REVIEW

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A Review on Terpenoids

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ABSTRACT-

Due to the presence of active chemicals like terpenes, phenols, alkaloids, etc., medicinal plants are recognised for their significance in a variety of applications, particularly pharmaceutical ones**.** Terpenoids are a very prominent class of natural compounds produced in diverse genera of plants, fungi, algae and sponges. They gained significant pharmaceutical value since prehistoric times, due to their broad spectrum of medical applications. This article provides a review of literature, biosynthesis and different plants producing terpenoids.

KEY WORDS- Metabolite, Volatile, Terpenoids, Isoprene,

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Introduction-

Plants produce primary and secondary metabolites which encompass a wide array of functions (1). Primary metabolites, which include amino acids, simple sugars, nucleic acids, and lipids, are compounds that are necessary for cellular processes. Secondary metabolites include compounds produced in response to stress, such as the case when acting as a deterrent against herbivores (2,3). Plant secondary metabolites may be referred to as plant natural products, in which case they illicit effects on other organisms. There are three broad categories of plant secondary metabolites as natural products; terpenes and terpenoids, alkaloids, and phenolic compound.

Terpenoids also form a group of naturally occurring compounds majority of which occur in plants, a few of them have also been obtained from other sources. Terpenoids are volatile substances which give plants and flowers their fragrance (4).

The term 'terpene' was given to the compounds isolated from terpentine; a volatile liquid isolated from pine trees. The simpler mono and sesquiterpene is chief constituent of the essential oils obtained from sap and tissues of certain plant and trees. The di and tri terpenoids are not steam volatile. They are obtained from plant and tree gums and resins. Tetraterpenoids form a separate group of compounds called 'Carotenoids'. The term 'terpene' was originally employed to describe a mixture of isomeric hydrocarbons of the molecular formula $C_{10}H_{16}$ occurring in the essential oils obtained from sap and tissue of plants, and trees. But there is a tendency to use more general term 'terpenoids' which include hydrocarbons and their oxygenated derivatives. Although this review focuses on plant terpenoids. In this review we discuss detailed about the classification biosynthesis and chemical test for the identification of terpenoids.

Isoprene Rule

Thermal decomposition of terpenoids give isoprene as one of the products. Otto Wallach pointed out that terpenoids can be built up of isoprene unit. (5). Isoprene rule states that the terpenoid molecules are constructed from two or more isoprene units.

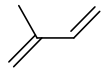


Fig. 1 Structure of Isoprene

Further Ingold suggested that isoprene units are joined in the terpenoid via 'head to tail' fashion.

But in some cases, they are joined by tail-to-tail fashion e.g., carotenoids.

CLASSIFICATION OF TERPENOIDS (6-10)

Terpenoids are of two types according to their occurrence:

1. **Simple terpenoids** -Simple terpenoids occur in steam volatile essential oil and obtained from a sap and plant tissues of certain plants and trees.
2. **Complex terpenoids** – Complex terpenoids are not steam volatile and obtained from gum and resin of plants

Most natural terpenoids hydrocarbon have the general formula $(C_5H_8)_n$. The $(C_5H_8)n$. is called as isoprene unit (2 -Methyl-1,3- Butadiene). So, these are also known as isoprenoids. They can also be classified on the basis of value of n or number of carbon atoms present in the structure of Isoprene unit (Table-1). Each class can be further subdivided into subclasses according to the number of rings present in the structure.

1. **Acyclic Terpenoids:** They contain open structure.

2. **Monocyclic Terpenoids**: They contain one ring in the structure.
3. **Bicyclic Terpenoids:** They contain two rings in the structure.
4. **Tricyclic Terpenoids:** They contain three rings in the structure.
5. **Tetracyclic Terpenoids:** They contain four rings in the structure.

