

## ANTIOXIDANTS IN FOOD

*This paper attempts to lead the reader an understanding of what free radicals are and how they can form during lipid oxidation. Also, it provides some information out natural antioxidants (tocopherols and tocotrienols, flavonoids, polyphenols, tannines, melanoidihes, carotenoids, ascorbates) and the echanisms of their protection from radical damage. The sources of natural antioxidants are: oil seeds, teas, vegetables, fruits, spices and herbs.*

For a health-conscious consumer, the words "free radicals" and "antioxidants" have become fashionable [1-4]. A free radical is any chemical species capable of independent existence that possesses one or more unpaired electrons. Free radicals are:

- oxygen-centered radicals ( $O_2^{\bullet-}$  – superoxide anion,  $\bullet OH$  – hydroxyl,  $HO_2^{\bullet}$  – hydroperoxyl,  $LOO^{\bullet}$  – peroxy,  $LO^{\bullet}$  – alkoxy radicals);
- carbon-centered radicals ( $R^{\bullet}$  – alkyl,  $\bullet CCl_3$  – trichloromethyl radicals);
- sulphur-centered radicals ( $RS^{\bullet}$  – thyl radicals);
- nitrogen-centered radieals ( $NO^{\bullet}$  – nitric oxide in which the unpaired electron is delocalized between both atoms,  $C_6H_5N = N^{\bullet}$  – phenyldiazine).

Oxygen, an a ir component indispensable for the maintenance of terrestrial life, is present in the atmosphere as a stable triplet biradical ( $^3O_2$ ), in the ground state. Once inside the human body, it can be transformed, by a four-electron reduction process, to water, via superoxide ( $O_2^{\bullet-}$ ), a hydroxyl radical ( $\bullet OH$ ) and hydrogen peroxide ( $H_2O_2$ ) as reactive intermediates. Singlet oxygen ( $^1O_2$ ) is formed from the excited state of various sensitizers such as chlorophyll, acridine and other pigments. Among the major cellular and extracellular components, proteins, enzymes, lipids, DNA and RNA form the primary targets for these reactive oxygen species. However, the oxidation of the unsaturated fatty acid components of cell membranes is the oxidative event that occurs most frequently inside the human body [5].

Oxygen free radicals formed during normal metabolism may reach cytotoxic levels as a consequence of an unbalanced prooxidant/antioxidant dynamic equilibrium (Fig. 1).

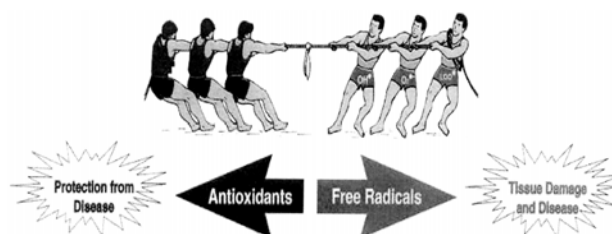


Figure 1. Illustration of the relationship antioxidants – free radicals

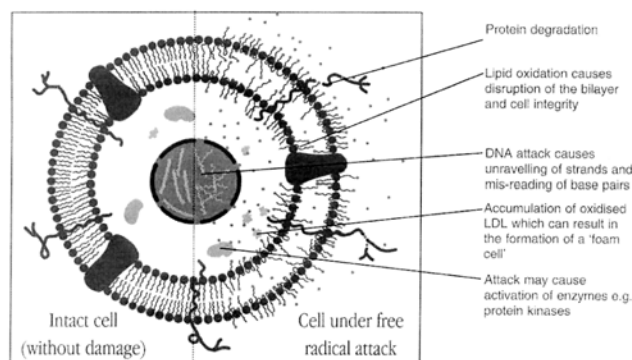


Figure 2. The role of free radicals in cellular damage

They can damage cell membranes and other vital cell components such as genetic material in the nucleus, and inactivate enzymes. Damage to body cells has been implicated in a variety of diseases (Fig. 2).

### OXIDATIVE PROCESSES IN FOOD

Food quality, excluding bacterial and enzymatic spoilage, deteriorates on standing due to oxidative processes induced and propagated by atmospheric oxygen. The appearance, texture, flavor and odor of foods are affected by oxidative processes [6-7]. The extent of these changes depends on the type of food and conditions.

