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A valuable observation on natural plants extracts for Valuable Functionalization of Cotton fabric (an overview)

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Abstract

Finishing textiles was widely used to impart various functionalities into fabric substrates, such as anti-microbial finishing, UV-protection, water repellent, self-cleaning and many others. However, the chemical finishing involves the use of large quantities of energy, chemicals, and water. Some chemical finishes in the wastewater can be harmful to humans, and the presence of chemicals in finished textiles can cause skin irritation in some people, so every day attempts to introduce cleaner, sustainable, and greener chemical finishing are urgently needed. Among the developed approaches are safer chemicals with minimal or no toxicity to human health and the environment, safe solvents and auxiliaries, energy efficiency (reduced temperature and pressure), natural, biodegradable, and renewable chem

Keywords: Finishing textiles, natural plants extract, biodegradable, and renewable chemicals

1. Introduction

Nanotechnology is an important field in modern research that is concerned on obtaining new particles ranging in size from 1 to approximately 100 nanometres. Within this size, all the properties (chemical, physical, and biological) of each of the atoms and molecules change[1]. Nanoparticles have unique properties due to their size, diffusion, and structural composition and are therefore a very important component of the rapidly developing field of nanotechnology.

Currently, particles in the form of nanoscale are used in many industrial applications, including finishing textiles. As a result of the imparting of nanotechnology in the finishing of textile materials, many characteristics were obtained in the materials giving many functional properties, including anti-microbial finishing, UV protection, self-cleaning, water and dust resistance, and other many functional characteristics that can be incorporated into textile materials using nanotechnology[2]. With the growing interest in eco-friendly products, which are non-toxic and biodegradable, the trend has been to manufacture nanoparticles by using eco-friendly materials instead of harmful chemicals.

In this study we are going to use extracts from some parts of different plants (Psidium Guava Leaves, Citrus Sinensis Peel (Orange Peel)) to obtain multi-functional finishing on cotton fabrics via nanotechnology approach.

2. Cotton fabrics

Cotton fibres are the purest source of cellulose, which is the most common polymer in nature. Cotton is a linear cellulose polymer and cellobiose is the repeating unit (**Figure 1**), which is made up of two glucose units. Cotton is composed of approximately 65–70% crystalline region and approximately 35–30% amorphous region[3]. Cotton has many desirable properties .it is breathable, comfortable, and durable, so it is valuable in the textile industry.

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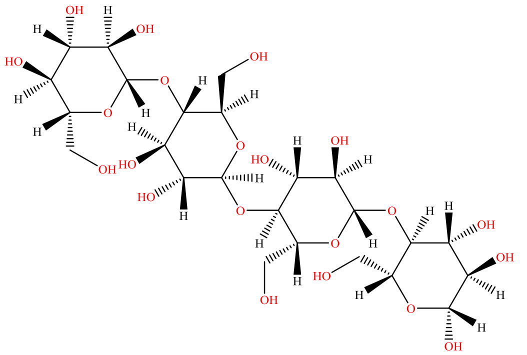

Figure 1: chemical structure of the cellulose

3. Textile finishing

Textile Finishing refers to the treatments that are made on textile materials to give them new functional properties and enhance the appearance, texture, or performance of fabrics. There are two textile finishing definitions, both of which were widely accepted and used. One of them is from a narrow point of view, defining textile finishing as the final step in the manufacture of textile fabrics, where the final properties of the fabric are developed to complete the performance of the fabric by inserting special functional properties. [4]

The other definition is broad, referring to any operation to improve a fabric's appearance or value after it has come out of the loom or knitting machine. Pre-treatments like scouring and bleaching are also included in the finishing step in this respect. In general, some preparatory treatments should be carried out before other finishing processes are applied to achieve the enhanced finishing effect [5]. Irrespective of any definition, finishing aims to make textiles more acceptable to the consumer and to achieve several objectives; including functionalization, enhanced quality, improved performance, and attractiveness of the textile materials [6]. so that Finishing completes the performance of the fabric and gives it special features including the final touch [7]. Textile finishing can be classified into two distinct areas, mechanical finishing, and chemical finishing.

3.1. Mechanical finishing

Mechanical finishing or 'dry finishing' primarily uses physical (especially mechanical) means to change the properties of the fabric and usually also alter the appearance of the fabric. Mechanical finishing involves compressive shrinkage, calendaring, raising, Decatizing, and many others. Mechanical finishing is seen as dry, while moisture and chemical substances are also required to process the fabric successfully [8].

*3.2. **Calendaring***

One of the mechanical finishing treatments is a calendar, in which the fabric passes under controlled time, temperature, and pressure between heated rotating rollers (smooth or engraved). The result will be a soft handle, decreased thickness, and decreased slippage of yarn along with better lustre[9].

*3.2.1. **Raising***

The purpose of raising is to eliminate individual fibre ends to the fabric surface to create a soft and smooth handle, which is achieved using wire-covered rolls. If abrasive-covered rolls are used, a change of shade will result from the surface with short piles [10].

*3.2.2. **Decatizing***

Decatizing is achieved using a perforated roller immersed in hot water or blown-in water vapor to improve fabric durability, lustre, and handle[4].

3.3. Chemical finishing

To achieve the desired properties, the application of chemicals to textile substrates is usually regarded as chemical finishing, which can be achieved by several methods such as pad-dry-cure. Spraying and foaming [7].

Chemical finishing was widely used to impart various functionalities into fabric substrates, such as anti-microbial finishing, UV-protection, water repellent, self-cleaning, and many others. The chemical finishing, however, involves the use of large quantities of energy, chemicals, and water. Some chemical finishes in the wastewater can be harmful to humans, and the presence of chemicals in finished textiles can cause skin irritation in some people [4, 11-15].

Everyday attempts to introduce cleaner, sustainable and greener chemical finishing are therefore urgently needed, generally called "green chemistry". Among the developed approaches are safer chemicals with minimal or no toxicity to human health and the environment, safe solvents and auxiliaries, energy efficiency (reduced temperature and pressure), natural, biodegradable, and renewable chemicals.

3.3.1. Application methods of chemical finishing

3.3.1.1. Pad, dry, and cure

The padding process is one of the most common methods for the application of chemical finishes. The fabric is immersed in a liquor containing chemicals, the soaked fabric is then squeezed into a padder to extract excess liquor. The fabric must be dry after the application of the chemical finish and the finish must be fixed to the surface of the fibre if necessary, typically by additional heating in a 'curing' stage[7].

3.3.1.2. Foam application

In liquor, the active chemicals may be diluted to form foam by air. By removing some of the water in the liquor with air, the volume of water added to the fabric can be greatly decreased. Surfactants are used in the liquor in the application of foam to stabilize the foam and the finish is spread on the fabric by the final foam breakdown[10].

3.3.1.3. Spray application

Spraying can be used under certain circumstances to add a finish to a cloth. To ensure fair coverage on all sides of the cloth, multiple spray units may be used. Spray systems must be engineered to prevent overlapping spray patterns that can contribute to an unequal distribution. As sprayed chemicals pose a much greater risk of inhalation than liquor baths or foam, spraying may present health and safety issues. To tackle these elevated threats, extraction methods or closed chambers may be employed[10].

3.3.2. Materials used for functionalization of fabrics

3.3.2.1. Synthetic Agents

Over the past few decades, extensive studies have been reported to study the application of various chemicals to textile surfaces for antibacterial, UV protection, and water repellent finishing[16-23]. The synthetic finishing agents most widely used for finishing are briefly discussed as follows.

<u>Quaternary Ammonium Compounds (QACs)</u>

Quaternary Ammonium Compounds (QACs) can be used as antimicrobial agents because these compounds carry a positive charge of the nitrogen atom which is known to be responsible for its antimicrobial action. The antimicrobial activity in its chemical composition also relies on the length of the alkyl chain, the presence of the per fluorinated group, and the number of cationic ammonium groups [24]. QACs are valuable biocides that damage a wide range of bacteria, but with fungi, they are less effective.

The antimicrobial activity comes from the polar interaction between the positive charge on the QACs and the negative charge on the bacteria cell membrane which results in the QACs – microorganism complex formation. This, in essence, destroys the essential properties of the cell membrane and thus the destruction of protein activity. QACs also affect bacterial DNA and cannot thus replicate. in addition to this polar interaction, There is also a non-polar interaction with the hydrophobic alkyl chain. This allows the hydrophobic group to enter the microorganism, causing the alkyl ammonium group to disrupt all main functions of the microorganism cell by the interaction with the cell membrane[25].

<u>UV absorbers</u>

UV absorbers are organic or inorganic compounds with a high UV absorption spectrum of 290–360 nm[26]. UV absorbers integrated into the fibres transform electronic excitation energy into thermal energy, act as radical scavengers, and singlet oxygen quenchers. The high-energy, short-wave UVR activates the UV absorber to a higher energy state and can then dissipates the absorbed energy as long-wave radiation[27]. 2-hydroxy benzophenones, 2-hydroxy phenyl benzotriazoles, 2-hydroxy phenyl-Striazines, and chemicals such as benzoic acid esters and hindered amines are widely used as UV absorbers [28-31].

3.3.3. Natural compounds

Many natural compounds have been used in the functionalization of textile materials to impart or enhance their properties. These natural materials can be derived from natural plants or animals (from different parts of each of them). In recent years many researchers have been used natural compounds in their work to improve the biological and chemical properties of textile fabrics such as antimicrobial [32], anti-flammable **[33-36],** insect repellent, ultraviolet protection, dyeing, and printing performance. **[37-55]**

3.3.3.1. Nanoparticles

Nanoparticle is an important feature due to its countless applications. Nanoparticles have shown important developments in the field of bio-medical devices, filters, antimicrobials, catalysts, optics, optical fibres, agriculture, textile, and other fields. Nanoparticles are particles that are smaller than or equal to 100nm. Nanoparticles may be either amorphous or crystalline or composite. Their chemistry may be primarily non-metal (for example, carbon), metallic (for example, silver (Ag), gold (Au)), semiconductor (for example, cadmium (Cd), selenium (Se)), or combination. Their shapes may be spheres, rods, horns, tubes, and platelets. **[19, 33, 40, 56-69]**

4. Nanomaterials in Functional Finishing

Nanotechnology is the technology of small objects that are less than 100 nm in scale. Scientists have found that small-scale materials, small particles, thin films, etc., may have substantially different properties than the same materials on a larger scale. This helps one to understand and monitor small structure assemblies through endless possibilities of developing systems, structures, and materials. [15, 34, 70]

4.1. Synthesis of nanoparticles

The methods of nanoparticle synthesis are usually divided into two classes

4.1.1. Top-down Synthesis

A destructive approach is used in this method. Starting from larger molecules which are broken down into smaller units and converted into nanoparticles. Grinding/milling, chemical vapor depositions (CVD), physical vapor deposition (PVD) are examples of this method [71]. **(Figure 2)** shows that the top-down technique entails the transformation of bulk material into powder form using energy, which is then converted into smaller fragments with several layers and then to monolayers, resulting in the creation of nanoparticles.