Table -1. Classification on the basis of value of n or number of carbon atoms present in the structure

Number of carbon atoms	Value of N	Class
10	2	Monoterpenoids($C_{10}H_{16}$)
15	3	Sesquiterpenoid($C_{15}H_{24}$)
20	4	Diterpenoids($C_{20}H_{32}$)
25	5	Sesterterpenoids($C_{25}H_{40}$)
30	6	Triterpenoids($C_{30}H_{48}$)
40	8	Tetraterpenoids ($C_{40}H_{64}$)
>40	>8	Poly terpenoids (C_5H_8)n

Some examples of mono, sesqui and di Terpenoids**:**

1.Mono Terpenoids

1. **Acyclic Monoterpenoids**

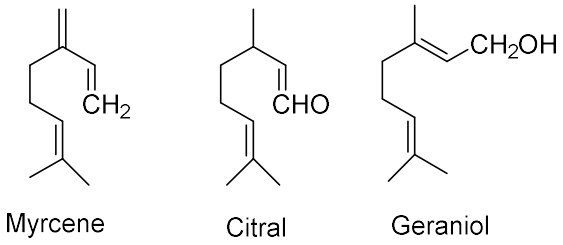


Fig. 2 Structure of Myrcene, Citral & Geraniol

2. **Monocyclic monoterpenoids**

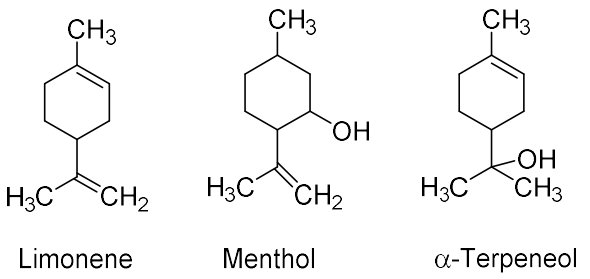


Fig. 3 Structure of Limonene, Menthol & α-Terpeneol

2.Bicyclic monoterpenoids: These are further divided into three classes.

a) Containing -6+3-membered rings

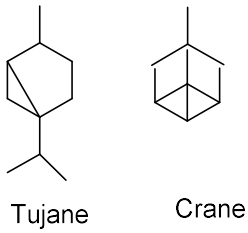


Fig.4 Structure of Tujane & Crane

b) Containing -6+4- membered rings

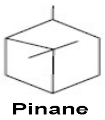


Fig. 5 Structure of Pinane

c) Containing -6+5-membered rings

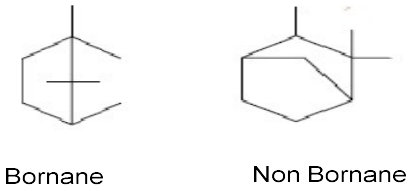


Fig. 6 Structure of Bornane & Non Bornane

3.Sesquiterpenoids

i) Acyclic sesquiterpenoids ii) Monocyclic iii) sesquiterpenoids

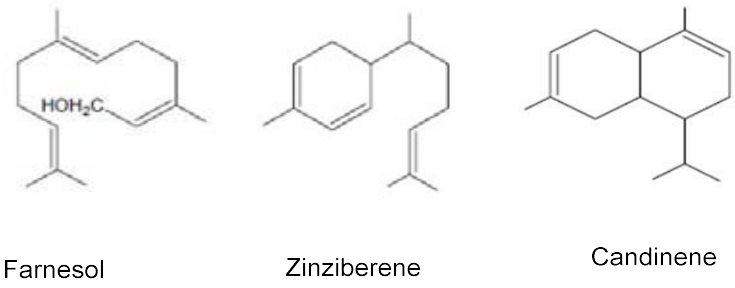


Fig. 7 Structure of Farnesol, Zingiberene & Candinene

PROPERTIES OF TERPENOIDS: (11-13)

3.1General Properties

- They are colourless, fragrant liquids lighter than water and are volatile in nature.
- A few of them are solids e.g., camphor.
- They are soluble in organic solvents, alcohol, and fixed oils and are usually insoluble in water.
- They are open chain or cyclic unsaturated compounds having one or more double bonds.
- They give addition reaction with hydrogen, halogen, acids, etc. and addition products possess antiseptic properties.
- They undergo polymerization and dehydrogenation.
- They are easily oxidized nearly by all the oxidizing agents.
- On thermal decomposition, most of the terpenoids yield isoprene as one of the products.
- They are optically active.
- They become darker in colour upon long exposure in air or sunlight.

