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NATURAL ANTIOXIDANTS

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Abstract: *Antioxidants sourced from nature play a pivotal role in maintaining human health. Enzymatic antioxidants like catalase and peroxidase, alongside high-molecular-weight non-enzymatic antioxidants such as albumin and ferritin, bolster cellular defense mechanisms. Phenolic compounds, plentiful in plants, act as antioxidants and fall into different categories like phenolic acids, flavonoids, tannins, lignans, and lignin. These compounds showcase antioxidant prowess by neutralizing free radicals and binding metals, with their efficacy influenced by structural nuances and environmental factors. Moreover, flavonoids, tannins, lignans, diterpenes, and carotenoids stand out for their antioxidant prowess. Carotenoids like lycopene, present in tomatoes, display notable antioxidant potency, contributing to health advantages like mitigated disease risks. Additionally, tocopherols (vitamin E) and ascorbic acid (vitamin C) demonstrate antioxidant properties, shielding against lipid oxidation and providing supplementary health perks. The diverse range of natural antioxidants found in plants underscores their significance in fostering health and combating ailments linked to oxidative stress.*

Keywords: *Antioxidants, natural antioxidants, phenolic compounds, vitamin E.*

Annotatsiya: *Tabiiy manbalardan olingan antioksidantlar, inson salomatligini saqlab qolishda muxim vazifani bajaradi. Katalaza va peroksidaza kabi fermentli antioksidantlar, bir qator yuqori molekulalovchi noferment antioksidantlar, masalan, albumin va ferritin, xujayralarni himoya mexanizmlariga yordam beradi. O'simliklarda mavjud fenol birikmalar antioksidant hususiyatlariga ega bo'lib, quyidagi guruxlarga bulinadi: fenol kislotalar, flavonoidlar, taninilar, lignan va lignilar. Ushbu birikmalar erkin radikallarin neytralizatsiya qilish va metallarni xelatlash xisobiga antikosidantilk xususiyatiga ega bo'lib, ularninig effektivligi strukturaga va atrof muxitdagi shart sharoitga bog'liq. Bundan tashqari, flavonoidlar, taninlar, lignanlar, diterpenlar va karotinoidlar antioksidant hususiyatlari bilan ajralib turishadi. Pomidorlarda topilgan likopin karotinoidlar, faol antioksidant xususiyatga ega bo'lib, salomatlik va kasalliklarning oldini oladi. Shuningdek, tokoferollar (E vitamini) va askorbin kislota C vitamini) lipidlarni oksidlanishidan himoya qiladi va salomatlik uchun qo'shimcha imkoniyat yaratadi. O'simliklarda topilgan turli tabiiy antioksidantlar inson salomatligini qo'llab quvvatlash va oksidlanish bilan bogliq bo'lgan kassaliklarga qarshi kurashishda yerdam berishi qanchalik muximligini ko'rsatadi.*

Tayan so'zlar: *Antioksidantlar, tabiiy antioksidantlar, fenol birikmalar, vitamin E.*

Аннотация: *Антиоксиданты, полученные из природных источников, играют ключевую роль в поддержании здоровья человека. Ферментативные антиоксиданты, такие как каталаза и пероксидаза, наряду с высокомолекулярными неферментативными антиоксидантами, такими как альбумин и ферритин, способствуют клеточным механизмам защиты. Фенольные соединения, обильно присутствующие в растениях, служат антиоксидантами и классифицируются на различные группы, такие как фенольные кислоты, флавоноиды, танины, лигнаны и лигнин. Эти соединения обладают антиоксидантными свойствами за счет нейтрализации свободных радикалов и хелатирования металлов, причем их эффективность зависит от структурных факторов и условий окружающей среды. Кроме того, флавоноиды, танины, лигнаны, дитерпены и каротиноиды выделяются своими антиоксидантными способностями. Каротиноиды, включая ликопин, обнаруженные в помидорах, проявляют значительную антиоксидантную активность, способствуя здоровью и снижению риска заболеваний. Кроме того, токоферолы (витамин Е) и аскорбиновая кислота (витамин С) обладают антиоксидантными свойствами, защищая от окисления липидов и обеспечивая дополнительные преимущества для здоровья. Разнообразие природных антиоксидантов, обнаруженных в растениях, подчеркивает их важность в поддержании здоровья и борьбе с заболеваниями, связанными с окислительным стрессом.*

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Ключевые слова: *антиоксидант, натуральный антиоксидант, фенольные соединения, витамин Е.*

Introduction

Natural antioxidants can be grouped into different categories: enzymatic antioxidants such as catalase and peroxidase, low-molecular-weight hydrophilic antioxidants like ascorbic acid, and lipophilic antioxidants including tocopherols and carotenoids. Phenolic compounds are a byproduct of plant secondary metabolism and act as natural antioxidants in food. They're abundant in plants and offer protection against infections and UV radiation, functioning as antioxidants [1].

Aromatic herbs and plant roots are rich sources of phenolic compounds, including phenolic acids, flavonoids, tannins, lignans, and lignin found in leaves and flower tissues [2]. In recent years, many phenolic acids have been discovered in oilseeds, such as ferulic and vanillic acids in cottonseed, and sinapic acid in rapeseed meal [3-5].

The antioxidant properties of phenolic compounds (Figure 1) are seen in their ability to neutralize free radicals, deactivate singlet oxygen, and bind metals. The effectiveness of these compounds as antioxidants increases with the positioning of hydroxy groups from ortho to para. Polymeric phenols have been found to be more potent antioxidants compared to monophenols [6]. The solvent type, polarity, isolation method, and testing approach also influence their antioxidant activity [7].

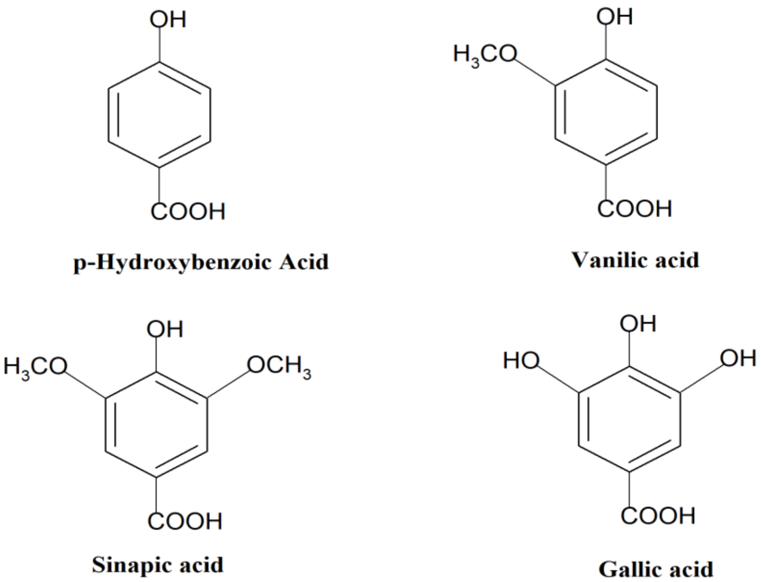


Fig.1. Chemical Structure of Phenolic Acids

Flavonoids represent the most abundant category of natural phenolic compounds, being both water-soluble and lipid-soluble. Many flavonoids serve as pigments, contributing diverse hues to plant tissues. For instance, anthocyanins are responsible for the red, blue, and purple hues in flowers, while flavones, flavonols, aurones, and chalcones create yellow and orange tones [8]. Flavonoids act as primary antioxidants and also form neutral complexes by chelating metals. They are found in nature either as free compounds or bound to glycosides. The antioxidant efficacy of flavonoids hinges on their chemical configuration, the quantity, and the positioning of hydroxyl groups within the molecule, as illustrated in Figure 2.

The fundamental structure of flavonoids comprises a flavone nucleus (2-phenyl-benzo-γ-pyran) formed by two benzene rings (A and B) connected by a pyran ring (C). Flavonoids are commonly categorized into 10 major classes based on the level of oxidation of the three-carbon fragment: Catechins (flavan-3-ols, derivatives of flavan-catechins, leucoanthocyanins), Leucoanthocyanidins (flavan-3,4-diols), Flavanon (flavone derivatives - flavanones, flavanonols, flavones, flavonols), Dihydrochalcones, Chalcones, Anthocyanidins and anthocyanins, Flavanonols, Flavones and isoflavones, Flavonols, Aurones. Numerous flavonoids demonstrate antioxidant activity and chelating properties [9, 10]. The antioxidant properties of flavonoids are influenced by environmental factors such as the presence of metals, light exposure, and the aqueous or lipid medium [11, 12].

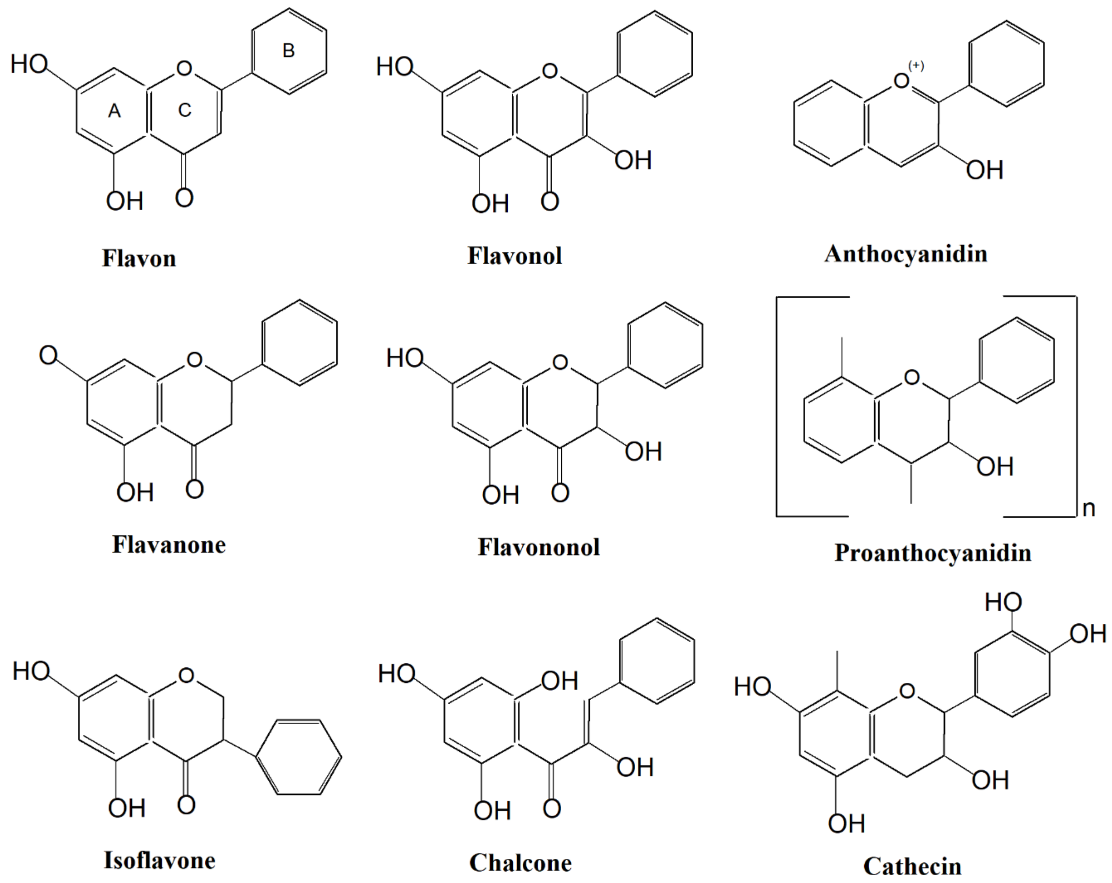


Fig.2. Chemical Structure of Flavonoids

Tannins are polyphenolic compounds with a high molecular weight. Tannins possess astringent properties and a distinct binding taste. Tannins are categorized into two groups: those formed by a polyatomic alcohol (e.g., glucose) with hydroxyl groups that are partially or fully etherified by gallic acid or related compounds (known as hydrolysable tannins, e.g., gall and ellagitannins), and those formed by the condensation of phenolic compounds like catechins (referred to as non-hydrolysable or condensed tannins, e.g., proanthocyanidins). Their structure comprises 5 to 7 aromatic rings with 12-16 phenolic groups in the molecule [13, 14].

Lignans are a group of plant-derived substances and are considered phytoestrogen-like compounds, being one of the main classes of phytoestrogens (Figure 3). Flax and sesame seeds are the richest sources of lignans. The initial lignans discovered in foods were secoisolariciresinol and matairesinol. The primary lignans in the human diet are pinoresinol and lariciresinol, which collectively constitute around 75% of the total lignan intake. The remaining 25% includes secoisolariciresinol and matairesinol. Other important lignans in food include syringaresinol and hydroxymatairesinol. Lignans function as antioxidants [15].

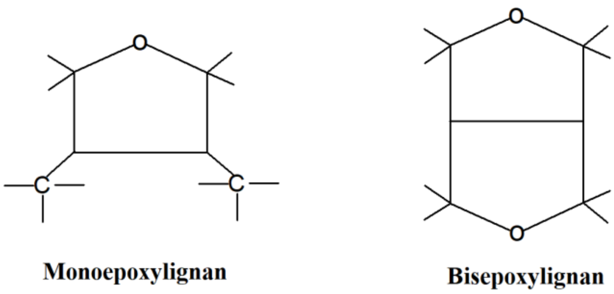


Fig.3. Chemical Structure of Some Lignans

Diterpenes. Polyphenolic compounds responsible for the antioxidant properties of many plants not only slow down the oxidation process but also influence the nutritional value of food products [16].

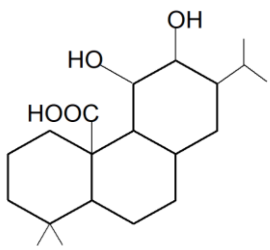
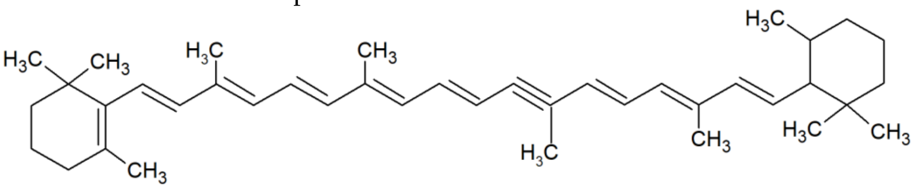
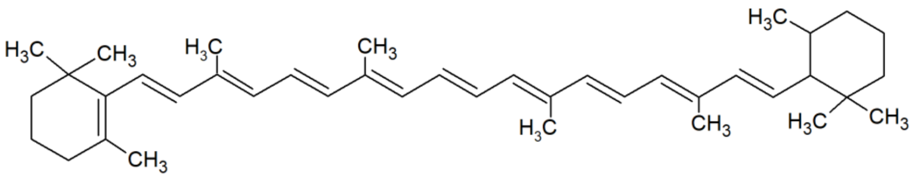


Fig.4. Chemical Structure of Carnosic Acid

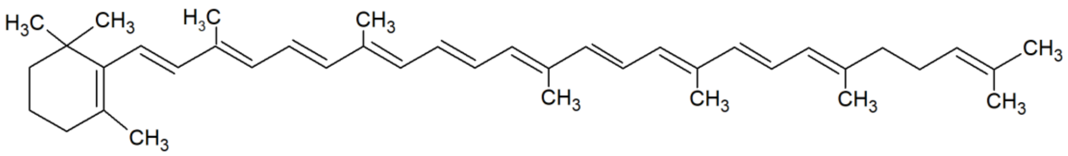
Carotenoids. An important active compound of lipophilic vitamins is trans-retinol or vitamin A1. Vitamin A activity includes about 50 natural compounds from the carotenoid group, known as provitamin A [17]. β-carotene is one of the most commonly found carotenoids in food products and exhibits high activity as an antioxidant compared to provitamin A [18].



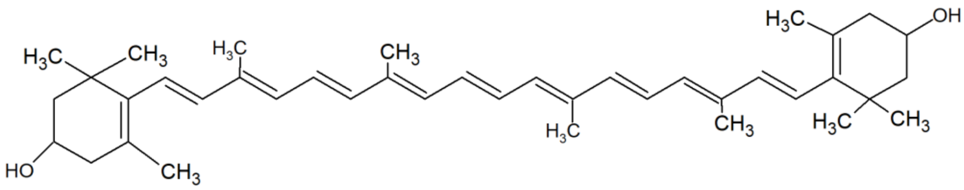
α- carotenoid



β-carotenoid



γ-carotenoid



β-xanthophyll

Fig.5. Chemical Structure of Some Carotenoids

The primary source of vitamin A is plants, as animals cannot produce carotenoids. However, marine animals and fish fats are rich in vitamin A and provitamin A. Among plant oils, palm oil has the highest carotenoid content, and raw palm oil is a provitamin A source [19].

Carotenoids are classified into carotenes and xanthophylls. The simplest carotene is the cyclic polyunsaturated hydrocarbon lycopene. Other examples include phytoene and phytofluene.

Xanthophylls are formed from the biochemical oxidation of carotenoids. They are not commonly found in foods, except in tomatoes (Figure 5).

Carotenoids also occur naturally and can inhibit singlet oxygen and slow down oxidation. The ability to inhibit singlet oxygen depends on the number of double bonds in the molecule [20].

The effectiveness of carotenoids in inhibiting singlet oxygen follows this order: lycopene > alpha-carotene > beta-carotene [21].

Lycopene is a significant pigment produced by plants and microorganisms. Its color is often masked by green pigments like chlorophyll in unripe fruits and vegetables. As fruits ripen, chlorophyll decreases, revealing lycopene and other carotenoids, which provide vibrant colors to fruits (e.g., tomatoes, pineapples, lemons) and many flowers (e.g., narcissus). Carotenoids also contribute to the coloration of certain birds and marine animals (e.g., shrimp, crab, salmon) [22].

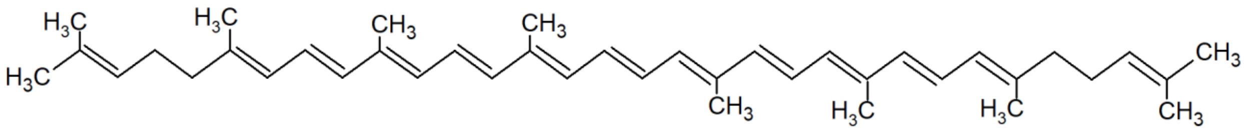


Fig. 6. Chemical Structure of Lycopene

The importance of lycopene stems from several key qualities (Figure 6):

It's naturally found in blood plasma and tissues [23].

It can neutralize singlet oxygen and hydroperoxide radicals [24].

It slows down the oxidation of LDL (low-density lipoprotein) lipoproteins [25].

It lowers the risk of various diseases like atherosclerosis and cancer [26].

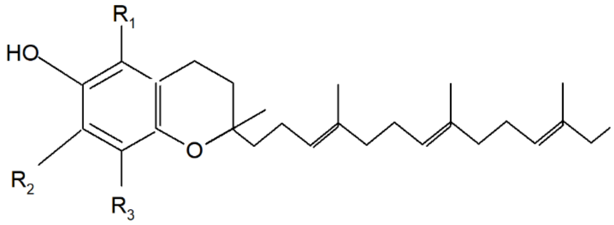


Fig.7. Chemical Structure of Tocopherol

Tomatoes are the primary source of lycopene. In ripe tomatoes, lycopene is the predominant carotenoid, making up 80-90% of all pigments [27]. Tomatoes are also packed with vitamins B and C, β-carotene, and lycopene. While 100 g of tomato skin contains about 12 mg of lycopene, the same amount of tomato flesh has only 4 mg. This means the concentration of lycopene in tomato skin is three times higher than in the flesh [28]. Lycopene's antioxidant properties shine through in its ability to deactivate singlet oxygen and free radicals [29].

Tocopherol, a form of vitamin E, is exclusively produced by photosynthetic organisms. Among its various forms, α-tocopherol is the most biologically potent, with β-tocopherol at around 50% of α-tocopherol's activity, γ-tocopherol at about 10%, and δ-tocopherol at roughly 3% of the activity.

The antioxidant activity of tocopherols (Figure 7) increases in the order $\alpha < \beta < \delta < \gamma$. Their effectiveness is influenced by temperature, and at high concentrations, they can act as prooxidants [30].

During food processing, the tocopherol content in food products typically decreases by 10% to 50%. Likewise, during prolonged storage of vegetable oils at room temperature, the tocopherol levels decline. For instance, after six months of storage, olive oil saw a 32% reduction in tocopherol content [31]. Vitamin E is sourced from plants and animals. Alpha, beta, gamma, and delta tocopherols are found in vegetable oils. Consuming enough vitamin E helps shield biomembrane lipids from oxidation, thus slowing down the body's aging process.

Vitamin C, also known as ascorbic acid (Figure 8), is a crucial component found in antioxidant-rich foods. It falls under the category of water-soluble antioxidants and serves as a chelating agent. It shields vitamin E and membrane lipids from oxidation. In oils and fats, it's often used in the form of esters with palmitic acid, like ascorbyl palmitate, at concentrations ranging from 0.006% to 0.040% (Figure 8). Fruits and vegetables are abundant sources of vitamin C. Rose hips and citrus fruits, in particular, boast high vitamin C content [32-34].

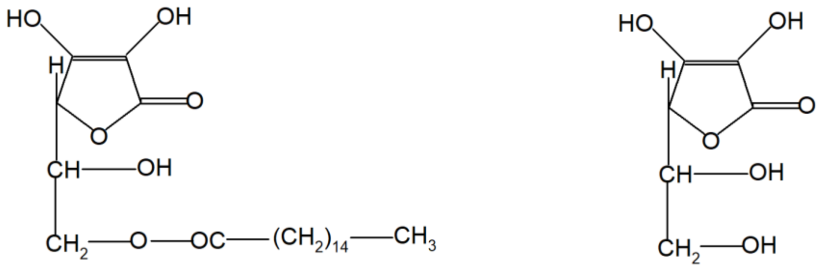


Fig.8. Chemical structure of ascorbyl palmitate and ascorbic acid

Sources of Natural Antioxidants. Flora act as abundant fountains of substances with antioxidative characteristics. Multiple research facilities have undertaken investigations into organic compounds to delve into the antioxidative features of botanical elements present in oil-producing seeds, fruits, veggies, and beyond. A plethora of biologically potent substances not only demonstrate antioxidative capabilities but also harbor antimutagenic and anticarcinogenic attributes [35].

Conclusion

Antioxidants play a vital role in slowing down autoxidation. Whether natural or synthetic, they must be safe, used in limited amounts, and not alter food product characteristics. They can be classified based on action mechanisms, origin, and structure. Primary antioxidants delay initial autoxidation stages, while secondary ones interrupt reactions during ongoing processes. Antioxidants react with free radicals, breaking reaction chains and slowing oxidation. Synthetic antioxidants are more effective but less safe than natural ones. They're categorized based on chemical characteristics and have specific usage regulations. Natural antioxidants, although limited by lower activity, are gaining popularity due to safety concerns. Plant-derived antioxidants, rich in bioactive compounds, are increasingly favored. Phenolic compounds and tocopherols are commonly used natural antioxidants. Tocopherols, like α-tocopherol, exhibit significant biological activity, protecting lipids from oxidative damage.

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