4.1.2. Bottom-up synthesis

This method is used in reverse since NPs are made up of comparatively simpler compounds, which is why this approach is often considered a building-up approach. Sedimentation and reduction techniques, which include sol-gel, green synthesis, spinning, and biochemical synthesis, are examples of this method [71]. In **Figure 2**, the bottom-up technique involves precursor molecules that are then ionized with energy. The resulting radicals, ions, and electrons condense to form clusters, which are then converted into nanoparticles.

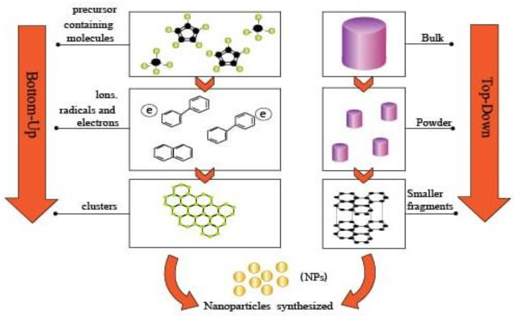

Figure 2: Top-down and bottom-up approaches for the synthesis of NPs

4.2. Nanoparticles Used in Textile Functional Finishing

Nanotechnology has real trade potential for the textile industry. This is mostly because traditional methods used to impart various properties to fabrics often do not contribute to permanent results and lose their purpose after washing or wearing. Nanotechnology can give high durability for fabrics, since Nano-particles have a wide surface-to-volume ratio and high surface energy, resulting in enhanced fabric affinity and increased durability.

The coating is a common procedure used to apply nanoparticles to textiles. Several techniques can apply a coating to fabrics, including spraying, transfer printing, rinsing, and padding. Padding is the most widely used of these methods. Nano-particles are attached to the fabrics by using a padder calibrated to the appropriate pressure and speed, accompanied by drying and curing [72].

Nano materials in different ways, such as metal nanoparticles, metal oxides, and Nano composites, are used for the protection of UV, water repellent, antibacterial, and deodorizing of textiles. Chemical methods are the most common methods of synthesis of nanoparticles. Over the last few decades, the development of metal nanoparticles using green chemistry methods using plant extracts and enzymes has gained a great deal of interest, as certain chemical methods cannot prevent the use of poisonous and dangerous reagents and hence face environmental challenges [73].

Plants are enriched by a range of natural ingredients, including reducing and stabilizing agents and thus tend to be the best candidates for large-scale biosynthesis of various nanoparticles. Synthesized nanoparticles are used in various applications, including dyeing and finishing textiles. The most studied nanomaterial for functionalizing textiles are silver nanoparticles (AgNPs). They give a good antimicrobial activity to the treated textile and produce various hues based on their size and form.[74].

Apart from Ag, Gold nanoparticles are also very important for treating wool and cotton fabrics. Various sizes of gold nanoparticles are used to obtain antimicrobial activity and a variety of colours on natural and synthetic textiles. nanogold rods have recently been applied to cotton to give it UV protection.[32].

Zinc oxide nanoparticles (ZnO NPs) attract also research interest for use in numerous application fields due to their outstanding photo catalytic activity, non-toxicity, high availability, biocompatibility, and low price. Zinc oxide gives antibacterial, UV protection, and self-cleaning effects on textile products[75].

Several crosslinkers such as polymeric amines can be used to anchor the nanoparticles with the fabric. TEM, X-ray photoelectron spectroscopy, and electron microscopy are some of the methods widely used to characterize the deposition of nanoparticles on textile surfaces. Similarly, nanoparticles of other metals and metal oxides, such as copper oxide (CuO), titanium dioxide (TiO_2), nickel oxide (NiO), ferric oxide (Fe_2O_3), and cobalt oxide (CoO), can also be used for the functionalization of the fabrics[32].

5. Natural plants

In recent decades, human health has been severely threatened by various health concerns. Textile products based on synthetic agents have been produced and there are still quite a few commercially available. Although synthetic agents are very effective and have a long-lasting impact on textiles, they are a cause for concern due to the associated side effects in the environment such as water contamination [76].

Wet processing of textile substrates, beginning with its preparation for colouring followed by finishing, is important for its added value in terms of aesthetic value, removal of impurities, colour tone, colour pattern, and necessary functionality. However, some conventional processes are water, energy, and chemical-intensive. Recently, both academic research and textile industrial product production have been stepped up to pursue safe dyeing and finishing technologies, using plant waste and non-food plant extracts. **[77-83]**

Nowadays, there is also a strong demand for textiles dependent on eco-friendly agents that not only help to significantly mitigate the harmful effects associated with using synthetic agents on textile fabrics, but also conform to the regulatory agencies' legislative requirements.

Based on environmentally sustainable plant-based products characterized by biocompatibility, biodegradability, non-toxicity, in addition to their recently discovered properties such as mosquito repellent, UV protection, antimicrobial activity, and water repellent, the manufacture of more attractive and highly practical value-added textiles has gained worldwide prominence [84]. Natural bioactive compounds have recently gained growing interest in the textile industry as promising alternatives to synthetic finishing agents Because of their eco-friendliness, biocompatibility, antibacterial activity, antioxidant, and UV protection. A variety of natural finishing agent sources, including Mentha longifolia, Trigonella foenum-graecum, orange, mango, psidium guava, bananas, tamarind, onion, and other natural finishing agents are cited. [85] Plant parts such as roots, leaves, twigs, stems, heartwood, bark, wood shavings, flowers, fruits, rinds, hulls, husks, and so on serve as natural finishing agent sources **[19, 39, 48, 86-90].**

5.1. Commonly Bioactive compounds in plants extract

Most plants have a lot of compounds such as follows

5.1.1. Phenolics

The largest group of phytochemicals in the plant kingdom is most widely distributed. The three most common dietary phenolic groups are phenolic acid, polyphenols, and flavonoids. Phenols (C_6H_5OH) are thought to be the simplest class of natural compounds. Phenolic compounds are a large and complicated group of chemical constituents found in plants. (**Figure 3**) illustrate some phenolic compounds in natural plants. They are secondary metabolites and, as protecting compounds, play an important role. [91]

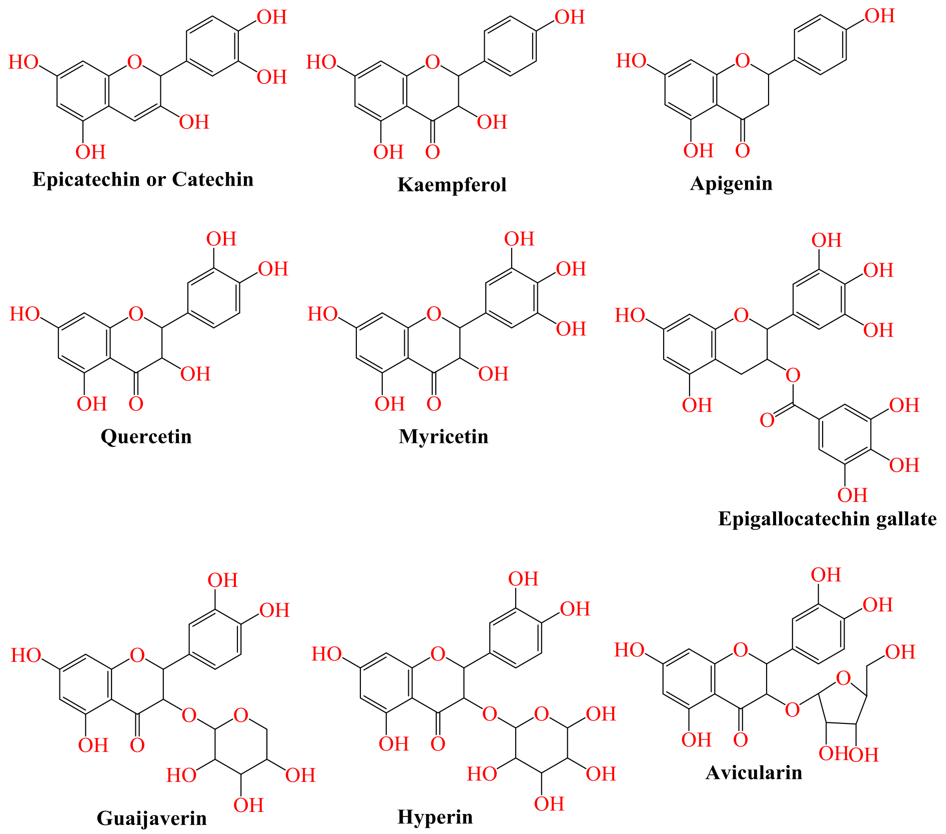

Figure 3: chemical structure of some phenolic compounds in natural plants

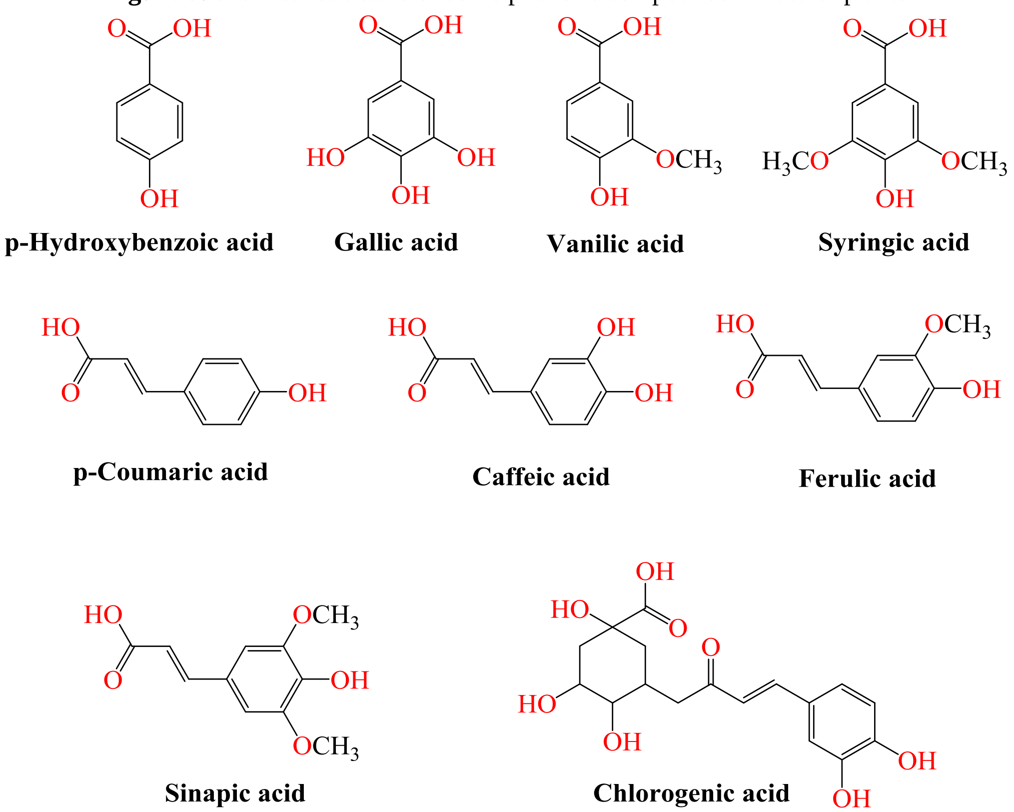

Figure 4: chemical structure of some phenolic acid compounds in natural plants

5.1.2. Phenolic acid

The word phenolic means phenols that have one functional group of carboxylic acid. Naturally, two distinct carbon frameworks are included in phenolic acids, which are hydroxybenzoic and hydroxycinnamic structures. **Figure 4** illustrate some phenolic acid compounds in natural plants. Hydroxycinnamic acid compounds with hydroxyl carboxylic acids and glucose are formed as simple esters. The property of these compounds is to combat oxidative damage that leads to different diseases such as degenerative, coronary, cancer, and inflammation [91].

5.1.3. Flavonoids

Polyphenolic compounds that are ubiquitous are flavonoids. Approximately 4000 flavonoids have been known, of which most of the flavonoids are present in vegetables, fruits, beverages (coffee, beer, tea). **Figure 5** illustrate some flavonoids compounds in natural plants. In recent years, flavonoids have been substantially increased due to their potential benefits for human health[91]. It is responsible for the production of greater antioxidant, anti-allergic, anti-platelet, anti-tumor, and anti-inflammatory activities.

5.1.4. Tannins

Tannins are difficult to explain chemically and contain a wide variety of oligomers and polymers. Tannins are a heterogeneous category of high molecular phenolic compounds capable of forming reversible and permanent complex substances such as alkaloids, nucleic acids, polysaccharides, minerals, and proteins. They are split into four main classes depending on their structural properties, such as complex-tannins, condensed-tannins, ellagitannins, and gallotannins (see **Figure 6**) [91].

5.1.5. Alkaloids

The name derived from "Alkaline" alkaloids is used to describe any base containing nitrogen. They are natural products that contain heterocyclic nitrogen atoms (see **Figure 7**). They are synthesized by a large number of organisms, such as bacteria, animals, plants, and fungi [91]. With acid, it forms salts. In molecular structures, alkaloids are numerous and vary, because their normal classification is difficult.

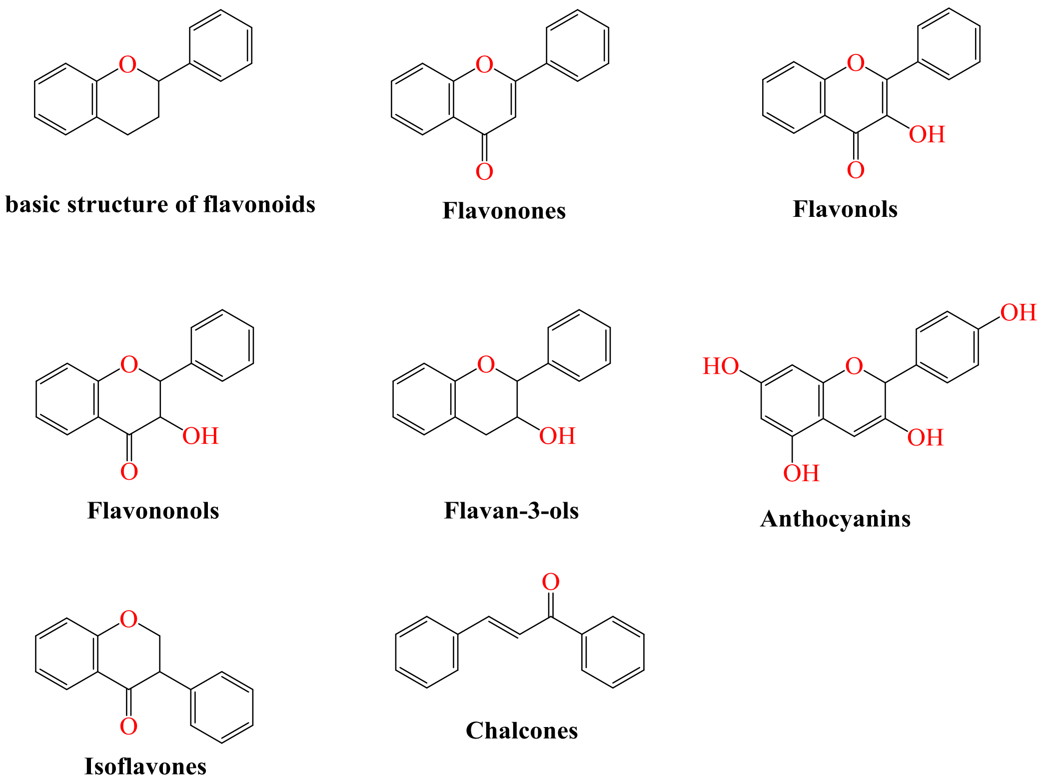

Figure 5: chemical structure of some flavonoids compounds in natural plants

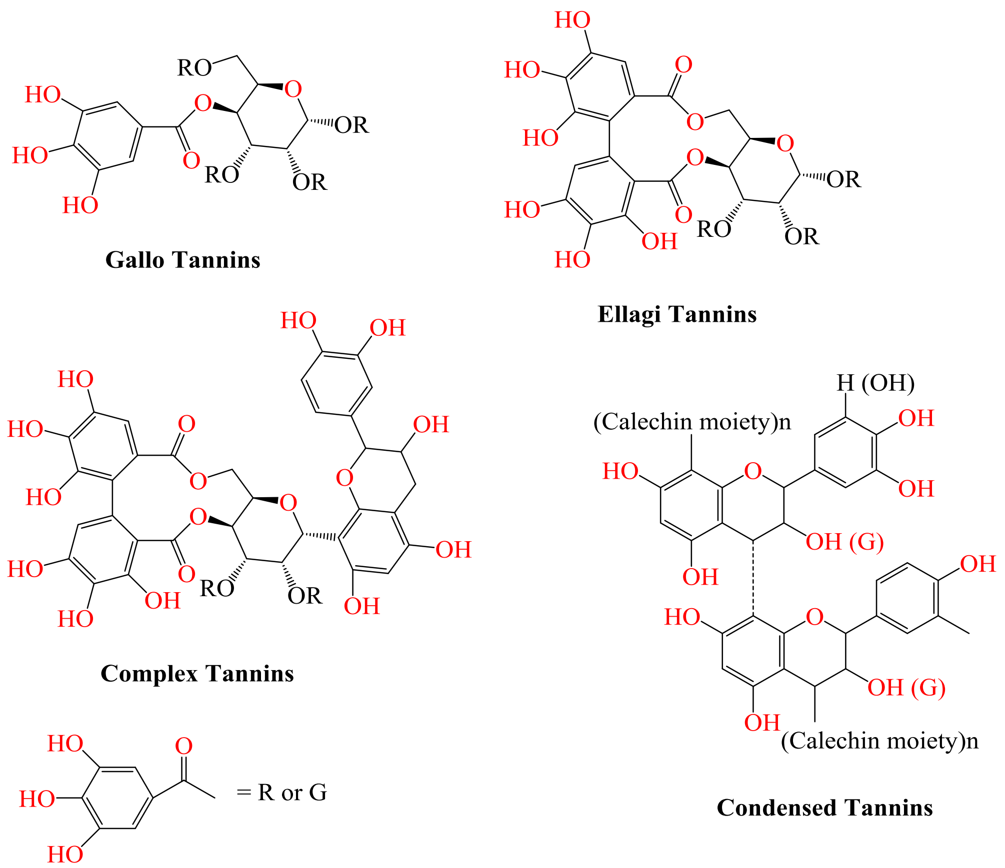

Figure 6: chemical structure of some tannins compounds in natural plants

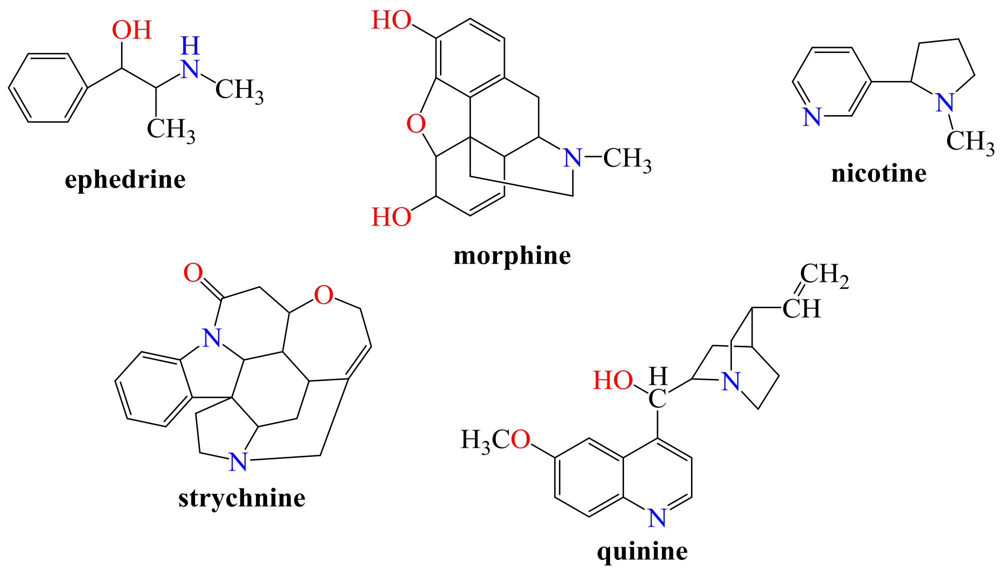

Figure 7: chemical structure of some alkaloids compounds in natural plants

5.1.6. Anthraquinones

Anthraquinone is an aromatic compound, also known as anthracenediones (see **Figure 8**). It is a major member of the quinone family and has a large structural variety of compounds in the polyketide group. Anthraquinones contain secondary metabolites as glycosides in insects, plants, and fungi. They have antioxidant, antimicrobial, anti-tumor, and anti-inflammatory properties [91].