3.2 Physical Properties

- Terpenoids are colourless liquid.
- Soluble in organic solvents and insoluble in water.
- Most of the terpenoids are optically active.
- Boiling point 150 – 1800^0 C.

3.3 Chemical Properties

- They are unsaturated compounds.
- They undergo addition reaction with hydrogen, halogen, and halogen acids.
- They undergo polymerization and dehydrogenation in the ring.
- On thermal decomposition, terpenoid gives isoprene as one of the products.

CHEMICAL TEST FOR TERPENOIDS

4.1 SALKAWOSKI TEST:

A few drops of concentrated sulphuric acid were added to the chloroform solution, shaken and allowed to stand. Lower layer turned yellow.

4.2 LIEBERMAN BURCHARD TEST

To the chloroform solution a few drops of acetic anhydride and 1ml of concentrated sulphuric acid was added. A deep red colour was produced.

4.3TRICHLORO ACID AND STANNIC CHLORIDE TEST

To the chloroform solution a few drops of thionyl chloride and a pinch of stannic chloride were added. A range of colours green, blue, purple and finally turning to red were obtained.

4.4 KAHLENBERG TEST

To 0.2 ml of the chloroform solution a few drops of antimony pentachloride and chloroform was added. A deep purple colour was observed.

4.5 Copper acetate Test:

Extract was dissolved in water and treated with 3-4 drops of copper acetate solution. Formation of emerald green indicates the presence of terpenoids

Difference between Terpenes and Terpenoids (14)

The key difference between terpenes and terpenoids is that terpenes are simple hydrocarbons whereas terpenoids are modified terpenes containing different functional groups and oxidized methyl groups**.** Terpenes and terpenoids are organic compounds. Terpenoids are derived from terpenes. Various different plants and animals produce terpenes, e.g. conifers and some insects. Terpenoids are also naturally occurring compounds.

Table -2. Difference between Terpenes & Terpenoids

Details	Terpenes	Terpenoids
Definition	Terpenes are large group of organic compounds which are simple hydrocarbons.	Terpenoids or isoprenoids are large group of organic compounds which are derived from isoprene.
Structure	Simple hydrocarbons compounds.	Hydrocarbon compound containing oxygen as functional group.
Types	Hemiterpene, Monoterpene, diterpene, sesquiterpene etc.	Hemiterpenoid, Monoterpenoid, diterpenoids, sesquiterpenoid etc.
Uses	Used in food industry, cosmetic, pharmaceutical and biotechnology industries.	Important in traditional herbal remedies.

BIOSYNTHESIS OF TERPENOIDS (15)

Terpenoids are important for plant survival and also possess biological and pharmacological properties that are beneficial to humans. In plants, isopentenyl diphosphate (IPP) and dimethylallyl diphosphate (DMAPP) can be synthesized via two compartmentalized pathways.

The mevalonic acid pathway of terpenoid biosynthesis operates in cytosol, theendoplasmic reticulum and peroxisomes as shown in **Fig. 8**.

Another part of terpenoid biosynthetic pathway starts in plastid by the condensation of pyruvic acid and glyceraldehydes-3-phosphate, which leads to the synthesis of1-deoxy-D-xylulose 5-phosphate as shown in **Fig.9.**

