Rafidain Journal of Science

https://rsci.uomosul.edu.iq

Vol. 34, No.1, pp. 121-127, March/ 2025

Review Article

Plant Terpenes

Alaa M.D. Al-Haidari **Ansam G. Abdulhalem**

Department of Biology/ College of Science/ University of Baghdad/ Iraq

p-ISSN: 1608-9391
e -ISSN: 2664-2786

Article information

Received: 3/9/2024
Reviced: 3/10/2024
Accepted: 4/11/2024

DOI: 10.33899/rjs.2025.186501

corresponding author:
Alaa M.D. Al-Haidari
alaadhafer2015@sc.40baghdad.edu.iq
Ansam G. Abdulhalem
ansam.ghzi@sc.uobaghdad.edu.iq

ABSTRACT

Different plants have been reported to be used in folk medicine which used a variety of plants in treatment of many diseases. These plants contained a various chemical constituent and which called secondary metabolic compounds such as phenols, alkaloids and terpenes. Because of biochemical as well as evolutionary decision-making in biological activities. There are about 25000 types of it produced in plants, terpenes are the major components of plant-derived essential oils especially monoterpenes as well as diterpenes which used as antibacterial and as food preservers. Terpenes and terpenoids have a variety of biological applications such as anti-inflammatory, antioxidant, anti-microbial, anti-allergic and anti-cancer properties, these terpenes are used in a wide range of industries, including cooking field, cosmetic, and pharmaceutical ones…. etc. This review is focused on the chemical structure, classification according to isoprene units, synthesis and presences of terpenes in plants and their applications and uses.

Keywords: Secondary metabolites compounds, terpenes, classification, different applications.

INTRODUCTION

Plants produce two types of metabolic production; primary and secondary metabolic compounds (Croteau *et al*., 2000).

Primary metabolites are substances required for cellular functions including growth and reproduction that include nucleic acids, amino acids, lipids as well as carbohydrates. While secondary metabolites including the substances that are created as a result of stress, such as when acting as a herbivorous deterrent (Keeling and Bohlmann, 2006).

The plants have produced the secondary metabolic compounds, which are not required for cell viability but also for the species survival (Mushtaq *et al.*, 2020).

The secondary metabolic compounds are present in three basic types (terpens, alkaloids and phenols) as an in natural product; terpenes about 25000 different types, phenolic compounds about 8,000 types and alkaloids about12,000 different types (Croteau *et al*., 2000).

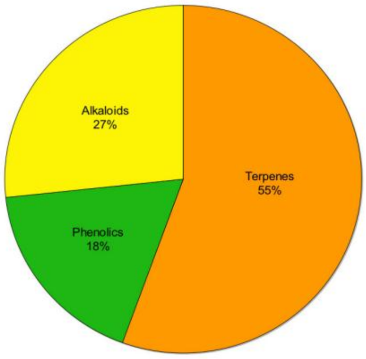

Fig. 1: The main types of plant secondary metabolites. According to Croteau *et al*. (2000).

Terpenes are defined as chemicals having simple hydrocarbon structures, including pinene, myrcene, limonene, and terpinene, while terpenoids, or oxygen-containing hydrocarbons, are a modified class of terpenes with distinct functional groups and oxidized methyl groups moved or removed at various positions (Perveen, 2018). Furthermore, it has been demonstrated that terpenoids are one of the secondary metabolites that aromatic and medicinal plants produce and that they are essential for disease resistance (Burt, 2004). According to Hyldgaard *et al*. (2012) terpenoids can be divided into phenols, epoxides, alcohols, aldehydes, esters, ethers, and ketones, examples of terpenoids are include carvacrol, citronellal, geraniol, linalool, linalyl acetate, piperitone, menthol, and thymol.

Synthesize of terpenes

Both the cytosolic mevalonic acid (MVA) pathway and the plastid's 2C-methyl-D-erythritol-4-phosphate (MEP) pathway are responsible for the synthesis of terpenes and terpenoids. These pathways lead to the formation of precursors called isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP) **(**Oldfield and Lin, 2012; Stephane and Jules, 2020).