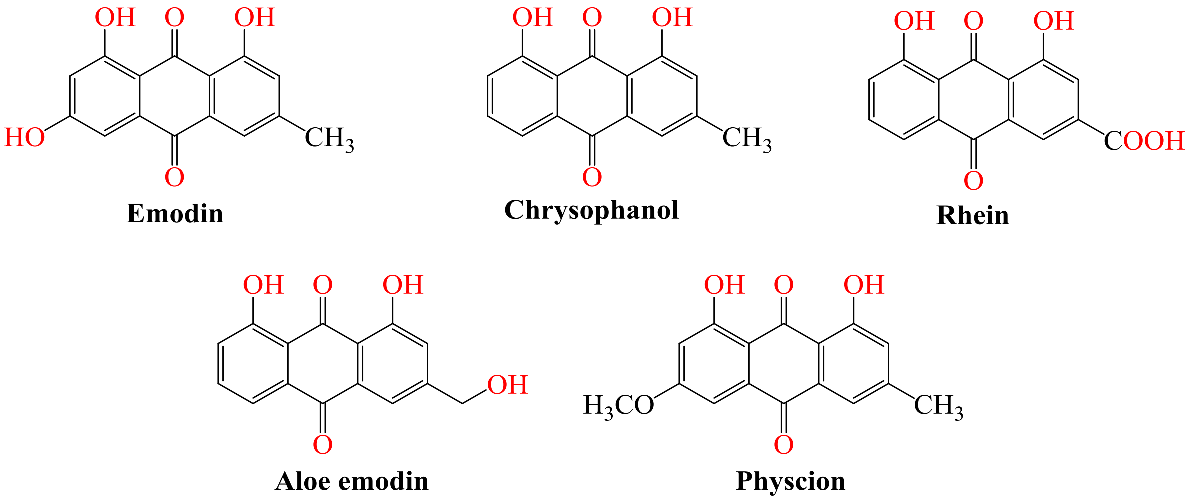

Figure 8: chemical structure of some anthraquinones compounds in natural plants

5.1.7. Saponins

Chemically, saponins are a group that includes substances such as triterpenoids, glycosylated steroids, and steroid alkaloids. Glycosylated steroids are classified into two major groups, furostan, and spirostan derivatives. The carbohydrate portion consists of one or more sugars containing aglycone-linked arabinose, xylose, galactose, glucose, rhamnose, or glucuronic acid. Saponins with one sugar molecule attached to the C-3 position are called monodesmoside saponins and bidesmoside saponins are called saponins with two sugar molecules attached to C-3 and C-22[91].

5.1.8. Terpenoids

Terpenoids are the largest and most diversified chemical class among the numerous compounds contained in plants (see **Figure 9**). Plants of these metabolites have a broad range of essential functions for growth and production as well as for protection in the biotic and abiotic ecosystems. It is used in the pharma industries. The structure of terpenoids is biologically active and is used for treating many diseases, especially malaria[91].

5.1.9. Glycosides

They appear in a wide range of natural substances of which the carbohydrate component consists of one or more sugar or uronic acids. They are used in the field of medicine like antibiotics.

5.2. Some important Plant extracts used for textile functionalization

5.2.1. Psidium guava

Psidium guajava is a small tree belonging to the myrtle family, commonly referred to as guava (Myrtaceae). Guava trees grow in many countries with tropical and subtropical climates, thus enabling production around the world. [92] Psidium guajava is a small tree that is 10 m long with a thin, smooth, peeling bark. The leaves are opposite, short-petiolate, oval blade with pronounced pinnate veins, 5–15 cm long. The flowers are somewhat showy, the petals white up to 2 cm long, the stamens numerous [93].

Much of the pharmacological and chemical analysis has been performed on the leaves. Traditionally, it has been used as a medicinal plant worldwide for a variety of diseases because of the bioactive compounds found in psidium guava leaves. Psuiduim guava leaves are rich in flavanoids, carotenoids, polyphenols, tannins, terpenoids, saponins, alkaloids, glycosides, and anthraquinones. [94, 95]. Essential oils are present in leaves containing α-pinene, limonene, β pinene, isopropyl alcohol, menthol, terphenyl acetate, caryophyllene, longicyclene, and β-bisabolene. oleanolic acid is also found in the leaves (see

Figure 10 and **Figure 11**)[96]. Leaves have a high limonene and caryophyllene content [95].

The plant has functional properties such as antibacterial, wound healing, anti-oxidant and anti-allergic activity [97]. It is also used to treat wound healing, cold, and cough, weight loss, improves eyesight, avoids hair loss, decreases wrinkles, improves skin texture, and controls diabetes.

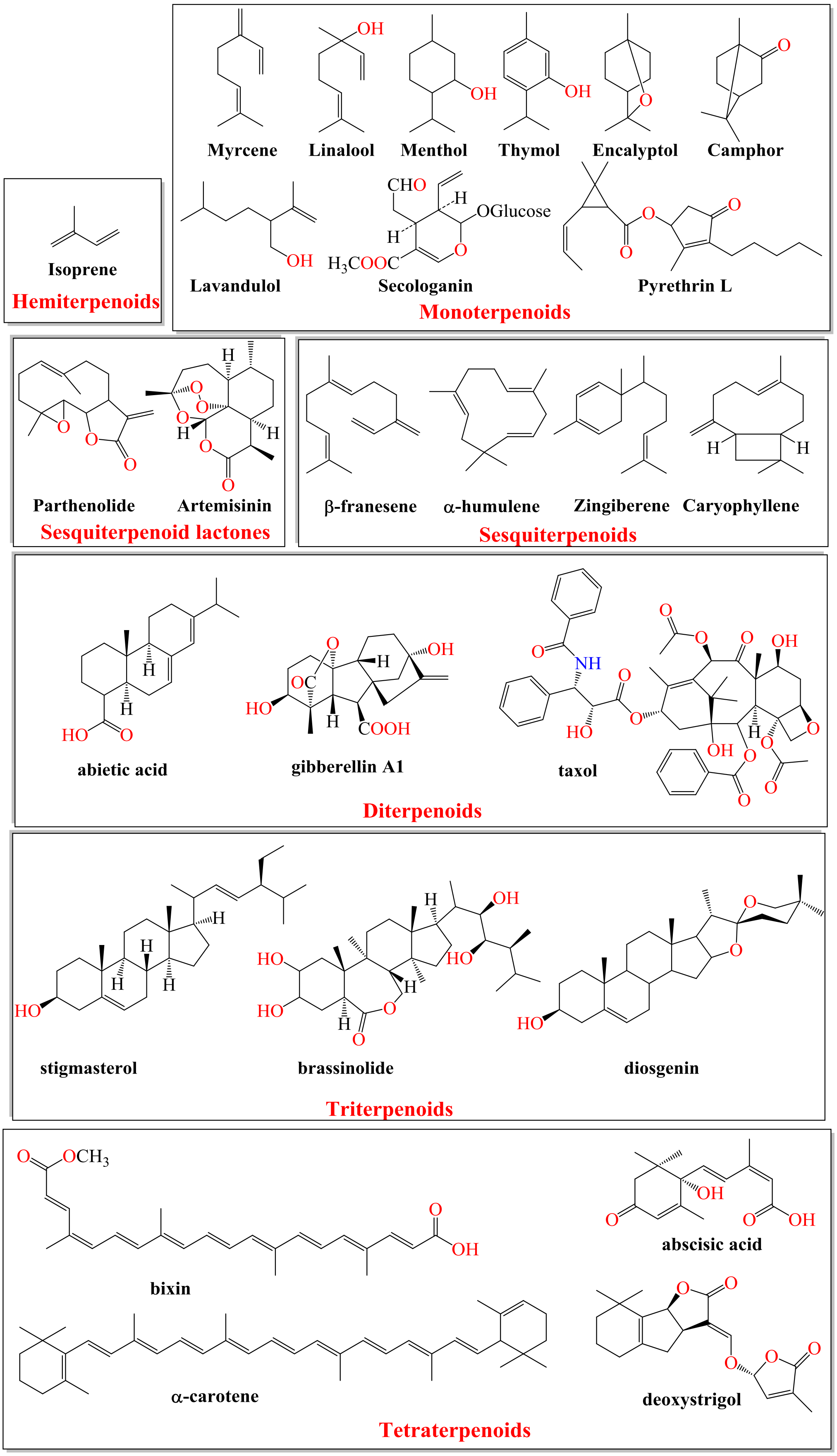

Figure 9: chemical structure of some terpenoids compounds in natural plants

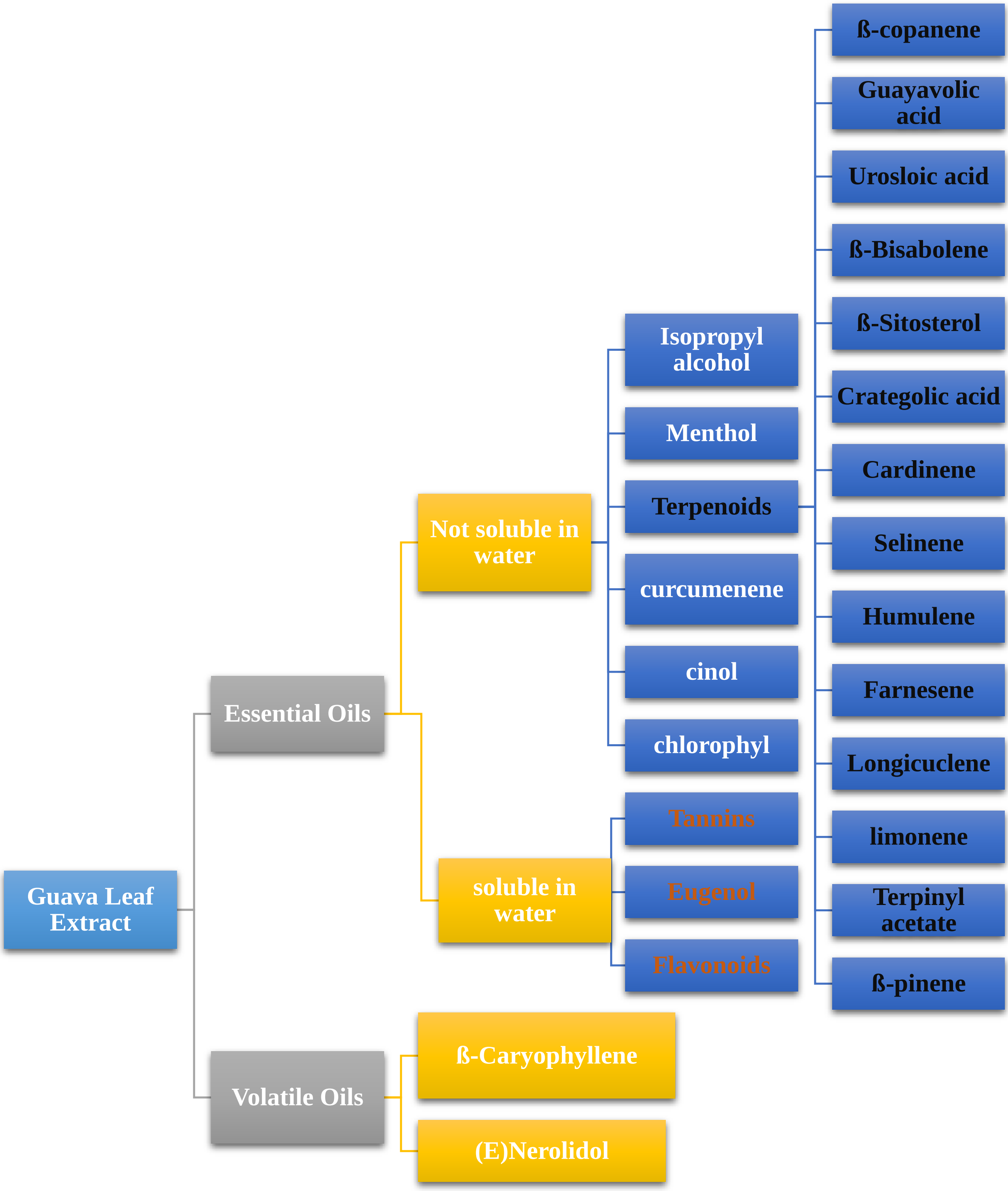

Figure 10: bioactive compounds in Guava leaf extract

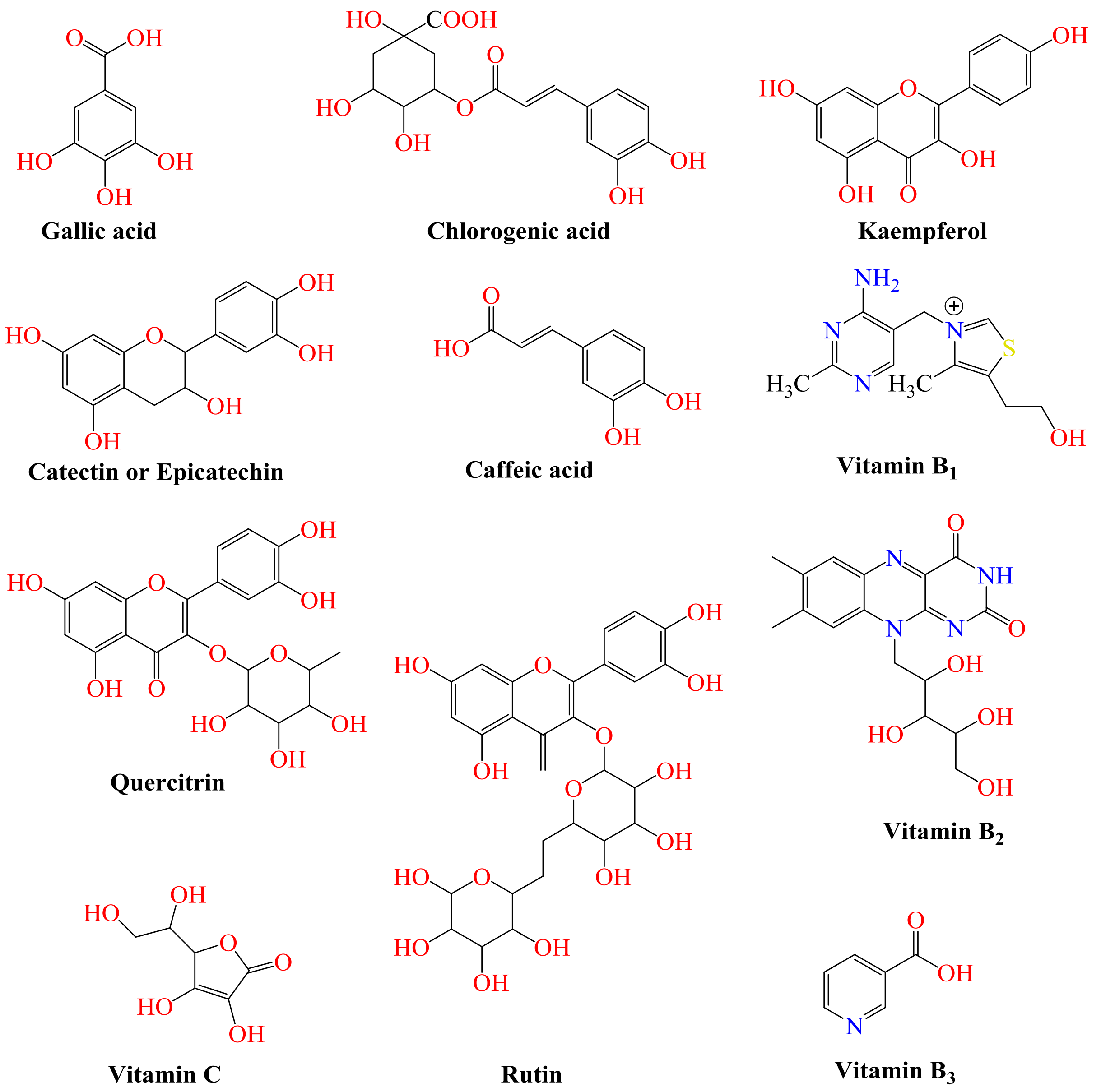

Figure 11: Chemical structure of some bioactive compounds in Guava leaf extract

5.2.2. Citrus Sinensis Peel (Orange Peel)

Citrus sinensis, also called sweet orange, is not consumed only as a fruit, but as a medicinal herb in certain countries. It belongs to the family of Rutaceae and is very widespread in tropical and subtropical regions. The world's annual citrus fruit production now stands at over 110 million tonnes, and oranges have become the world's most widely produced fruit. [98] Orange peels, however, account for about 44 percent of the fruit body and can thus contain an immense mass of by-products. These orange peels are typically disposed of as waste, which may cause significant environmental harm [99].

Considering the enormous amount of "waste" produced in the food supply chain, orange peels have an enormous potential to be used as a value-added product, including for the recovery of natural antioxidants, pectin, enzymes or for the production of ethanol, organic acids, essential oils and prebiotic single-cell proteins[100]. Furthermore, the orange peel is a rich source of fibre and vitamin C, and many nutrients, including flavonoids, limonene, and phenolics (**Figure 12** and **Figure 13**). It is divided into two major sections, epicarp, and mesocarp. Epicarp is a coloured peripheral surface, primarily composed of parenchymal cells and cuticles. It is covered by an epidermis of epicuticular wax with several small aromatic oil glands providing its particular scent. Mesocarp is a light white middle layer located under the epicarp. It consists of tubular cells joining together to create a mass of tissue packed into the intercellular area [101]. In some areas of the world, orange peel has been used as a traditional medicine to alleviate gastrointestinal pain, skin irritation, ringworm infections, help in neuroprotection, and improve heart health [102].

Orange peel has many active biocomponents, such as vitamins, flavonoids, lignins, carotenoids, saponins, sterols, terpenoids, and phenols. Orange peels have a very high limonene content. limonene is especially concentrated in orange peels, comprising around 97% of this rind's essential oils. Main compounds in orange peel, such as ascorbic acid and flavonoids, are beneficial to human health[103]. In the orange peel species, the flavonoids primarily exist in four types: Eriocitrin, Narirutin, Hesperidin, and Naringin. Citrus sinensis peel contains 1.5 percent essential oils[104].

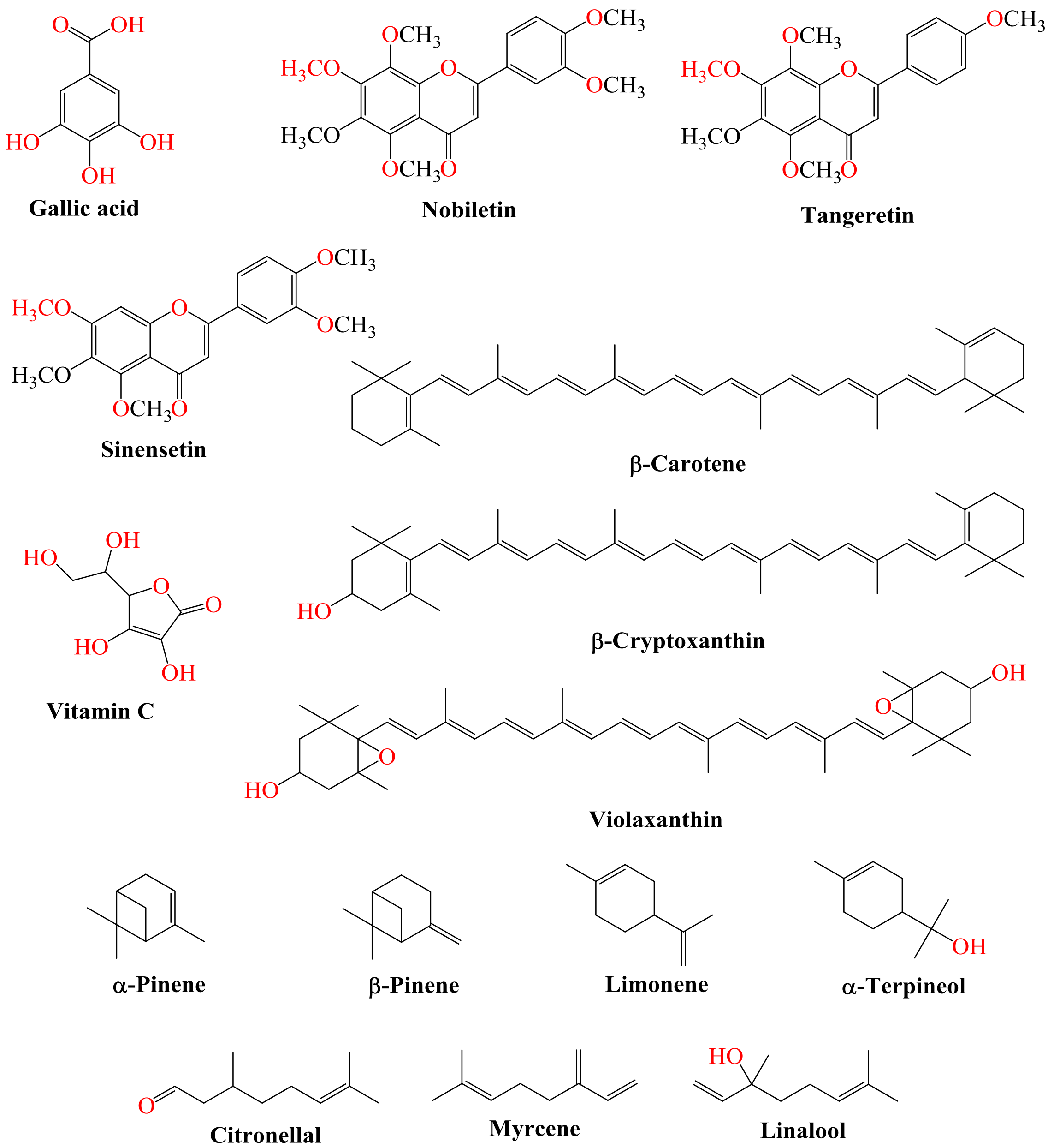

Figure 12: Chemical structure of some bioactive compounds in Orange peel extract

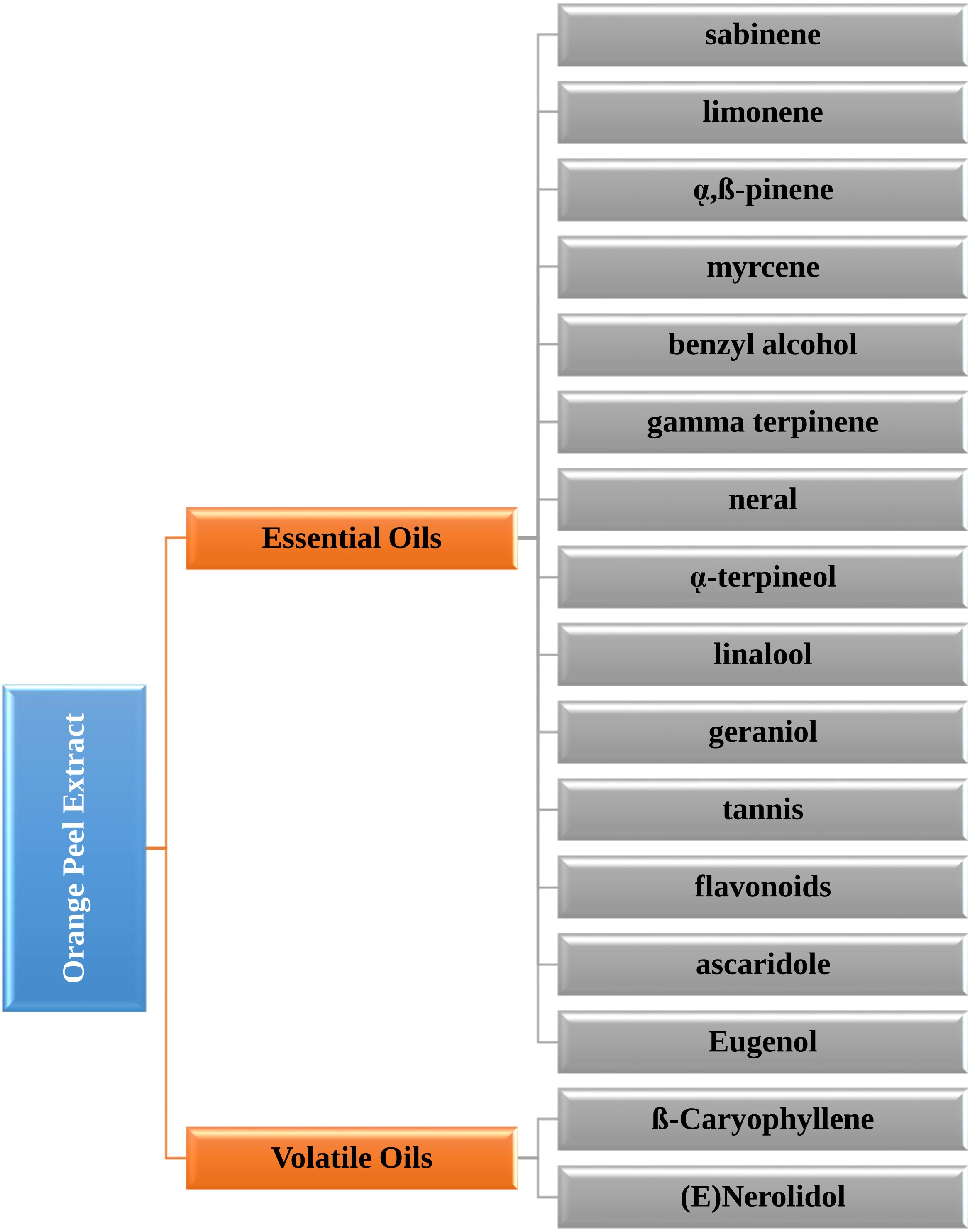

Figure 13: bioactive compounds in orange peel extract

5.3. Extraction of natural plants

Plants are currently considered to be of significant interest due to their special attributes as a major source of active bioactive compounds that can contribute to multi-functional finishing to the fabric. The study of plants begins with the processes of preparation and extraction, a significant step in the processing of bioactive components from plant materials. **[105]**

5.3.1. Preparation processing of plants

The initial stage in the study of plants is the preparation of plants to preserve biomolecules in plants before extraction. Extractions can be obtained from fresh or dried plants. The pre-preparation of plant products, such as grinding and drying, affects the retention of phytochemicals in the final extracts. The plants should be washed thoroughly to remove any dust from them and ensure that is very clean before using them [106].

Both fresh and dry plants have active bio compounds. In some cases, the dried sample is chosen considering the time needed for experimental work. The time between harvesting and experimental work should be short to preserve the freshness of the samples, as fresh samples are delicate and fragile. No major impact on total phenolic was observed in the comparison between fresh and dry Moringa oleifera leaves[107].

5.3.2. Methods of extraction

Extraction is the separation of active components of plants using selective solvents by standard procedures**[108].** The object of all extraction is to isolate the soluble metabolites of the plant, leaving the insoluble residue behind it. The initial crude extracts using these methods contain a complex mixture of many plant metabolites, such as alkaloids, glycosides, phenolics, terpenoids, and flavonoids**[106].** Any of the extracts collected could be able to be used as treating agents in the form of fluid extracts. Various extraction methods widely used are discussed below.

5.3.2.1. Aqueous Extraction

Traditionally, water extraction has been used to extract active components from plants. In this process, the plant is first cut into small pieces or powdered and sieved to increase extraction efficiency. Then it is soaked with water and heated to boiling point to produce a solution that is filtered to remove plant remnants[109].

5.3.2.2. Alcoholic extraction

An alcoholic solution is made by adding a quantity of alcohol. The plant is then placed into alcohol after cutting it into small pieces and boil at 70°C. Then the solution is filtered [109].

5.3.2.3. Alkaline extraction

alkaline solution (1%) is prepared by adding sodium carbonate or sodium hydroxide to the water. The plant is added to it and then heated at the required temperature. After that, the solution is filtered [110].

5.3.2.4. Acidic extraction

Acidic solution (1%) is prepared by adding HCl to water. Then the plant is added to it and heated at the required temperature. After that, the solution is filtered to remove plant remnants[109].

5.3.2.5. Fermentation

The enzymes produced by microorganisms present in the environment or those present in natural resources are used in this method of extraction. The process of fermentation is like aqueous extraction, except those high temperatures are not needed for this method. Microorganisms disintegrate the active components binding with substances in a natural way. The disadvantages of this method are long extraction time, the need for immediate extraction of active components after harvesting, bad odor because of microbial effects, etc [109].

5.3.3. Extraction techniques

Various extraction techniques that can be used are discussed below

5.3.3.1. Soxhlet extraction technique

Before the dawn of the twentieth century, the Soxhlet extraction method was developed. This is one of the most popular methods of extraction today. This technology has been improved to minimize waste generation and the eco-efficiency of the extraction methodology. The technique positions a specialized piece of glassware between a condenser and a flask. The refluxing solvent washes the plant repeatedly in the flask, extracting the active compounds into the flask [111].

5.3.3.2. Ultrasound- assisted extraction

The ultrasound-assisted extraction is based on the action of ultrasound vibrations aimed at an extracted sample that improves the effectiveness of solvent penetration in a sample. This technique is characterized by high speed, ease, and usually takes a few minutes[112].

When the plant material that contains bioactive components is processed with water or some other solvent in the presence of ultrasound, very tiny bubbles or cavitation are produced in the liquid. These increase in scale, but when they reach to a certain size, they cannot maintain their form. When this occurs, the cavity will collapse or the bubbles will explode, causing high temperatures and pressure. Millions of these bubbles are formed and collapsed every second. The presence of a high temperature and pressure during extraction improves the efficiency of extraction within a short period [113] .The procedure can also be done at a lower temperature and thus the extraction of heat-sensitive molecules is easier. Ultrasound extractions can be considered as a green procedure because of reduction of solvent usage, and time resulting in lower power consumption [109].

5.3.3.3. Microwave-assisted extraction technology

The microwave-assisted extraction technology is a high-speed process used in various raw materials for selectively targeted compounds. During solvent extraction, the technology utilizes a microwave applicator as the energy source, leading to the following advantages: faster production, reduced energy consumption, improved quality, and reduced amount of the solvent used [114-116].

5.3.3.4. Supercritical Fluid Extraction

Supercritical fluid extraction uses CO_2 as an extraction medium. A gas behaves as a supercritical fluid above the critical temperature and pressure values. A fluid has physical properties between the liquid and the gas. They can spread more easily around the surface than a true liquid because their surface tension is much lower than liquids. Since their viscosity is also low, they have a high diffusivity and thus greater interaction with the sample [117].