Fig. 8 The mevalonic acid pathway of terpenoid biosynthesis in cytosol

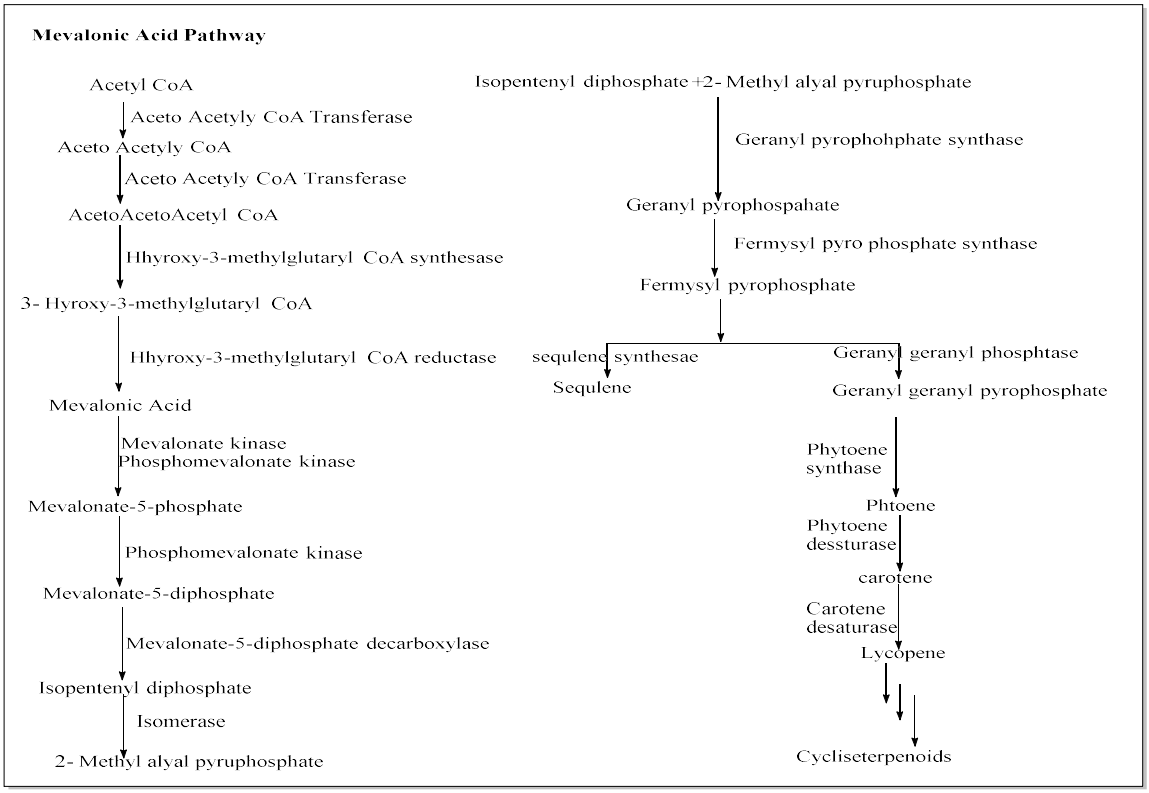
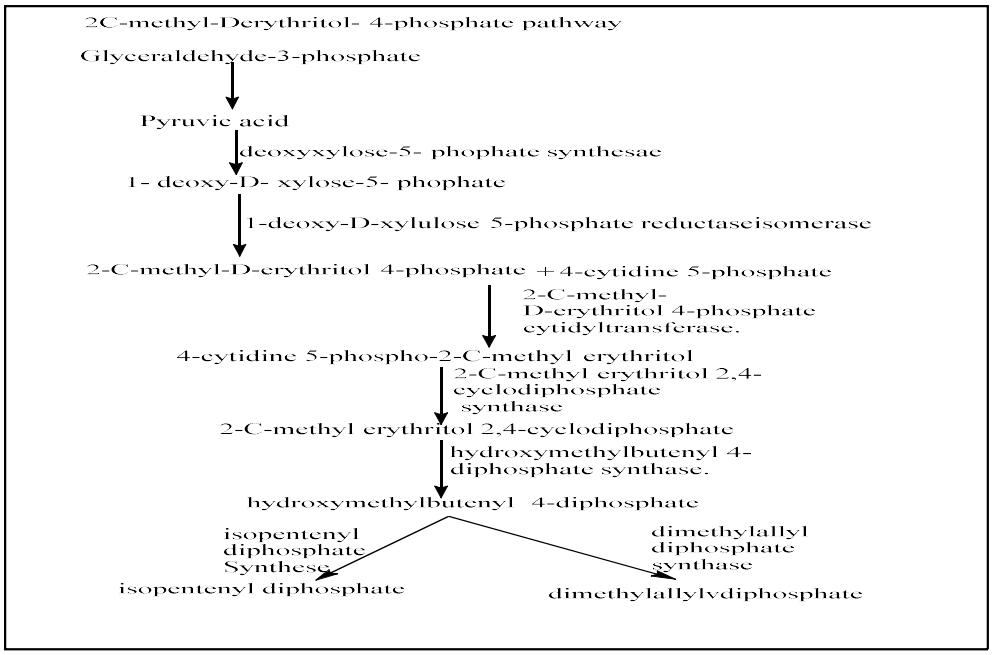