Terpenes presence in plants

The main compounds of volatile oils are terpeneoids, especially monoterpenes, sesquiterpenes and diterpenes (Mercedes *et al.*, 2020)

Volatile molecules represent 85-99% of essential oil of *Citrus* species, monoterpenes and sesequiterpenes being the most prevalent (González-Mas, 2019).

Volatileoils are created, collected, secreted and subsequently stored in specialized secretary structures, these structures in general are divided into three types:

1. Glandular hairs or the trichomes in the families: Asteraceae and Lamiaceae e.g. sage, mint and chamomile.
2. Resin ducts or internal ducts such as in coniferous trees.

3. Secretory cavities such as in *Eucalyptus* and *Citrus* plants (schizolysigenous in Rutaceae as well as schizogenous origin in Myrtaceae) (Rios, 2016). Volatile oils belong to two groups:

1- Terpenes
2- Aromatic and aliphatic compounds.

The terpenes are the most typical and plentiful substances produced by plants. Volatile hemiterpenes, monoterpenes, and diterpenes are biosynthesised by the methyl-d-erythritol-4-phosphate pathway (MEP), while sesiquiterpenes are produced by the mevalonic acid pathway (MAV), The cytoplasm and plastids of the cells are where the production of terpenes is located (Cheng, 2007).

According to Raut and Karuppayil, (2014) the main botanical families that produce essential oils are the Abietaceae family which contain *Pinus pinaster* is a source of turpentine; one of the most significant family is the Lamiaceae, which *Ocimum basilicum* is among them and *Lavandula* spp., *Origanum majorana*, *Melissa officinalis*, *Origanum* spp., *Mentha* spp., *Pogostemon cablin, Salvia officinalis* and *Rosmarinus officinalis*; the Cupressaceae, containing Cupressus species, Thuja species, and Juniperus species; the Myrtaceae, containing *Eucalyptus* spp., *Myrtus* spp. and *Melaleuca quinquenervia*; the Lauraceae which contain *Laurus nobilis*, *Aniba rosaeodora, Pimenta dioica* and *Sassafras albidum*.

One of the most significant families, the majority of commerciallyavailable natural perfumes and flavors come from essential oils derived from citrus fruits, which are abundant in the *Rutaceae* family (Do *et al.,* 2015), Citrus species such as *Citrus limon*, *Citrus aurantiifolia*, *Citrus reticulat, Citrus sinensis,* and *Citrus aurantium,* as well as members of Asteraceae families, such as *Gaultheria procumbens*, *Ledum palustr*,and *Santolina chamaecyparissus*.

Allium species from the Alliaceae have received the most research by Chaubey (2013) and Mnayer *et al.* (2014) they demonstrated the insecticidal, antimicrobial and antioxidant effectiveness of the essential oils extracted from this plant; the Apiaceae, which the essential oils have demonstrated insecticidal abilities. *Cuminum cyminum, Foeniculum vulgarae, Petrosellinum crispum* and *Anethum graveolens* (Sousa *et al.,* 2015), and hepatoprotective potential and antioxidant such as *Coriandrum sativum* and *Carum carvi* (Samojlik *et al.,* 2010); the Poaceae, containing *Cymbopogon citratus* being the most significant representative, Rosaceae which include *Rosa* spp. (Dobreva and Kovacheva, 2010).

The natural antimicrobials found in essential oils that are used in the food sector could beused to preserve food which act as antimicrobials (Hyldgaard *et al*., 2012). Numerous essential oils, including *Citrus aurantium*, *Mentha arvensis*, *Mentha spicata*, *Artemisia alba*, and *Mentha arvensis*, have been approvedfor use in agriculture in Europe (Raveau *et al*., 2020).

The chemistry and classification of plant terpenes:

Isoprene is the basic unit of terpenes, which is a simple hydrocarbon molecule. Typically, a terpene is a hydrocarbon molecule, while terpenoid relates to a terpenee with addition of oxygen. Therefore,
the precursors to other metabolites like carotenoids, sterols, rubber, plant hormones, turpentine, and phytol (the tail of chlorophyll) are called isoperenoids. (Zwenger and Basu, 2008).

