
17	Oxyavicine	-	-	x
18	Rhetsidimerine	x	-	-
19	Rutaecarpine	x	-	-
20	Sanguinarine	-	-	x
21	Simulano quinoline	x	-	-
22	Skimmianine	x	x	-
23	TMB (6,7,8-trimethoxy-2,3-methylendioxybenzophenantridine)	-	-	x
24	Zanthodioline	x	x	-
25	Berberubine	-	-	x
26	Coptisine	-	-	x
27	Rhetsinine	x	-	-
28	Rhetine	x	-	-
29	Quinazoline-6-carboxylic acid	x	-	-
30	1-Methoxy-7,8-dehydrorutaecarpine	x	-	-
31	6-Acetonyldihydro-chelerythrine	x	-	-
32	Dihydrochelerythrine	x	-	-
33	8-Acetonyldihydronitidine	x	-	-
34	Chelerybulgarine	x	-	-
35	Reticuline	x	-	-
36	Allocryptopine	x	-	-
37	Usambanoline	x	-	-
38	Dihydronitidine	x	-	-
39	N-Methyllaurotetanine	x	-	-
40	Nitidine	x	-	-
41	Arnottianamide	x	-	-
42	Fagaridine	x	-	-
43	Oxynitidine	x	-	-

Note: "x": present; "-": absent

Bubpawan et al., 2015; Pham et al., 2021). The differences in these values imply that the conditions of the environment, light, cultivation, soil, and extraction methods more or less affect the chemical compositions directly (Quoc, 2022).

In general, the chemical compositions of *Z. rhetsa* EOs are quite diverse, including various groups such as monoterpenes, oxygenated monoterpenes, sesquiterpenes, hydrocarbons, and ketones. The study of Pham et al. (2021) found different concentrations of these compounds in the EOs extracted from stem bark, leaf petiole, fruit petiole, fresh leaf, fresh fruit and dried fruit by hydrodistillation. The different concentrations led to different bioactivity of samples. This method of hydrodistillation is still widely used in Vietnam at the lab and industrial scales.

Application of *Z. rhetsa*

Medicine

In traditional medicine, all parts of *Z. rhetsa*, such as the roots, bark, spines, and leaves are widely used to prepare various medicinal preparations. For instance, Indians use a paste made from the spine of *Z. rhetsa* to relieve pain and improve lactation in breastfeeding mothers (Payum et al., 2013). According to Maduka and Ikpa (2021), the fruit of *Z. rhetsa* can treat toothache, dizziness, bloating, malaria, urinary diseases, and rheumatism, whereas the bark has positive properties to be a remedy for stomach and chest pains, and also treats snake bites. In addition, leaves of *Z. rhetsa* are considered befinecial in treating intestinal worm infections (Yadav and Tangpu, 2009). Also, many previous studies revealed that *Z. rhetsa* was an antimicrobial, antiseptic and antidiabetic agent; it can treat inflammatory dermatosis, cholera, and rheumatism (Nimachow et al., 2011; Singh et al., 2014).

In addition to the applications in traditional medicine, *Z. rhetsa* is also widely used in modern medicine. Some of the main compounds present in this plant have been reported to be used in drug preparation technology. For instance, columbamine can be used to treat colon cancer (Lei et al., 2019) and sesamin can reduce cardiovascular disease risk (Dalibalta et al., 2020). One of the typical applications of modern medicine is that of an *in vitro* thrombolytic model used to evaluate the hemolytic ability of different extracts from the root bark of *Z. rhetsa* along with streptokinase. From the above research model, Zohora et al. (2019) confirmed the complete thrombolytic activity of the root of the plant. In addition, Santhanam et al. (2016) pointed out that the presence of bioactive compounds in *Z. rhetsa*, such as lignans and alkaloids, had cytotoxic effects towards the B16-F10 melanoma cell line. According to the evidence mentioned above, *Z. rhetsa* has a huge potential in medicine; however, in developing countries, uses of this plant are not exploited thoroughly, especially in Vietnam. We need to focus on other bioactive compounds to discover their effects on human health. This is also a common trend in the world today.

Food

Many previous studies recorded that *Z. rhetsa* was used as a popular condiment in some Asian countries (Pham et al., 2021; Maduka and Ikpa, 2021). *Z. rhetsa* leaf is the main ingredient for pork salads and curries in Northern Thailand and India. In Vietnam, the majority of ethnic people in the northern provinces and the Central Highlands use *Z. rhetsa* fruit as a spice in daily foods to replace pepper because of its pungent properties. *Z. rhetsa* is also a spice that helps to make a name for famous specialties throughout Vietnam, such as buffalo meat upstairs kitchen, pa pỉnh tộp, and "chẩm chéo" salt. Also, in the production of pork bologna, *Z. rhetsa* not only plays the role of spice but also a natural preservative with antibacterial and antioxidant properties. Pork bologna is a popular product widely used in food processing in Vietnam and it is a product with its own unique flavor that is made from ground pork but is different from sausages.