Fig.9 The Pyruvic acid pathway of terpenoid biosynthesis in plastid



ISOLATION OF MONO AND SESQUITERPENOIDS

Both mono and sesquiterpenoids have common source i.e., essential oils. Their isolation is carried out in two steps:

1. Isolation of essential oils from plant parts
2. Separation of Terpenoids from essential oils.

i) Isolation of essential oils from plant parts -There are four methods of extractions of oils.

1. Expression method
2. Steam distillation method
3. Extraction by means of volatile solvents
4. Adsorption in purified fats

ii) Separation of terpenoids from essential oils

1. Fractional distillation
2. Fractional crystallization
3. Chromatographic technique such as TLC, GLC, HPLC and column chromatography

1. Expression method

In this method the plant material is crushed. Juice obtained is filtered. Then juice is centrifugated, half of essential oil is obtained in the centrifugate. Solid residue is used for isolation of inferior oil by distillation.

2. Steam distillation method

Steam distillation is most widely used method. In this method macerated plant material is steam distilled to get essential oils into the distillate form. These are extracted by using pure organic volatile solvents. If compound decomposes during steam distillation, it may be extracted with ether at 50^{o} C. After extraction solvent is removed under reduced pressure.

3. Solvent extraction method

Solvents like hexane and ethanol is used to isolate essential oils. It is used for the plant parts having low amount of essential oil. Plant material are treated with the solvent; it produces a waxy aromatic compound called a "concrete. "Then it mixed with

alcohol, the oil particles are released. Then it passes through a condenser then it separated out.

4. Enfleurage

The fat is warmed to 50^0 c in glass plates. Then the fat is covered with flower petals and it kept for several days until it is saturated with essential oils. Then the old petals are replaced by fresh petals, it is repeated a number of times. After removing the petals, fat is treated with ethanol when all the oils present in fat are dissolved ethanol. The alcoholic distillate is then fractionally distilled under reduced pressure to remove the solvent. (17).

Significant natural terpenoids have also been found in diverse marine organisms, for example brown algae and sponges. Some notable terpenoids synthesized in all these organisms are listed in Table1

Table -3. Occurrence and medical application of terpenoids, natural compounds from plants and seawater algae, sponges and fungi.