The isoprene unit, which serves as the building block for terpenes, is a five-carbon molecule with the general formula (C5H8) n. as showed in figure 2.

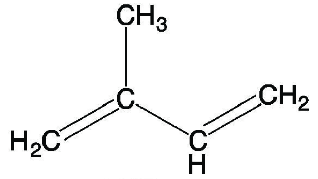

Figure 2: Chemical structure of isoprene unit.

The nomenclature of these compounds is extremely complex. They can be classified based on the value of n or the number of carbon atoms in the structure (Zwenger and Basu, 2008), as showed in table (1).

Table (1): Terpenes classification based on the number of isoprene units.

Class of terpenes	Chemical structure	No. of carbon atoms	Value of n
Monoterpenes	($C_{10}H_{16}$)	10	2
Sesquiterpenes	($C_{15}H_{24}$)	15	3
Diterpenes	($C_{20}H_{32}$)	20	4
Sesterpenes	($C_{25}H_{40}$)	25	5
Triterpenes	($C_{30}H_{48}$)	30	6
Tetraterpines	($C_{40}H_{64}$)	40	8
Polyterpines	(C_5H_8)n	>40	>8

n: is the number of isoperene unit.

Terpenes compounds are unsaturated hydrocarbons which related to the basic isoprene molecule (Cheng et al., 2007) demonstrated that Monoterpenes are the simplest terpenes and are produced through the biosynthesis of two isoprene molecules. Their composition is typically expressed using the formula (C5H8)n. Due to this, monoterpenes contain two isoprene units, sesquiterpenes have three isoprene units and diterpenes have four isoprene units,..etc. (Cheng et al., 2007).

Applications and uses of Terpenes:

Terpenes have many applications within human communities. They have been used to their fullest extent as taste enhancer and medications by the food and pharmaceutical industries. Many plant terpenes have been employed in medicine, and the terpenes family of organic compounds has contributed significantly to medical advancements (Salminen *et al*., 2008; Lange, 2016). More than 105 types of plant terpenes, including more than 12,000 from the diterpenes group alone, have been evaluated for therapeutic applications in nature (Zi *et al*., 2014). Due to the aforementioned pre-selection effects, this quantity is small in comparison to the numerous plant natural products that have been discovered using modern methods.

In order to reach sufficient quantities, many are only created in little amounts, either in accumulate entirely in specialized tissues, or in response to elicitation or significant advancements in plant breeding and genetic development (Kirby and Keasling, 2009; Lange *et al.*, 2011).

Islam *et al*. (2003) demonstrated that terpenes have demonstrated antibacterial properties; this is significant given an increase in bacteria that are resistant to antibiotics. According to reports, terpenes have antimicrobial properties against bacteria that are susceptible to antibiotics as well as those that are resistant to them. These effects are primarily caused by the terpenes' capacity to encourage cell rupture and inhibit the synthesis of proteins and DNA (´Alvarez-Martínez *et al*., 2021). Several terpenes showed antibacterial activity against *Staphylococcus aureus*, including carvacrol, carvone, eugenol, geraniol, and thymol (Gallucci *et al*., 2009). It has been demonstrated that a number of botanical chemicals, including azadirachtin, carvone, menthol, ascaridole, methyl eugenol, toosendanin, and volkensin, have antibacterial, antifungal, and insect pest repellant qualities (Pandey *et al*., 2017).

Terpenes, which are found in plant oils, have increased potential *in vivo* by suppressing a variety of bacterial species. For example, Prabuseenivasan *et al.* (2006) demonstrated that that *Pseudomonas aeruginosa* has showed broad-spectrum action against cinnamon oil. Terpene compositions can vary significantly between species. For instance, plant oils isolated from *Neolitsea foliosa* that have antibacterial activities contained sesquiterpenes like caryophyllene but did not contain monoterpenes (John *et al*., 2007).

Al-Haidari (2010) showed that the terpenes extracted from different plants have inhibitory effects against algae. The most well-known terpene is rubber, a polyterpene composed of isoprene repeating subunits that has been widely used by humans.