Supercritical carbon dioxide (CO_2) fluid extraction is a successful alternative to solvent extraction since it is non-toxic and does not leave traces. The critical carbon dioxide temperature and pressure values are 31.4°C and 1070 pounds per square inch (psi), respectively [118].CO_2 is a non-polar molecule that behaves like a non-polar organic solvent. To increase the solubility of polar solutes, a cosolvent or a modifier can be applied. The downside of the procedure is the high expense of the machines and the extraction of polar compounds is poor[119]

6. Functionalization of textile fabrics

6.1. Anti-microbial Finishing

The growth of microorganisms in textiles, natural fibre-based textiles, could be discussed in terms of large receptive surface areas, as well as the availability of appropriate growing conditions, such as temperature, oxygen, moisture, and nutrients. The growth of the microorganism has negative impacts not only on textiles but also on the wearer as it results in the biodegradation of textile products along with their dissemination which lead to health risk [70].

An efficient antimicrobial finish should be: fast-acting to be efficient, capable of destroying or stopping the growth of microorganisms, it should be durable to washing or dry cleaning, compatible with other ingredients in the finishing process, limited environmental and product quality effects, simple to apply for low cost and low toxicity requirements. **[61, 120-127]**

6.1.1. Mechanism of antimicrobial finishes

Anti-microbial agents can be classified into two categories; Leaching and non- Leaching (see **Figure 14**).

Leaching type: The finishing agent is released in a gradual manner on the surface of the material or from inside the material to the surrounding environment and spread slowly, and this type of finishing agent has good effectiveness on the microbes present on the surface of the fabric or surrounding it [128].

Non-leaching type: This type of finishing agent is chemically related to the surface of the fabric and therefore it only works on the microbes present on the surface of the fabric and not on the environment surrounding the fabric, and then the killing of microbes is carried out as the microbe moves towards the finishing agent and not vice versa[128].

6.1.2. Silver as an antimicrobial agent

Silver in human health care has a long and fascinating history as an antibiotic. It has been developed for use in water purification, wound care, bone prosthesis, reconstructive orthopaedic surgery, cardiac instruments, catheters, and surgical equipment. Advanced biotechnology has allowed ionizable silver to be integrated into fabrics for medicinal use to reduce the risks of infection and personal hygiene [128].

Compared to other salts, silver nanoparticles exhibit an important antimicrobial property owing to their incredibly wide surface area, which offers stronger interaction with microorganisms [129]. Silver nanoparticles (Ag NPs) penetrate the microorganism cells, where they bind to the thiol groups of enzymes and DNA. When AgNPs present in the cell, their essential physiological roles, such as cell wall synthesis, membrane transport, and DNA group synthesis, are inhibited or deactivated. AgNPs interact with the thiol groups of proteins which disrupt their enzymatic functions. In addition, the binding of metal ions to bacteria's DNA makes them lose their reproductive ability. Mechanism of antibacterial finishes using silver as an antimicrobial agent was illustrated (see Figure **15**).

In the presence of oxygen, AgNPs can also accelerate the production of reactive oxygen species (ROS) that are highly toxic to cells. While ROSs are natural side products in the cell respiration process, their production in large quantities results in "oxidative stress", causing harm to microorganisms' lipids, proteins, and DNA so it destroys the cells of the microorganisms. The formation of reactive oxygen species is shown in the following reaction: [25]

6.1.3. Titanium and Zinc oxide nanoparticles as antimicrobial agents Zinc oxide nanoparticles also show outstanding antimicrobial activity against Gram-negative and Gram-positive bacteria, fungi, molds, and viruses. The explanation for this is their oxidative photo catalytic behaviour, which is typical of semiconductor photo catalysts. Light activation (photo catalysis) of ZnONPs has been shown to greatly improve their antimicrobial function. The photocatalytic destroying of microorganisms can be described by several mechanisms. It is presumed that the photo catalytic mechanism of ZnO NPs involves the formation of ROS, such as superoxide anions (O_2^-), H_2O_2, and hydroxyl radicals (OH) as follows [25] :

TiO_2 or ZnO +hν → $h^* + e^-$

$H^* + H_2O$ → • OH $+H^+$

$e^- + O_2$ → $\bullet O_2^-$

$\bullet O_2^- + H^+$ → H_2O •

$2H_2O$ • → $O_2 + H_2O_2$

The photocatalytic mechanism on ZnONPs also prevents fungal growth by disrupting cell function, which induces deformation in bacterial cells. Peroxidation of lipids often causes DNA damage and disrupts cell membrane morphology.

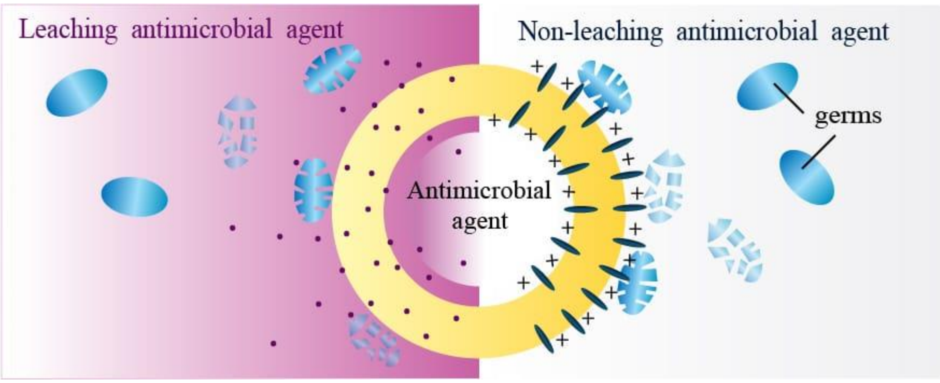

Figure 14: Mechanism of antibacterial finishes

$$H_2O + \frac{1}{2}O_2 \xrightarrow{Ag^+, Ag\,NP} H_2O_2 \rightarrow H_2O + ROS$$

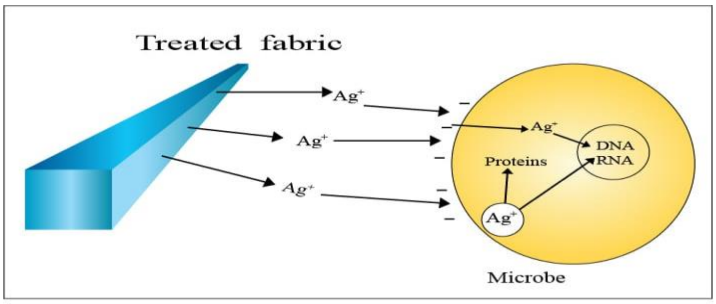

Figure 15: Mechanism of antibacterial finishes using silver as an antimicrobial agent

6.1.4. Evolution of antimicrobial activity

To assess the efficacy of the antibacterial action in textiles, various tests have been used. These tests are as follows:

6.1.4.1. Qualitative test

Rapid qualitative approach for evaluating the antibacterial activity against both Gram-positive and Gram-negative bacteria of the treated textile materials. In this test, by seeing the inhibition zone around the sample examined, it can be shown whether or not a tested finishing agent protects the textile against microorganisms. The following steps are used in these types of methods: preparation of the chosen inoculum bacteria; inoculation of agar and positioning of the examined textile sample on the inoculated agar plates in such a way that good contact is obtained between the sample and the agar. Finally, by assessing the size of the inhibition region, the clean area around the sample, the antibacterial activity assessment is obtained. [25]

6.1.4.2. Quantitative test

Test approaches based on the count of bacteria in the colony are used. In this case, at '0' touch time and after an 18-24 h incubation cycle or other selected periods, the number of bacteria inoculated on test and control textile samples is measured. Bacterial enumeration is subsequently obtained by the strength of luminescence produced by an enzymatic reaction [adenosine triphosphate (ATP) method] or by visual counting of colonies on the agar plate as culture forming units (CFUs). The antibacterial activity value is calculated based on the amount of ATP or the number of CFUs determined at '0' contact time and after the 18-24 h incubation cycle. [25]

6.2. Ultra violet (UV) Protection

Ultra violet radiation has wavelengths ranging from 100 to 400 nm. The sun is the primary source of UV rays in nature. Because the ozone layer blocks much of the UV radiation from the sun, the Earth's surface is penetrated only by UV rays of comparatively long wavelengths, i.e., UVB (290-320 nm) and UVA (320-400 nm) radiation. However, these UVA and UVB rays can also have adverse effects on our bodies and our atmosphere. For instance, UVA and UVB are responsible for the development of multiple pathologies, such as skin cancer, immune system suppression, premature aging of the skin, and Alzheimer's disease. [130]

UV radiation can also cause significant damage to textiles, plastics, paints, and wood products in the form of discolouration and decreased mechanical properties. The production of effective UV protection materials is therefore very critical to our health and environment. [130]

UV protection properties make use a translucent coating of UV absorbent materials on the fabric's surface. In other words, chemical agents or nano-inorganic compounds, such as UV absorbers and UV blockers, can be added to textile fabrics to increase the UV protection factor (UPF) and the sun protection factor (SPF). UPF and SPF are defined as the properties of the UV protection of the modified material. Some factors can play an important role in protecting the skin against UV radiation, such as additives, fabric materials and weaving methods, and the hue of coloured fabrics. The UV protection property of fabrics and apparel is of great importance to end-users around the world and researchers continue to study each of the success factors that can impact the UPF of fabrics. [131]

6.2.1. Mechanism of UV protection

When radiation hits the surface of the fibre, it may be reflected, absorbed, transferred through the fibre, or pass between the fibres (**Figure 16**). The relative levels of radiation reflected, absorbed, or transferred depend on several factors, including the fibre form, the fibre surface smoothness, and the inclusion or absence of fibre delustrants (delustrant is a substance that reduces the lustre (sheen) of synthetic fibres), dyes and UV absorbers. [3]

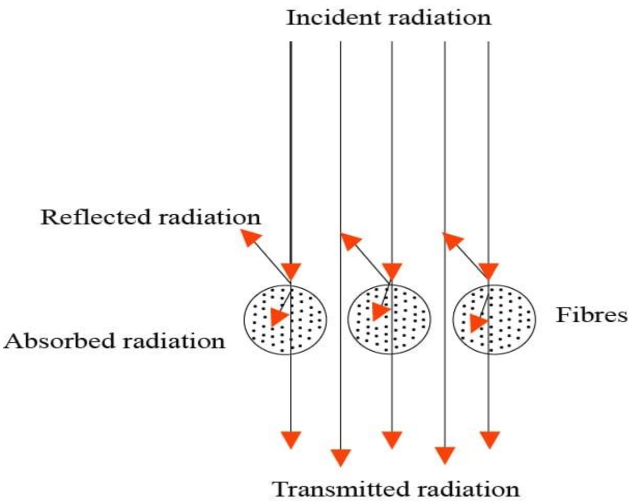

Figure 16: radiation in contact with a textile surface

6.2.2. Classification of UV absorbers

UV absorbers are organic or inorganic compounds with high absorption in the UV range of 100 to 400 nm. Organic UV absorbers are relatively inexpensive and usually translucent so that they can be used in many-coloured fabrics and textiles. However, the bulk of the organic absorbers are eventually destroyed by the UV radiation they absorb, and thus, the UV absorption efficiency declines with time. Furthermore, Organic UV absorbers are small molecules that can leach out of textiles and can cause health issues until they contaminate food and water. [130]

In comparison to organic UV absorbers, inorganic UV absorbers, such as zinc oxide (ZnO), titanium dioxide (TiO_2), and cerium oxide (CeO_2), have excellent light-fastness. It is predicted that the inherent stability of inorganic UV absorbers will have a UV protective effect for a much longer duration than organic UV absorbers. Many inorganic UV blocking systems based on particles or thin film coatings have been developed. These metal oxides have the same UV protection mechanism.