Lipid oxidation has both positive and negative effects. At low levels, the products of lipid oxidation are

responsible for the desirable aroma of fried foods and some of the characteristic flavor properties of cooked meats of different species, roasted nuts, and so on. On the other hand, lipid oxidation does not only cause the problems in the development of rancidity in processed foods, but also causes serious damage to the human body. The oxidative degradation of lipids in food may be initiated by endogenous species ( $H_2O_2$ , ROOH) and radicals ( $O_2^{\cdot-}$ ,  $ROO^{\cdot}$ ,  $\cdot OH$ ) or by exogenous species ( $^1O_2$ ,  $O_3$ ), radicals ( $NO^{\cdot}$ ,  $SO_3^{\cdot-}$ ) and physical agents (UV, ionizing radiation, heat). The targets of attack of these agents are diverse and are specific to each agent and the conditions [8]. A general scheme of the oxidation of lipids by a free radical chain mechanism is presented in Fig. 3.

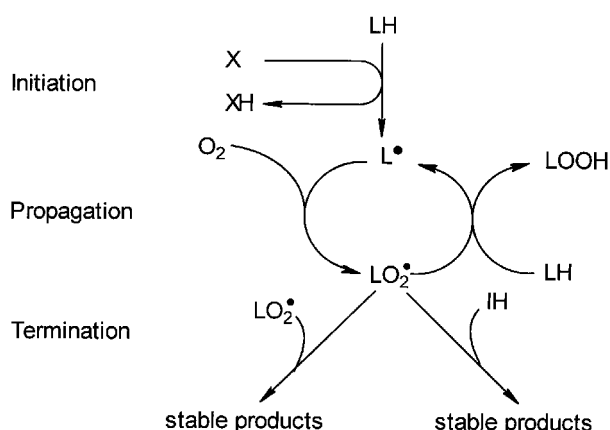
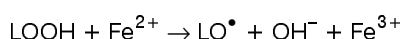


Figure 3. The oxidation of lipids by a free radical chain mechanism, LH—lipid; L—lipid radical; LOO—lipid peroxy radical; IH—antioxidant

Ferrous and ferric ions *in vitro* appear to react more readily with lipid hydroperoxides (LOOH) than with molecular oxygen:



Alkoxy ( $LO^{\cdot}$ ) and peroxy ( $LOO^{\cdot}$ ) radicals are capable of an extracting hydrogen atom from polyunsaturated fatty acids.

## NATURAL ANTIOXIDANTS

A number of antioxidants, both artificial and natural, has been examined in an attempt to control lipid oxidation in food products [9–11]. Many antioxidants are present as constituents of some plants. Sometimes it is necessary to enrich food with antioxidants from plant extracts to prevent the toxic effect of a free radical reaction.

An antioxidant may be defined as a substance that, when present at low concentrations comparable with those of an oxidizable substrate such as fats, proteins, carbohydrates or DNA, significantly delays or

prevents oxidation of the substrate. Antioxidants can act at different levels in an oxidative sequence that involves lipids. For example, they may act by decreasing localized oxygen concentrations; first preventing chain initiation by scavenging initiating radicals, such as hydroxyl radicals; binding metal ions in forms that will not generate lipid peroxidation initiating species, such as hydroxyl radicals, ferryl radicals, or  $Fe^{2+}/Fe^{3+}/O_2$  complexes, and/or will not decompose lipid peroxides to peroxy or alkoxy radicals; decomposing peroxides by converting them to non-radical products, such as alcohols; and/or by chain-breaking whereby intermediate radicals, such as peroxy and alkoxy radicals, are involved [12–25].

A variety of mechanisms provides defense against radical damage. Synthetic antioxidants (butylated hydroxyanisole—BHA, butylated hydroxytoluene—BHT, tertiary-butyl hydroquinone, esters of 3,4,5-trihydroxybenzoic acid, etc.) are widely used because they are effective and cheaper than natural ones. On the other hand, it has been shown that BHT can intensify carcinogenesis, cause pulmonary damage in mice, and liver necrosis and hemorrhagic death in rats while BHA induces neoplasia in the forestomach of rats [16].

Recent publications indicate that plant antioxidants play an important role in biological systems *in vitro*, acting as agents of antioxidative defense. Natural antioxidants can be isolated from oilseeds, grains, beans, vegetables, fruits, leaf waxes, bark, roots, spices and seaweeds. The main antioxidants are listed in Table 1 according to the food and materials they are found in [17].

One approach to assessing antioxidant activity is to directly examine free radical production and its inhibition by an antioxidant. Electron spin resonance (ESR) spectrometry is the only analytical technique that directly measures free radicals. ESR relies on the

Table 1. Materials of natural antioxidants

Group	Example
I. Plants	
1. Oil seeds	Sesame, sunflower
2. Grains	Rice hull, rice bran
3. Beans and nuts	Soybean, red bean peanut shell, lotus seed
4. Germ	Sesame
5. