

UNVEILING NATURE'S GIFT TO EXTEND FOOD SHELF LIFE BY USING PLANT-BASED ANTIOXIDANTS, FROM CHROZOPHORA ROTTLERI

Abstract

Chrozophora Rottleri, also known as Suryavarti, is a Euphorbiaceae family medicinal herb. This plant can be found in a variety of environments, including Central Java, India, Myanmar, Thailand, and the Andaman Islands. Tribes and traditional healers use it for a variety of therapeutic purposes. It contains alkaloids, sugars, glycosides, tannins, steroids, flavonoids, and saponins, as well as phytochemicals with antibacterial, antioxidant, anti-inflammatory, anti-helminthic as well as antimutagenic functions. Amid worries about this safety regarding synthetic antioxidants, *Chrozophora rottleri* offers a natural alternative, providing safer preservation methods in food and cosmetics. Natural Antioxidants derived from plants improve food safety and improving overall health.

Keywords: *Chrozophora Rottleri*, Medicinal Herb, Antioxidants, Food safety, Natural Antioxidants.

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I. INTRODUCTION

Chrozophora Rottleri (Geiseler) A. Juss. ex Spreng, commonly known as Suryavart. It is a member of the Euphorbiaceae family and a naturally occurring medicinal herb. This annual plant blossoms from January to April and has monoecious flowers, three-lobed leaves, and stems covered in silvery hair. This herb has substantial therapeutic significance and is found in places like Malesia, India, the Andaman Islands, Thailand, and Myanmar. The medical benefits of *Chrozophora rottleri* are well known; its leaves are used to treat dermatitis, while its roots are used to treat asthma, burns, colds, coughs, cuts, and wounds. The herb is renowned for its caustic, drastic, and emetic properties. The seeds are additionally employed as a cathartic. [1] [2]. The major phytochemicals identified in *Chrozophora rottleri* encompass alkaloids, carbohydrates, glycosides, tannins, steroids, flavonoids, and saponins. Notably, specific compounds such as quercetin 3-o-rutinoside (rutin), acacetin 7-o-rutinoside, and chrozo phorin were also present. Interestingly, the seeds of *C. rottleri* contained a blue dye. Further analysis revealed the presence of apigenin, apigenin 7-O-methyl ether, apigenin 7-O- β -D glucopyranoside, and two unique acylated flavonoids: apigenin 7-O-(6'''-E-p-coumaroyl)- β -D- glucopyranoside and apigenin 7-O-(3'''-E-p-coumaroyl)- β -D- glucopyranoside. These special flavonoid compounds are found in the plant. The traditional use of this herb by indigenous cultures and native medical practitioners adds to its importance [11] [7].

Chrozophora rottleri has a number of beneficial properties, it contains antioxidants that can help in free radical scavenging and oxidative stress reduction [3]. The plant has anti-inflammatory properties that may aid in the reduction of inflammation and symptoms [4]. *Chrozophora rottleri* possesses antibacterial characteristics [5]. *Chrozophora rottleri* possesses antihelminthic properties [6]. And also, it's found antimutagenic properties [1].

II. TAXONOMIC CHARACTERS OF *CHROZOPHORA ROTTLERI*

The Euphorbiaceae family, which has 300 genera and 5000–7500 species, with seven genera being the most well-known, includes *Chrozophora rottleri*. *Chrozophora brocchiana*, *Chrozophora gangetica*, *Chrozophora mujunkumi*, *Chrozophora oblongifolia*, *Chrozophora plicata*, *Chrozophora sabulosa*, *Chrozophora tinctoria*, and *Chrozophora rottleri* are just a few of the many species that make up the genus. *Chrozophora rottleri*, also known as *Chrozophora plicata* var. *rottleri* or *Croton rottleri* Geiseler [7].

This plant, which is classified as an undershrub or herb, can reach a height of 60 cm and has flowering twigs that are 2-2.5 mm thick. Its leaves have a petiole of 0.8-5.5 cm and oval, frequently not clearly 3-lobed blades measuring 2.6-9 by 2.6-9 cm. The leaves are covered with stellate and simple hairs. With petals of 3.7-3.8 by 1.5-1.6 mm and anthers measuring roughly 0.9-1.3 by 0.7 mm, staminate flowers are yellow and 4-6 mm broad. Pistillate blooms have a diameter of 3.2–3.3 mm, a greenish–yellow colour, an oval ovary, and a style that is 0.5–0.8 mm long. Fruits are roughly 8 by 9 mm in size, and seeds are roughly 3.8 by 3.9 by 3.2 by 3.6 mm in size. This plant, which is native to many areas, exhibits distinctive botanical traits and reproductive traits that contribute to its varied ecosystem interactions [8].

- 1. Chrozophora Brocchiana:** *Chrozophora brocchiana* is a shrubby herb that can reach heights of 60 to 150 cm and has a strong taproot. The stem is hairy and tangled with white velvet. Simple, triangular-ovate, alternating leaves with silky hairs on the lower surfaces and sparse hairs on the upper surfaces. Flowers have five petals that are rich red colour and are unisexual. The fruit is a three-lobed capsule with three seeds within that is covered in lustrous, white, or violet-tinged scales.
- 2. Chrozophora Oblongifolia (Delile) A. Juss. Ex Spreng:** The plant, *Chrozophora brocchiana*, grows 1 meter tall, it can develop into an erect shrub, subshrub, or woody herb. The leaves contain 3 to 5 noticeable nerves that protrude from the base and are triangular-ovate to triangular-lanceolate. They are pubescent on both sides. The blooms are unisexual, with female flowers having larger pedicels and lanceolate sepals and petals while male flowers have yellowish petals and lanceolate sepals. The fruit is trilobate and spherical, bluish-purple in colour, and has silvery-lepidote scales on it. The triangular-ovoid, yellowish-gray, coarsely tuberculate seeds have an ovoid shape. The plant frequently has several branches, sturdy, woody stems, and leaves that are clearly petioled and ovate-rhomboid or lanceolate in shape.
- 3. Chrozophora Plicata:** *Chrozophora plicata* oil has a composition of linoleic, oleic, and saturated acids similar to cottonseed oil, but has varied quantities of linolenic and oleic acids, ranging from 60-75%. The whole plant's methanolic extract has demonstrated inhibitory activity against yeast-glucosidase, suggesting potential as an anti-diabetic medication in the future. Additionally, the fruit of the plant can be used to make colours, stains, inks, tattoo inks, and mordants. *Chrozophora plicata* leaf extracts also demonstrated significant fungitoxicity against *p-aphanidermatum* [9].

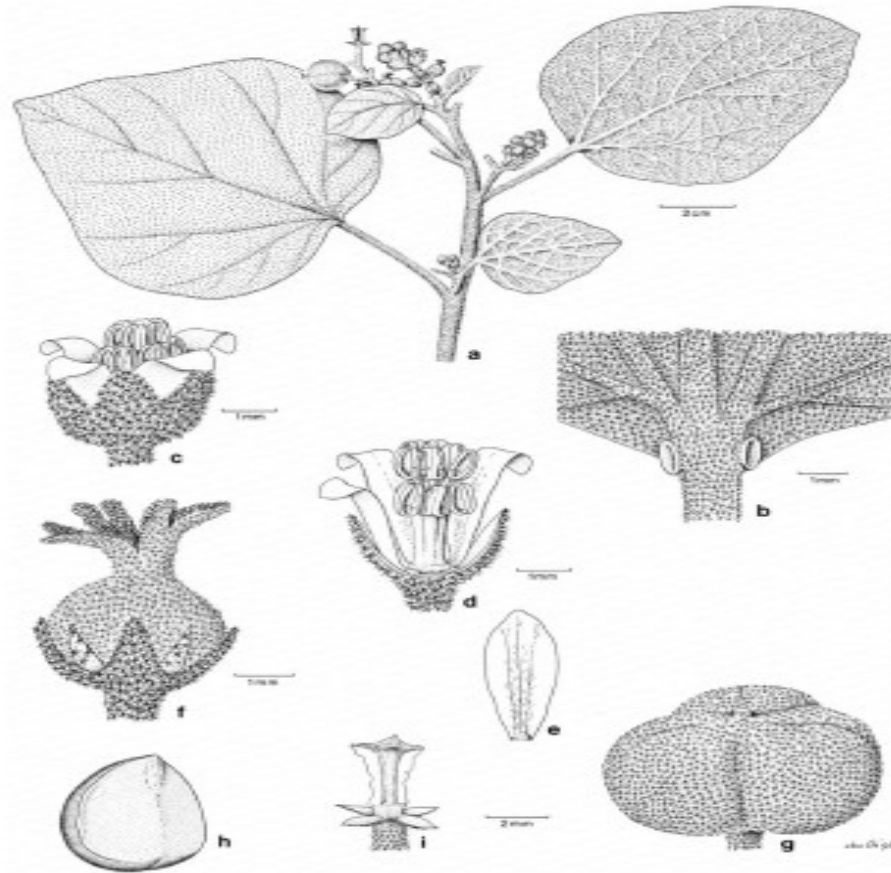


Figure 1: Morphology of the Plant [10]

a. Habit; b. abaxial basal leaf glands; c. staminate flower; d. staminate flower with a few sepals and petals cut to reveal united stamens; e. staminate petal; f. pistillate flower; g. fruit; h. seed. [10].

Source: Welzen, P. C. (1999). Revision and phylogeny of subtribes Chrozophorinae and Doryxylinae (Euphorbiaceae) in Malesia and Thailand. *Blumea: Biodiversity, Evolution and Biogeography of Plants*, 44(2), 411-436.

III. PHYTOCHEMISTRY AND PHARMACOLOGY

Alkaloids, sugars, glycosides, tannins, steroids, flavonoids, and saponins are among the primary phytochemicals found in *C. rottleri*. Rutin, acacetin 7-o-rutinoside, and chrozophorin are all notable chemicals. Its seeds, interestingly, create a blue dye. Apigenin, apigenin 7-O-methyl ether, apigenin 7-O--D glucopyranoside, and two distinct acylated flavonoids. were discovered: apigenin 7-O-(6-E-p-coumaroyl)- -D glucopyranoside and apigenin 7-O-(3-E-p-coumaroyl)- -D glucopyranoside. This species, *Chrozophora Rottleri*, has been found to have flavanones for the first time. *C. rottleri's* complex phytochemical composition has great

promise for a variety of uses. Its diverse molecules have significance in traditional medicine as well as possible industrial applications [11]

In India, stem powder is used to treat jaundice, while Sudan utilises it to speed up the healing of wounds. The leaves and fruits of Nepal are used as cold and cough treatments. Leucoderma, sunstroke, and sunburn are all treated with leaf powder. It also has anti-helminthic effects and is used as an Ayurvedic treatment [12].

The whole plant is used as an antioxidant that can help in free radical scavenging and oxidative stress reduction [3]. The plant has anti-inflammatory properties that may aid in the reduction of inflammation and symptoms [14]. *Chrozophora rottleri* possesses antibacterial characteristics [15] [17]. *Chrozophora rottleri* possesses antihelminthic properties. [16]. And also, it's found antimutagenic properties [1].

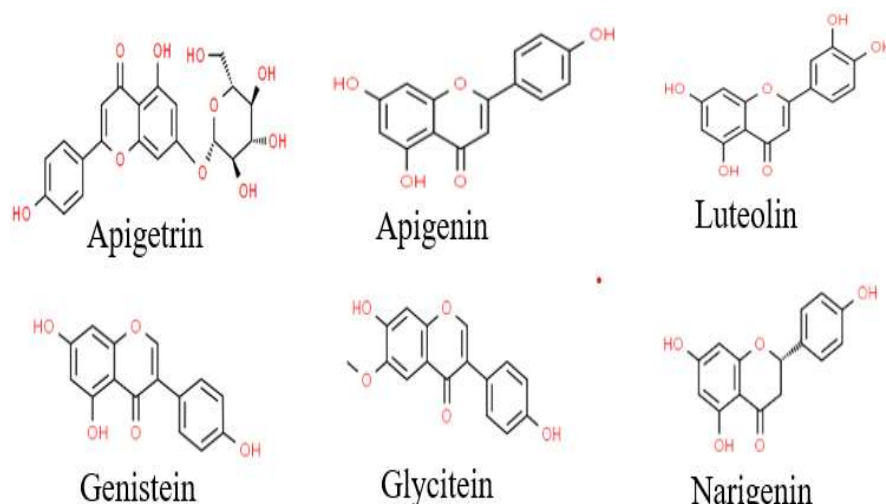


Figure 2: *Chrozophora Rottleri* Principle Metabolites [13]

Source: Sathish, R., Visagaperumal, D., & Chandy, V. Isolation, Phytochemical Investigation and Biological Screening Of Leaf Of *Chrozophora Rottleri*.

Chrozophora rottleri has a wide range of uses in different parts of the world. In India, the plant's stem powder is used to cure jaundice, suggesting its promise in traditional medicine. Meanwhile, in Sudan, the herb is used to expedite wound healing, emphasizing its wound-healing capabilities. The leaves and fruits of *Chrozophora rottleri* have therapeutic use in Nepal, where they are used to treat colds and coughs. Furthermore, the plant's leaf powder is used to cure illnesses such as leucoderma, sunstroke, and sunburn. This adaptable plant also has anti-helminthic properties, adding to its potential medicinal utility. Furthermore, *C. rottleri* is used in Ayurvedic practises, which is consistent with its historical use in traditional medical systems. This versatile plant has a broad range of uses, from treating specific disorders to being an essential component of holistic healing practises. The use of *C. rottleri* in numerous cultures and for various health conditions highlights its importance in traditional and herbal medicine systems. [12]. The whole plant is used as an antioxidant that can help in free radical scavenging and oxidative stress reduction [6]. The

plant has anti-inflammatory properties that may aid in the reduction of inflammation and symptoms [14]. *Chrozophora rottleri* possesses antibacterial characteristics [15] [8]. *Chrozophora rottleri* possesses antihelminthic properties [16] And also, it's found antimutagenic properties [1].

- 1. Anti-Oxidant Activity:** The repressing limit of *Chrozophora Rottleri* when it was assessed it shows IC₅₀ worth of *Chrozophora Rottleri* against these free revolutionaries were viewed as a lot higher ($p < 0.001$) than the guidelines utilized, demonstrating that they have less cell reinforcement movement. In view of the information, we reasoned that *Chrozophora Rottleri* doesn't show huge cell reinforcement potential under in-vitro conditions. The current review didn't show any proof of in-vitro cell reinforcement movement against normally experienced free revolutionaries in human pathology. The individual phyto-constituents of *Chrozophora Rottleri* may show cell reinforcement capacity in higher fixation than the combination of phytoconstituents present in *Chrozophora Rottleri*. The Phyto-constituents screening will frame a base for the medication disclosure research.
- 2. Anti-Bacterial Activity:** The antibacterial movement of leaf concentrate of *Chrozophora rottleri* Oxalis corniculata, Parthenium hysterophorus, and solanium xanthocarpum were assessed *in-vitro* against some clinical disconnects by agar well distribution technique. Two solvents chloroform and methanol were utilized for extraction of mixtures from new leaves. The antimicrobial capability of the leaf is not entirely set in stone by the estimating of the zone of restriction. It was closed from the outcomes that both chloroform and methanol separate have viable in restraining the growth of clinical detaches. The result uncovered that methanol extraction has more antibacterial potential than chloroform removal [12].
- 3. Antimutagenic Properties:** The study using *Chrozophora rottleri* leaf extract on albino mice demonstrated its effectiveness against mutations brought on by EMS (Ethyl methanesulfonate). The strong antimutagenic ability of the crude extract of *Chrozophora rottleri* leaf in the mouse bone chromosomal aberration experiment served as a demonstration of the extract's efficacy. It is thought that the antioxidant elements in *Chrozophora rottleri* such as polyphenolic compounds, flavonoids, and other micronutrients, are responsible for the antimutagenic action seen in this organism against EMS. These bioactive substances most likely cooperate to provide their anti-mutational actions. The distinct elements found in the extract and their combined effects on fending off mutagenic agents like EMS would have an impact on the level of protection offered by the *Chrozophora rottleri* extract [17].
- 4. Antioxidant Activity of *Chrozophora Rottleri* Extracts:** The antioxidant activity of *Chrozophora rottleri* extracts was evaluated using methanolic, hexane, and aqueous leaf extracts. All of these extracts exhibited concentration-dependent scavenging activity against several free radicals. [16] [18].

The plant contains a lot of phytochemicals Alkaloids, sugars, glycosides, tannins, steroids, flavonoids, and saponins are among the primary phytochemicals found in *C. rottleri*. Rutin, acacetin 7-o-rutinoside, and chrozo phorin are all notable chemicals. Apigenin, apigenin 7-O-methyl ether, apigenin 7-O--D glucopyranoside, apigenin 7-O-(6-

E-p-coumaroyl)- -D glucopyranoside and apigenin 7-O-(3-E-p-coumaroyl)- -D glucopyranoside [11]. The main phytochemicals found in *Chrozophora rottleri* are apigenin and naringenin, according to earlier findings. Natural flavonoid apigenin has a range of biological benefits, including anti-inflammatory, anti-cancer, anti-oxidative, and neuroprotective actions. *Chrozophora rottleri* promotes its prospective usage as a natural source of therapeutic chemicals with a variety of health-promoting benefits [16]. The combination of these phytochemicals in *Chrozophora rottleri* extracts leads to its total antioxidant activity, making it a good candidate for prospective application in a variety of health and medicine disciplines. Based on this, the plant is rich in antioxidant agents.

5. **Antioxidants:** An antioxidant is a molecule stable enough to donate an electron to a rampaging free radical and neutralize it, thus reducing its capacity to damage [48]. Antioxidants prevent damage by scavenging free radicals and preventing their interaction with dietary components. although antioxidants inhibit peroxidation initiators, chelating metals, inhibiting reactive species production, quenching peroxides, breaking autoxidation chains, and decreasing local O₂ levels. and quenching chain initiators and eradicating reactive oxygen and nitrogen species. Free radicals are formed by the reaction of oxygen, nitrogen, and sulphur molecules, resulting in reactive oxygen, nitrogen, and sulfur species. Superoxide anion, hydrogen peroxide, peroxyxynitrite as well as singlet oxygen are all examples of reactive oxygen species (ROS). Reactive nitrogen species (RNS) is formed when nitric oxide reacts with superoxide to generate peroxyxynitrite, whereas RSS is formed when thiol reacts with ROS [20] [21].

When oxidative species, whether ROS or RNS, are regulated, they have favorable benefits. They aid in cellular homeostasis, act as signaling molecules, promote ATP generation in mitochondria, and allow the body to perform apoptosis, phagocytosis, and xenobiotic detoxification. Excessive oxidant production, on the other hand, upsets homeostasis, resulting in oxidative damage in essential biomolecules such as lipids, DNA, and proteins. This damage is at the root of many human diseases, including cardiovascular disease, some malignancies, autoimmune disorders, arthritis, and neurological issues. The pathogenic effects on Alzheimer's disease and the ageing process are particularly significant [22] [43].

Although antioxidants, which have bioactive qualities that improve food quality and consumer health. They preserve sensory and nutritional properties while extending shelf life despite not being nutrients. Antioxidant emphasizes their importance as food additives, protecting goods without sacrificing their sensory or nutritional value. Reactive species formation is prevented by antioxidants in both food systems and the human body. The difference between lab-produced and natural substances is that the latter is derived from organic sources like plants, animals, and microorganisms. Although both have a role in food preservation, their effectiveness varies. Natural and synthetic antioxidants protect food quality by combating oxidative damage during storage and processing, preserving nutrients, colour, taste, and attractiveness. While synthetic antioxidants excel at maintaining high-lipid foods, natural antioxidants excel at reducing negative effects and preventing chronic diseases. concur, pointing out that natural antioxidants prefer less rancid products while synthetic antioxidants favour foods with greater levels of rancidity [23] [24].

The desire to combat free radicals and halt food degradation is driving the increased interest in using antioxidants for food preservation. Synthetic antioxidants work as preservatives but indirectly influence the body's processes [24].

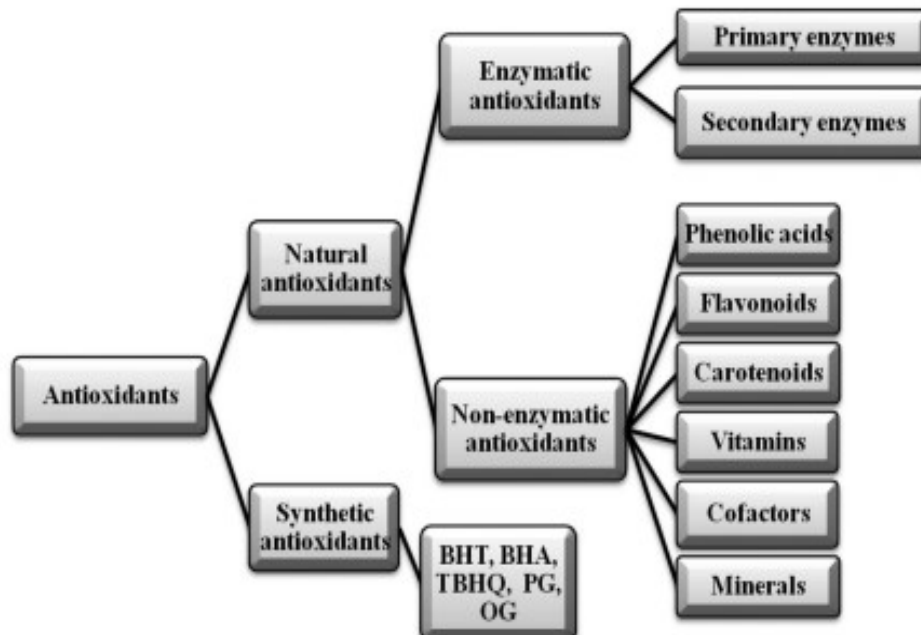


Figure 3: Various Antioxidant Classes (Natural and Synthetic Antioxidants) [40]

Source: Bensid, A., El Abed, N., Houicher, A., Regenstein, J. M., & Özogul, F. (2022). Antioxidant and antimicrobial preservatives: Properties, mechanism of action and applications in food—a review. *Critical Reviews in Food Science and Nutrition*, 62(11), 2985-3001.

6. Synthetic Antioxidants: Synthetic antioxidants are made in laboratories by chemical reactions. Synthetic antioxidants have gained popularity because they are more stable, work better, and are less expensive. They're widely used as food additives to prevent rancidification, and they're regarded for their great efficacy and widespread availability. Synthetic antioxidants are added to food as preservatives, primarily to prevent lipid oxidation. Because natural antioxidants are unstable, they are used as food preservatives. BHA, BHT, PG, and TBHQ are examples of artificial antioxidants. They are important synthetic antioxidants in the food sector, whereas 2-naphthol, 4-phenylphenol, and 2,4-dichlorophenoxyacetic acid are extensively employed in fruits and vegetables.

Despite widespread adoption, safety concerns have arisen over time. Long-term consumption of synthetic antioxidants has been linked to health difficulties such as skin allergies, gastrointestinal problems, and even an increased risk of cancer. High dosages have been linked to DNA damage and accelerated ageing. BHA and BHT have been linked to liver issues and carcinogenesis in animal studies. Furthermore, the environmental impact and fate of these chemicals are still unknown [24] [26].

Synthetic and natural food preservatives can both be employed alone or in combination. Both kinds of antioxidants are used in the food sector, however synthetic antioxidants may be carcinogenic. Natural alternatives, on the other hand, provide more advantages for human health with less adverse effects. As a result, there is an increasing emphasis on utilising fruits, vegetable waste, and plant extracts high in phenols as beneficial resources to improve food preservation techniques [27].

Because of their health benefits and absence of negative effects, natural antioxidants obtained from plants, fruits, vegetables, and other natural sources are gaining favour. In food and cosmetics, natural antioxidants typically replace synthetic preservation. As a result, natural antioxidants are becoming increasingly popular as safer and healthier alternatives.

- 7. Replacing Synthetic Antioxidants with Natural Antioxidants:** Phytochemicals are important sources of antioxidants since they help to maintain redox balance and are classified as antioxidants due to their redox activity. Plant chemicals are divided into two categories: primary constituents (sugars, amino acids, and so on) and secondary constituents (alkaloids, terpenes, and phenolics). Carotenoids, flavonoids, acids, vitamins, and tocopherols are antioxidant Phyto-constituents found in plants such as fruits and vegetables. Because of their compatibility with human physiology, these plant-based antioxidants are thought to be biologically more potent than synthetics. Plant extracts and phytoconstituents have been shown in studies to be effective regulators of lipid peroxidation and oxidative stress, potentially providing health benefits [28]. Plant-based antioxidants are classified into three types: phenolic chemicals, vitamins, and carotenoids. Phenolic compounds not only have antioxidant capabilities, but they also have antibacterial and antifungal activities, which influence food flavours and textures. Vitamins E and C, which are soluble in lipids and water, respectively, play important roles. Carotenoids, which are present in fruits and vegetables, have antioxidant properties and the potential to be used as food colouring. Food-grade antioxidants must meet regulatory-approved safety standards. Apart from efficacy, they should not alter sensory properties and must be stable during processing and storage. While certain natural antioxidants have lower activity than synthetics, they can still be beneficial when used within regulatory guidelines. Organoleptic properties are taken into account when selecting natural extracts. According to studies, natural extracts such as chamomile and fennel have higher antioxidant activity than synthetic counterparts. Plant extracts made from rosemary, grape seeds, green tea, and other sources are also promising. As a result of this trend, functional meals with added value are being developed by investigating the antioxidant potential of agricultural and food byproducts [26].

Poly Phenols: Polyphenols are substances having many hydroxyl groups on aromatic rings that are found in plants. They can be divided into four groups: lignans, flavonoids, phenolic acids, and hydroxycinnamic acids. Anthocyanins, flavanols, and flavanones are a few of the types of flavonoids that are further broken down. Tannic and ellagic acids are phenolic acids. The three types of tannins are complex tannins, condensed tannins (proanthocyanidins), and hydrolyzable tannins (gallotannins, ellagitannins). Condensation and cyclization processes, which provide a variety of structural variations, are used in the synthesis of flavonoids. Cinnamic acid undergoes hydroxylation and methylation to produce phenylpropanoids, which serve as precursors for numerous other chemicals.

Phenylpropanoid dimers make up lignans. These polyphenols have a range of physiological and dietary impacts [29] and also have Antibiotic resistance, a global health concern, which has motivated the quest for new antimicrobial chemicals as bacterial resistance has increased. Polyphenols, terpenoids, alkaloids, and peptides are examples of plant chemicals that have demonstrated antimicrobial activity [30].

Plant extracts high in phenolics are preferred over synthetic antimicrobials due to the rising demand for natural antimicrobials brought on by health and environmental concerns. Enhancing food safety and preservation through controlled release in coatings and packaging is consistent with sustainability and quality concerns..[44].

The combination of well-known antioxidants and antimicrobials, such as phenolic compounds, with bio-based and synthetic polymers opens up fascinating possibilities for extending the shelf life of food applications. This can happen either directly through food contact or as a result of an all-encompassing plan. However, depending on the details of the diet, their effectiveness varies, necessitating thorough assessment procedures. For instance, pomegranate peel extract successfully reduces the oxidation of lipids and proteins in beef meatballs and prevents the growth of microorganisms, including melanosis, in chilled Pacific white prawns. Bee pollen, cocoa, and grape seed extract all show promise in various applications, moderating oxidation and improving product quality. It also improves the colour and quality of foods like strawberries and red radishes. Similar to oregano, phenolic-enriched extracts improve the frying abilities of vegetable oils by maintaining their natural antioxidants [31].

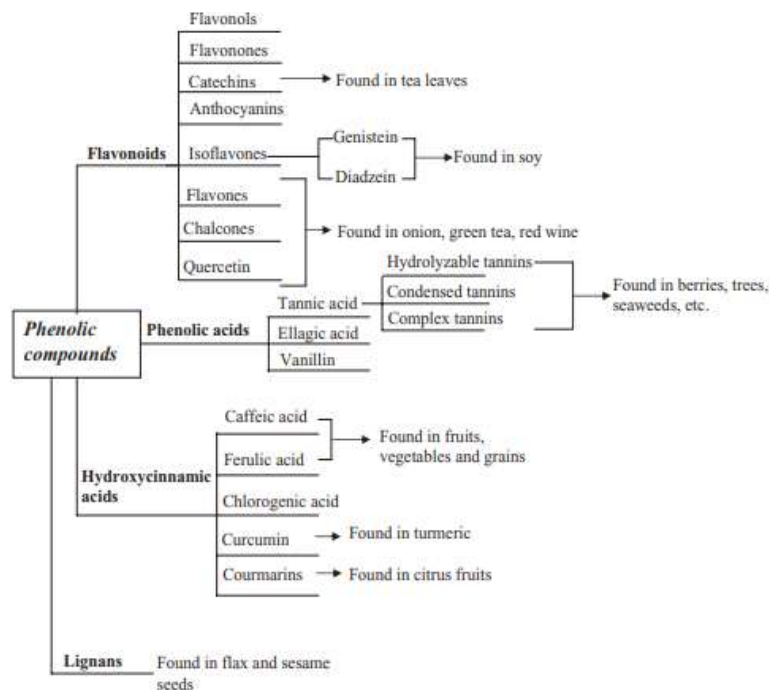


Figure 4: Classification of Phenolic Compounds [42]

Source: Maqsood, S., Benjakul, S., & Shahidi, F. (2013). Emerging role of phenolic compounds as natural food additives in fish and fish products. *Critical reviews in food science and nutrition*, 53(2), 162-179.

- 8. Tannins:** Tannins are mostly present in foods and drinks made from plants. These substances have historically been used in the leather tanning process, hence the term "tannin". They are extracted from various plant components, including algae, and some of them have medicinal and aesthetic uses, such as phlorotannins. Tannins are phenolic substances with a high molecular weight that can form potent interactions with proteins. They may be classified in to three subgroups: phlorotannins, hydrolysable tannins, as well as condensed tannins. Water-soluble hydrolysable tannins have glucose cores that have been esterified with phenolic chemicals like gallic or ellagic acid. In contrast to phlorotannins, which are present in brown seaweed and have antioxidant and other qualities, condensed tannins are polymers of flavan-3-ol units. Tannins are used in a variety of sectors, including leather, medicines, wood and food preserver. Food shelf-life is seriously threatened by microorganisms, fungi, yeasts, viruses, pollens, and chemicals both at home and in markets. It has been demonstrated that the tannins in foods like pomegranates, strawberries, and walnuts prevent the formation of microorganisms like methicillin-resistant *Staphylococcus aureus*. Pomegranate peel punicalagin exhibits powerful antibacterial activity against *Staphylococcus aureus*. Tannin-rich substances, such those found in pomegranate peel, also stop the development of the human norovirus. Tannins may function as antiviral agents, prolonging the shelf life of food. Guava, a fruit that ripens for example, benefits from tannin-based coatings that extend shelf life and maintain fruit quality [33].
- 9. Flavonoids:** Flavonoids are a large family of aromatic chemicals that are often prevalent among plant phenolics. They may be found in seeds, flowers, fruits, leaves, and bark. The Kingdom Plantae has about 10,000 classes, which support a wide range of plant functions. These secondary metabolites, which come from fruits, vegetables, wine, and teas, provide vibrant colours. Flavonoid subclasses including flavones, flavanols, and anthocyanins, each of which plays a unique function in the vitality and health benefits [45]. Based on their distinctive chemical structures, these substances provide a variety of health benefits, like anti-inflammatory, antioxidant, cardiovascular protection, and more. Due to their varied health-promoting properties, several flavonoids as quercetin, kaempferol, and genistein are the subject of intensive investigation. In addition to its importance in nutrition and ecology, flavonoids also aid in plant defence, pollination, and UV protection [34] Flavonoids are important micronutrients and antioxidants found in fruits and vegetables. They have the potential to be natural additives in food production, reducing synthetic substances and improving human health. These bioactive chemicals protect foods by inhibiting oxidation and microbial development. They limit lipid oxidation, protect quality, and inhibit spoilage bacteria in red meats and poultry in particular [32].
- 10. Carotenoids:** Carotenoids are found in plants, animals, and microbes, and there are over 700 different types. They have a 40-carbon tetraterpene structure and undergo structural modifications via hydrogenation, isomerization, cyclic forms, side-group addition, and glycosylation. Aside from coloration, carotenoids are antioxidants due to their conjugated PUFA chains, which fight free radicals. Their lipophilicity protects cell membranes and lipoproteins against peroxy radicals [35]. Food colour has significant sensory and

nutritional value. Carotenoids are added to food either directly or indirectly through animal feed to improve colour and nutritional value. Carotenoids have been adopted by active packaging films, prolonging the shelf life of products and improving their nutritional value. Their stability and bioavailability are enhanced by encapsulation technologies such as spray drying, emulsion, and nanotechnology. Carotenoid-rich feeding supplements improve nutritional value and antioxidant capacity in poultry and aquaculture. Carotenoids also maintain the integrity of packaging materials, shielding food from oxidation and UV ray damage [36].

Vitamin C: Vitamin C, a water-soluble compound, is a natural antioxidant in many plant-based products, [47] Vitamin C is found in citrus fruits, green peppers, redpeppers, strawberries, tomatoes, broccoli, brussels sprouts, turnip, Indian gooseberry and other leafy vegetables.[46]. Vitamin C is essential for several functions, including collagen formation, wound healing, haemorrhage prevention, and cellular defence. It has significant antioxidant properties, neutralising free radicals and ensuring the stability of important nutrients like as vitamins A, E, and folic acid. It is necessary for the production of adrenaline and serotonin, aids in iron absorption, and aids in heavy metal detoxification. The chemical is utilised in food additives that aid in the retention, stabilisation, and antioxidant activities of various foods such as meat, beverages, and baked goods. Ascorbic acid is essential for preventing oxidation and discolouration in items such as ground meat and cold cuts.

Ascorbic acid is used in a variety of food products such as beer, gelatin, jams, bread, fruit juices, and various meats. Notably, ascorbic acid is essential in the manufacture of ground meat, avoiding oxidation and unwanted colouring during storage. This feature is particularly essential because it contributes to the product's appealing appearance while having no effect on its organoleptic capabilities. [36].

IV. CONCLUSION

Antioxidants are essential in the food industry because they prevent rancidity. They also help biologists and doctors by regulating ROS-related enzymes, which defend against illnesses caused by oxidative stress and oxidative species. Antioxidants have long been used to preserve food, with synthetic antioxidants dominating the market until recently. However, there is a discernible shift towards natural antioxidants in the food industry, considering their potential health advantages, spurred by the expanding consumer health awareness.

Natural antioxidants, which are essential in the food sector, provide several advantages. In functional foods, it is used to replace synthetic counterparts, assuring stability and avoiding oxidation-related damage during processing and storage. Resource efficiency and sustainability objectives of a circular economy are supported by using leftover food and underused plant resources. Due to their inherent advantages over synthetic antioxidants, such as being sourced from plants and having a low level of toxicity, natural antioxidants are preferred. Substances including phenolics, apigenin, flavonoids, and naringenin, among others, are seen as safer substitutes because of their potential health-promoting properties.

Natural antioxidants, such as those found in *C. rotleri*, can be effectively applied to food preservation processes to prevent fat and oil oxidation, reduce rancidity, and preserve

nutritional content. Natural antioxidants are becoming more popular in the food industry, highlighting the importance of adopting a healthier and more environmentally friendly technique of food preservation for the benefit of humans. Antioxidants are essential in the food sector, where they have traditionally been employed to keep food fresh by preventing oxidation and rotting. Synthetic antioxidants dominated the market in the past due to their effectiveness and low cost. However, there was a considerable shift in recent decades towards the use of natural antioxidants. This transition is mostly driven by consumer awareness of health and wellness Resulting in higher demand for more natural and healthier food products.

Natural antioxidants have the potential to provide considerable health advantages. Natural antioxidants are derived from plants and are generally considered safer with a lower level of toxicity than synthetic counterparts, which may raise concerns about potential health problems at high levels of intake. Because of their intrinsic safety profile, they are a popular choice among both consumers and the food industry. Natural antioxidants have numerous applications in the food industry. They are employed not just in functional food products, but also as substitutes for synthetic antioxidants in a variety of food processing and storage applications. Food manufacturers can improve the stability of their products and avoid oxidation deterioration by introducing natural antioxidants, guaranteeing that the nutritional value and quality of the food are retained for longer shelf life.

The source of natural antioxidants is one appealing feature. Unused plant materials and food waste both contain many of these antioxidants. This is in line with the circular economy's guiding principles, which emphasise sustainability and resource efficiency. The food sector may reduce waste and use resources more effectively by using these antioxidants sourced from plants. Natural antioxidants with potential to improve health include, among others, phenolics, apigenin, flavonoids, and naringenin. These compounds provide safer substitutes for synthetic antioxidants and support the use of natural antioxidants in the food sector.

The application of natural antioxidants is demonstrated specifically in *Chrozophora rottleri*, where these antioxidants can be successfully added to food preservation methods. They can do this to stop fats and oils from oxidising, cut down on rancidity, and support maintaining the overall nutritious content of food goods. This exemplifies the useful advantages of utilising natural antioxidants in food preservation techniques. The need of adopting healthier and more sustainable techniques of food preservation is highlighted by the growing usage of natural antioxidants in the food business. The food business is responding to consumer awareness from the effects of food choices on their health and the environment by embracing natural alternatives that provide both nutritional benefits and sustainable practises. In general, the change towards Overall, the shift towards natural antioxidants in the food business represents a trend in favour of healthier and more environmentally friendly food options, which is good for both consumers and the environment.

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