UV absorbers built into the fibre transform electrical excitation energy into thermal energy, acting as radical scavengers and singlet oxygen quenchers. High-powered, short-wave UVR stimulates the UV absorber to a higher energy state; the energy absorbed will then be dissipated as long-wave radiation. [132]

For example, ZnO has a band gap energy of ~3.3 eV which corresponds to a wavelength of ~375 nm. Light below these wavelengths has enough energy to excite electrons, and thus, is absorbed by ZnO. On the other hand, light with a wavelength greater than the band gape wavelength would not be absorbed. The inorganic semiconductors are not destroyed by the absorbed light but are usually converted into heat that is negligible at room temperature.

6.3. Mosquito Repellent textiles

Mosquitoes are one of the most dangerous vectors that carry parasites and pathogens affecting human life to a very great degree by transmitting deadly diseases such as malaria[133]. Mosquito repellent is a material added to the skin, clothes, or other surfaces that discourages the landing or climbing of insects (and arthropods in general) on that surface. Mosquito repellent substances are also available based on sound production, in particular ultrasound (inaudibly high-frequency sounds) [134].

6.3.1. Mechanism of Mosquito repellent

The behaviour of mosquito repellent agents can be classified into two types:

- Olfactory mode
- Tactile mode

Mosquitos normally use the warm and humid body convection as a means to contact humans by detecting a rise in the concentration of carbon dioxide in the atmosphere. In the **olfactory mode**, which is also called transpiration repellence, the moisture-sensing holes of the mosquitoes that help the mosquitoes to locate the living organisms are blocked so that they cannot locate humans. While **the tactile mode** is based on the action of the repellent agents on the nervous system of the mosquito, which allows them to reach a disturbed state and to resist their actions at sub-lethal/mortal/toxic doses, before knockdown because of their contact with the surface of the fabric. The tactile mode is also known as direct-contact repellence that eliminates insects from the surface before sucking blood. [135]

6.3.2. Classification of Mosquito repellent

Mosquito repellents can be also categorized on a different basis and are seen in (**Figure 17**). Mosquito repellents are classified as chemical or herbal repellents, based on their origin nature. They can also be categorized based on their actions. Repellent Insecticides are agents that are used to repel insects rather than to destroy or kill them. Contact insecticides are agents that contain neurotoxins that disrupt mosquito and insect nervous systems and render them unconscious as they come into contact with them. [135]

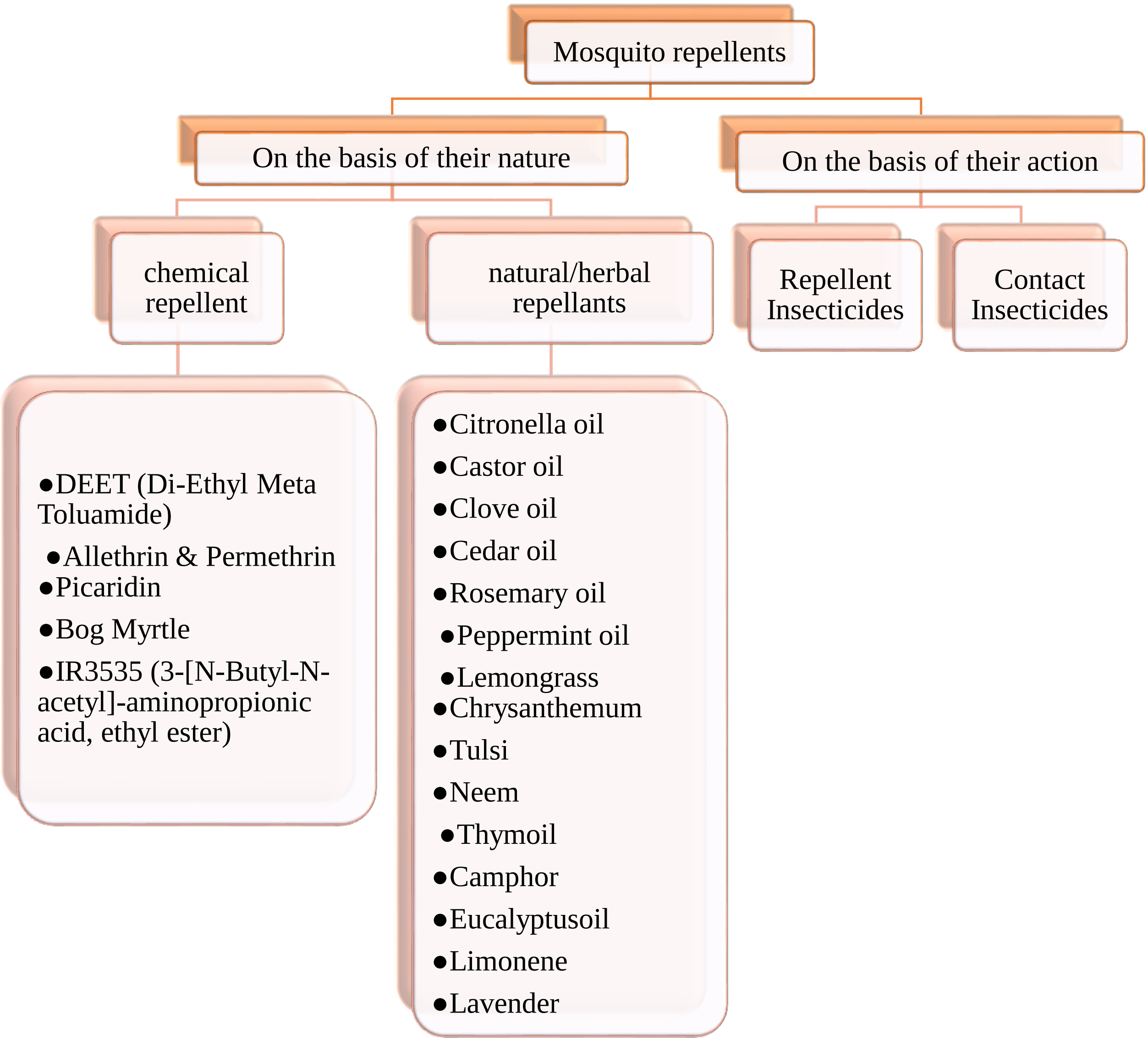

Figure 17: Classification of Mosquito repellent

6.4. Self-Cleaning Textiles

Self-cleaning textiles are one of the recent intelligent textile products that are attracting many researchers. Self-cleaning textiles are inspired by the lotus leaf effect that can repel water droplets and dirt from the surface because of their micro and Nano-hierarchical surface morphology and low surface energy. [131, 136].The fundamental concept of self-cleaning is the characteristics of forming spherical water droplet which simply rolls off the surface and thoroughly cleaning the surface from dirt particles, So one of the advantages of these materials is their ability to do self-clean without the use of traditional laundry processes. [137]

Nanotechnology is playing a vital role in the development of self-cleaning surfaces because nanoparticles alone can disperse well on diverse substrates more evenly and produce hierarchical morphology. The adhesion of nanoparticles with photo catalytic properties will result in improved self-cleaning properties. Nanoparticles such as titanium dioxide and zinc oxide are photo catalysts. They are used for imparting self-cleaning and anti-bacterial properties to the fabric. [137, 138]

6.4.1. Mechanism of self-cleaning using photo catalyst

When TiO_2 and ZnO NPs are illuminated by light with higher energy than its band gap, electrons jump from the valence band to the conduction band, forming electron (e^-) and electric hole (h^+) pairs on the photo catalyst's surface **Figure 18)**. The negative electrons and oxygen will interact to form free-radical oxygen O_2. While the positive electric holes and water will produce hydroxyl radicals OH. Since both products (O_2, OH) are chemically unstable, when an organic compound, such as dirt, toxins, or microorganisms, drops on the photo catalyst's surface, it can react with O_2 - and OH- to form carbon dioxide (CO_2) and water (H_2O). [136, 139]

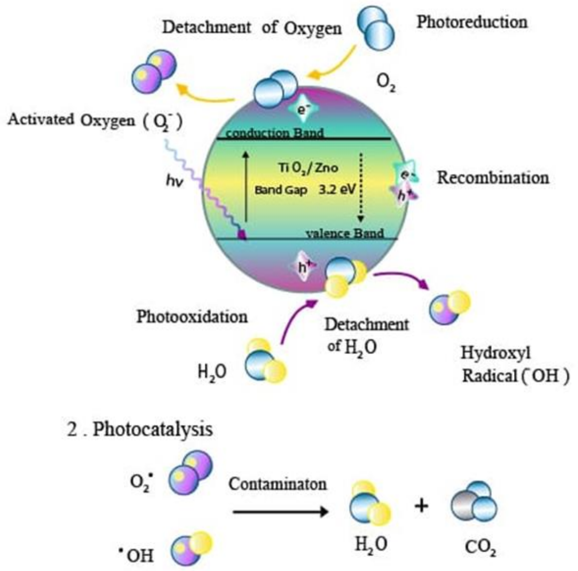

Figure 18: photocatalytic activity of TiO_2 nanoparticles

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