Menthol, camphor, pyrethrins (insecticides), cleansers, antiallergenic substances, and solvents are some additional significant terpenes. Other significant terpenes are digitoxigenin, carvone, limonene, hecogenin (a detergent), and rosin (a diterpene) (Croteau *et al*., 2000).

Terpenes also has application in agriculture as shown in a study by Villalba *et al*. (2006) they were suggested that if sheep ingested more grains, it was indicated that their tolerance to terpene consumption would improve. Terpenes also exhibited an effect on ungulate herbivory on other plants, which may assist balance ruminants' diets if they eat plants like sagebrush (*Artemesia sp*.). Gershenzon and Dudareva (2007) showed that plant terpenes have the ability to act as allelochemicals and draw in pollinators, repel herbivores, or draw in predators of herbivores.

CONCLUSIONS

Plant terpenes are one of the secondary metabolites compounds produced in plants, there are a large numbers of produced terpenes about 25000 types, the building unit of terpenes is isoperene unit, the number of these units is differ from one type of terpenes to another which distributed in a variety of plant families, However, these terpenes are very important compounds which act as antimicrobial, antialgal and have insecticidal and herbicidal activity and they have different applications such as foods, cosmetics, pharmaceutical and perfume industries.

REFERENCES

´Alvarez-Martínez, F.J.; Barraj´on-Catal´an, E.; Herranz-L´opez, M.; Micol, V. (2021). Antibacterial plant compounds, extracts and essential oils: An update review on their effects and putative mechanisms of action. *Phyto. medic*., ***90***, Article 153626. DOI: 10.1016/j.phymed.2021.153626 .

Al- Haidari, A.M. Dh. (2010). Evaluation of some locally grown plant extracts in control of algal growth, MSc thesis in Biology, College of Science, University of Baghdad.

Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods–A review. *Inter. J. Food Micro.* ***94,*** 223–253. DOI:10.1016/j.ijfoodmicro.2004.03.022Get rights and content

Chaubey, M.K. (2013). Insecticidal effect of *Allium sativum* (Alliaceae) essential oil. *J. Biol. Act. Prod. Nat.* **3**: 248–258. DOI:10.1080/22311866.2013.817733

Cheng, A.X.; Lou, Y.G.; Mao, Y.B.; Lu, S.; Wang, L. J.; Chen, X.Y. (2007). Plant terpeneoids: Biosynthesis and ecological functions**.** *J. Integ. P. Bio*. **49**, 179–186. DOI:1744-7909.2007.00395.

Croteau, R.; Kutchan, T.M.; Lewis, N.G. (2000). Natural products (secondary metabolites). In Buchanan B., Gruissem W. and Jones R. (Eds.), Biochemistry and molecular biology of plants. Rockville, M.D. *Amer. Soc. Plant Phy.*, 1250-1318.

Do, T.K.T; Hadji-Minaglou, F.; Antoniotti, S.; Fernandez, X. (2015). Authenticity of essential oils. *Trace Trends Anal. Chem*. **66**, 146–157. DOI:10.1016/j.trac.2014.10.007

Dobreva, A.; Kovacheva, N. (2010). Daily dynamics of the essential oils of *Rosa damascena* Mill. and *Rosa alba* L. *Agric. Sci. Tech.,* **2**, 71–74.

Gallucci, M.N.; Oliva, M.; Casero, C.; Dambolena, J.; Luna, A.; Zygadlo, J.; Demo, M. (2009). Antimicrobial combined action of terpenes against the food-borne microorganisms *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus*. *Flav. Frag. J.,**24***, 348–354. DOI:10.1002/ffj.1948

Gershenzon, J.; Dudareva, N. (2007). The function of terpene natural products in the natural world. *Nat. Chem. Biol*. **3,** 408- 412. DOI:10.1038/nchembio.2007.5

González-Mas, M.C.; Rambla, J.L.; López-Gresa, M.P.; Blázquez, M.A.; Granell, A. (2019). Volatile compounds in *Citrus* essential oils: Acomprehensive review. *Front. P. Sci*.,10 -12. DOI:10.3389/fpls.2019.00012

Hyldgaard, M.; Mygind, T.; Meyer, R.L. (2012). Essential oils in food preservation: Mode of action, synergies, and interactions with food matrix components. *Front. Micro*., **3**, 12- 19. DOI:10.3389/fmicb.2012.00012