Natural source	Category of terpene	Application in medicine
Legumes, vegetables	acyclic polyisoprene with chinoid segment C(5)10	Heart failure, cancer, various degenerative symptoms of elderly people
Eucalyptus globules	monocyclic monoterpene C10	Expectorant against bronchial catarrh (asthma), anti-ulcer activity
Mentha piperita	monocyclic monoterpene alcohol C10	Antibacterial, antispasmodic, antiseptic and anti-ulcer activity
Mentha spicata	monocyclic monoterpene alcohol C10	Prophylaxis against breast and prostate cancer
Cannabis sativa and *C. indica*	monocyclic monoterpene C10	Analgesic against spasms and asthma
Zingiber officinalis	monocyclic sesquiterpene C15	Component of ginger oil, odors and cosmetics industry, antiulcer, antiviral anticancer agent
Matricaria chamomilla	monocyclic sesquiterpene alcohol C15	Fine fragrances, cosmetic products, antiulcer and antilleishmaniasis drug
Atractylodeslancea, Pterocarpus santalinus	bicyclic sesquiterpene C15	Anti-dementia drug, antiangiogenic activity, induces apoptosis
Artemisia maritima	bicyclic sesquiterpene lacton C15	Anthelmintic
Matricariarecutita	bicyclic sesquiterpene lacton C15	Inflammatory skin and bowel diseases
Artemisia annua	monocyclic sesquiterpene lacton peroxide C15	Antimalarial drug
Phyllanthus engleri	bicyclic sesquiterpene C15	Renal cancer
Ginkgo biloba	bicyclic sesquiterpene C15	Alzheimer's disease, ischemic and haemorrhagic stroke, anti inflammatory effect
Illicium merrillianum	bicyclic sesquiterpene C15	Alzheimer's and Parkinson's diseases
Salvia sclarea	bicyclic diterpene alcohol C20	Leukemia, breast and colon cancer, fragrance ingredient
Plectranthus barbatus	bicyclic diterpene C20	Heart failure, autoimmune disorders, psoriasis, erectile dysfunction
Acanthopanax koreanum	tricyclic diterpene C20	Antiinflammatory agent, initiator of cell apoptosis, melangonesis inhibitor
Pinus sp.	tricyclic diterpene C20	Cytotoxic activity

Euphorbia resinifera	tricyclic diterpene C20	Drug against inflammatory and cancer pain, urologic disorders agent
Taxis brevifolia yew	tricyclic diterpene alkaloid C20	Cytostatic agent in cancer therapy
Trigonostemoncherrieri	tricyclic diterpene C20	Drug against Chikungunya-fever (disease mainly occurring in Africa)
Euphorbia peplus	tetracyclic diterpene C20	Ingenolmebutate (Picato®) drug against actinic keratoses
Cucurbitaceae sp.	tetracyclic triterpene C30	Anticancer, hepatoprotective and anti-inflammatory drug
Betula sp.	pentacyclic triterpene alcohol C30	Anticancer agent, , Antibacterial anti-HIV activity, Antiviral effect
Acacia victoriae	pentacyclic triterpene saponins C30	Anticancer agents, initiators of cell apoptosis
Solanum lycopersicum	bicyclic carotenoid C40	Vitamin A source, antioxidant activities, drug against age-related macular degeneration
Dilophusligulatus	monocyclic monoterpene C20	Cytotoxic activity
Epipolasisreiswigi	bicyclic diterpene C20	Antiviral activity, herpes simplex
Dictyotadichotoma, Halimedastuposa	bicyclic diterpeneC20	Antimicrobial and cytotoxic activity
Spongia officinalis	diterpeneC20	Antimicrobial and cytostatic activity
Aplysilla rosea, Dendrilla rosea	tricyclic diterpeneC20	Cytostatic activity
Luffariella variabilis	monocyclic sesterterpeneC25	Analgesic, Antiinflammatory and Antibiotic Activity,Hepatitis C inhibitor
Cacospongiascalaris, Spongiavirgultosa	tetracyclic sesterterpeneC25	Cytotoxic activity
Fusidium coccineum Corchorusaestuans L.	tetracyclic triterpene acid C30	Bacteriostatic antibiotic

CONCLUSION

According to the data gathered for this review, terpene and terpenoid and their primary active components are essential in the pharmaceutical and medical sectors due to their potential for a variety of therapeutic effects, including, antibacterial, anti-inflammatory, anticancer antioxidant, and anti-allergic. Seeing the increasing demand of these compounds, we also explained the biosynthesis of terpene and terpenoid. We also illustrated the classification and chemical tests for the terpene and terpenoid.

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