As a way to increase profits, processors often add Borax (sodium tetraborate decahydrate), a chemical that helps increase the toughness of pork bologna and enhances its antibacterial and antifungal activity. Therefore, many studies have been established to find a natural alternative to help products with the desired structure as well as prolong the shelf life. Rongsensusang et al. (2021) have studied and successfully applied spices (perilla, rose, and *Z. rhetsa*) in the processing of pork patties. The results showed that the oxidation parameters, such as TBARS (Thiobarbituric acid reactive substances), peroxide value, and microbial count of the control sample were significantly higher, whereas the antioxidant capacity and sensory scores of treated samples improved strongly after storage. This proves that the spices have positive efficacy in the preservation process, especially *Z. rhetsa*. In addition, Antony et al. (2019) suggest that the dry fruits of *Z. rhetsa* are a natural antioxidant to control the rancidity of peanut oil. The presence of dry fruit powder decreases peroxide and para-anisidine values compared to control samples. One of the most interesting things about *Z. rhetsa* is that its seed cover extract (SCE) is an important component of active films including gum arabic, polyvinyl alcohol, sorbitol, and SCE. Ground chicken meat packed in these films improves shelf life from 6 to 12 days in chilled conditions (Muppalla and Chawla, 2018).

Cosmetics

The use of extracts from the plant as active ingredients in sunscreen formulations is being studied extensively for their safety. This has been proved by the study of Santhanam et al. (2013); the authors have shown that the ethyl acetate and butanol fractions of *Z. rhetsa* have significant antioxidant activity and reduce exposure to harmful ultraviolet light for skin. This study points out that *Z. rhetsa* bark extract can be used as a natural active agent in broad-spectrum sunscreens and anti-aging cosmetic preparations. Other results also indicated that *Z. rhetsa* bark extract was a potential dermo protective ingredient in skincare or cosmeceutical products (Santhanam et al., 2016). Also, Thejashwini et al. (2020) report that *Z. rhetsa* fruit and leaves are considered mouth fresheners and are used in tooth care. Overall, the application of *Z. rhetsa* in cosmetics is still limited compared to other fields; however, the recent findings open many future research directions for this material.

Table 3. Chemical composition of essential oils extracted from dried fruits of *Z. rhetsa* from various regions

No.	Compounds	Content (%)		
		South India (Jirovetz et al., 1998)	Son La (Vietnam) (Pham et al., 2021)	Nan (Thailand) (Bubpawan et al., 2015)
1	Thujene	-	0.61	1.24
2	*α*-Pinene	3.87	0.67	5.92
3	Sabinene	47.12	33.71	6.57
4	*β*-Myrcene	0.74	2.02	4.47
5	*α*-Phellandrene	0.48	0.11	14.75
6	*β*-Phellandrene	2.11	0.35	1.87
7	*β*-Ocimene	-	2.55	4.02
8	*γ*-Terpinene	3.64	3.34	4.5
9	*trans*-Sabinene	-	-	0.54
10	*cis*-Sabinene hydrate	-	0.65	-
11	*α*-Terpinolene	0.71	30.37	2.36
12	Linalool	0.76	0.84	2.02
13	Terpinene	3.45	2.03	0.27
14	Terpinen-4-ol	6.61	7.73	9.22
15	Cryptone	-	-	0.81
16	*α*-Terpineol	7.73	3.27	2.66
17	Carvotanacetone	-	-	1.35
18	Geraniol	-	-	2.3
19	2-Undecanone	-	-	0.66
20	Carvacrol	-	-	1.54
21	*β*-Caryophyllene	0.63	0.11	0.79
22	*α*-Humulene	-	-	0.16
23	Germacrene-D	0.07	0.27	0.4
24	*δ*-Cadinene	-	-	0.18
25	Cyclododecane	-	-	0.15
26	*o*-Cymene	-	0.23	-
27	Limonene	4.06	8.29	-
28	*cis*-*p*-Menth-2-en-1-ol	-	0.42	-
29	*trans*-*p*-Menth-2-en-1-ol	-	0.31	-
30	*p*-Cymen-8-ol	-	0.32	-
31	Decanal	-	0.34	-
32	Octyl acetate	-	0.23	-
33	*trans*-Piperitol	-	0.13	-
34	Geranyl acetate	-	0.63	-
35	*β*-Pinene	5.99	-	-
36	*p*-Cymene	3.08	-	-
37	*β*-Elemene	1.58	-	-
38	Nonanal	0.89	-	-
39	Octanol	0.67	-	-
40	*γ*-Cadinene	0.57	-	-
41	Camphene	0.55	-	-

Note: "-": absent

Conclusion

There is a growing interest in the application of *Z. rhetsa* in medicine, cosmetics, and food system. *Z. rhetsa* contains many significant natural compounds, especially three major chemical groups, including alkaloids, polyphenols and terpenoids. These compounds are responsible for different biological activities, primarily antibacterial and antioxidant activities during food preservation, increasing the shelf life of the product. In addition, *Z. rhetsa* can treat many diseases (cardiovascular, vomiting, cough, dysentery, headache, etc.) and be used in skin care products. This paper also provides information on *Z. rhetsa* to compare the difference in regions, the same genus and different species of the chemical components. Therefore, this document can provide support to researchers who wish to conduct further studies on the application of *Z. rhetsa* in food technology in order to find optimal preservation methods. In addition, *Z. rhetsa* is also a good candidate for sunscreen or cosmeceutical or medicinal purposes due to its precious bioactive compounds.

Acknowledgement

The authors acknowledge Le Xuan Hiep and Huynh Ngoc Hieu of the Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City (Vietnam) for providing helpful advice in this study.

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