Islam, A.K.; Ali, M.A.; Sayeed, A.; Salam, S.M.; Islam, A.; Rahman, M.; Khan, G.R.; Khatun, S. (2003). An antimircrobial terpeneoid from *Caesalpinia pulcherrima* Swartz.: Its characterization, antimicrobial and cytotoxic activities. *Asian J. Plant Sci*. **2**, 17-24. DOI:10.3923/ajps.2003.1162.1165

John, A.J.; Karunakran, V.P.; George, V. (2007). Chemical composition an antibacterial activity of *Neolitsea foliosa (*Nees) Gamble var. *caesia* (Meisner) Gamble. *J. Essent. Oil Res*. **19**, 498-500. DOI:10.1080/10412905.2007.9699962

Keeling, C.I.; Bohlmann, J. (2006). Genes, enzymes, and chemicals of terpeneoid diversity in the constitutive and induced defence of conifers against insects and pathogens. *New. Phytol*. **170**, 657-675. DOI:10.1111/j.1469-8137.2006.01716.

Kirby, J.; Keasling, J.D. (2009). Biosynthesis of plant isoprenoids: Perspectives for microbial engineering. *Annu. Rev. P. Biol*., **60**, 335355. DOI: 10.1146/annurev.arplant.043008.091955

Lange, B.M.; Mahmoud, S.S.; Wildung, M.R.; Turner, G.W.; Davis, E.M.; Lange, I.; Baker, C.; Boydston, R.A.; Croteau, R.B. (2011). Improving peppermint essential oil yield and composition by metabolic engineering. *Proc. Natl. Acad. Sci*. USA. 108, 16944–16949. DOI:10.1073/pnas.1111558108

Lange, B. M. (2016). Online resources for gene discovery and biochemical research with aromatic and medicinal plants. *Phyto. Rev*. 15, 489–510. DOI:10.1007/s11101-015-9450-0

Mercedes, V.; Adel, M. S.;Fabrizio, A. (2020). Phytotoxic effects and mechanism of action of essential oils and terpeneoids. A review. *Plants*: 1571-1623.

Mnayer, D.; Fabiano-Tixier, A. S.; Petitcolas, E.; Hamieh, T.; Nehme, N.; Ferrant, C.; Fernandez, X.; Chemat, F. (2014). Chemical composition, antibacterial and antioxidant activities of six essentials oils from the Alliaceae family. *Mole*., **19**, 20034–20053. DOI: 10.3390/molecules191220034

Mushtaq, W.; Siddiqui, M.B.; Hakeem, K.R. (2020). “Mechanism of Action of Allelochemicals.” *Allelopathy*; Springer: Berlin/ Heidelberg/ Germany. pp. 61–66. DOI:10.1007/978-3-030-40807-7_7

Oldfield, E.; Lin, F.Y. (2012). Terpene biosynthesis: Modularity rules. *Angew. Chem*. (*Inter. ed. Eng*.), **51**, 1124–1137.

Pandey, A.K.; Kumar, P.; Singh, P.; Tripathi, N.N.; Bajpai, V.K. (2017). Essential oils: Sources of antimicrobials and food preservatives. *Fron. Micr. bio.,* **7**, 2161. DOI:10.3389/fmicb.2016.02161.

Perveen, S.; Al-Taweel, A. (Eds.). (2018). Terpenes and terpenoids. BoD–Books on Demand.

Prabuseenivasan. *In vitro* antibacterial activity of some plant essential oils. BMC Complement. *Altern. Med*., **6**, 39. DOI:10.1186/1472-6882-6-39.

Raut, J.S.; Karuppayil, S.M. (2014). A status review on the medicinal properties of essential oils. *Ind. Crop. Prod*. **62**, 250–264. DOI: 10.1016/j.indcrop.2014.05.055

Raveau, R.; Fontaine, J.; Lounès-Hadj, S.A. (2020). Essential oils as potential alternative biocontrol products against plant pathogens and weeds: A review. *Foods,* **9**, 365-370. DOI:0.3390/foods9030365

Ríos, J.L. (2016). Essential oils: What they are and how the terms are used and defined. In Essential oils in food preservation, flavor and safety. *Academic Press*. 3-10

Salminen, A.; Lehtonen, M.; Suuronen, T.; Kaarniranta, K.; Huuskonen, J. (2008). Terpeneoids: Natural inhibitors of NF-B signaling with anti-inflammatory and anticancer potential. *Cell. Mol. Life Sci*. **65**, 2979–2999. DOI:10.1007/s00018-008-8103-5.

Samojlik, I.; Lakic, N.; Mimica-Dukic, N.; Dakovic-Svajcer, K.; Bozin, B. (2010). Antioxidant and hepatoprotective potential of essential oils of coriander (*Coriandrum sativum* L.) and caraway (*Carum carvi* L.) (Apiaceae). *J. Agric. Food Chem*., **58**, 8848–8853. DOI:0.1021/jf101645n.

Sousa, R.M.O.; Rosa, J.S.; Oliveira, L.; Cunha, A.; Fernandes-Ferreira, M. (2015). Activities of Apiaceae essential oils and volatile compounds on hatchability, development, reproduction and nutrition of *Pseudaletia unipuncta* (Lepidoptera: Noctuidae). *Ind. Crop. Prod*., **63**, 226–237. DOI: 10.1016/j.indcrop.2014.09.052.

Stephane, F.F.Y.; Jules, B.K.J. (2020). Terpenoids as important bioactive constituents of essential oils. Essential oils-bioactive compounds. *New Persp. Appl.*, 1-15.

Villalba, J.J.; Provenza, F.D.; Olson, K.C. (2006). Terpenes and carbohydrate source influence rumen fermentation digestibility, intake, and preference in sheep. *J. Anim. Sci*., **84**, 2463-2473. DOI:10.2527/jas.2005-716.

Zi, J.; Mafu, S.; Peters, R.J. (2014). To gibberellins and beyond! Surveying the evolution of (di) terpeneoid metabolism Annu. *Rev. Plant Biol*. **65**, 259–286. DOI: 10.1146/annurev-arplant-050213-035705

Zwenger, S.; Basu, C. (2008). Plant terpeneoids: Applications and future potentials. *Bio.tech. Molec. Bio. Rev*., **3**(1), 1-7.

التربينات النباتية

الاء محمد ظافر الحيدري **انسام غازي عبد الحليم**

قسم علوم الحياة/ كلية العلوم/ جامعة بغداد/ العراق

الملخص

تستخدم النباتات المختلفة في الطب الشعبي حيث تستخدم في علاج العديد من الامراض وذلك بسبب احتواءها على العديد من المكونات الكيميائية والتي تسمى مركبات الايض الثانوي كالفينولات والقلويدات والتربينات وبسبب التأثيرات الكيموحيوية المختلفة في الفعاليات البايولوجية المختلفة، هنالك حوالي 2500 نوع من التربينات التي تنتجها وتكونها النباتات.

التربينات وخاصة التربينات الاحادية والثنائية هي المكون الرئيسي للزيوت الاساسية في النباتات والتي تستخدم كمواد مضادة للبكتريا وايضا كونها مواد حافظة حيث تستخدم بكثرة في حفظ الأغذية وتملك العديد من الخصائص البايولوجية المختلفة مثل مضادات الالتهاب ومضادة للفعالية التأكسدية ولها تأثير ضد بكتيري وضد الحساسية بالإضافة الى خصائصها المضادة للسرطان لذلك تستخدم على مدى واسع في الصناعات المختلفة كالصناعات الغذائية ومواد التجميل بالإضافة الى الصناعات الدوائية الصيدلانية ... الخ.

هذه المقالة تسلط الضوء على التركيب الكيميائي للتربينات النباتية وطرق تصنيفها اعتمادا على عدد وحدات الايزوبرين المكونة لها وطرق تصنيعها داخل النبات واماكن تواجدها في النبات كذلك اهم التطبيقات والمجالات اللي تستخدم فيها.

الكلمات الدالة: مركبات الايض الثانوي، التربينات، التصنيف، التواجد، التطبيقات المختلفة.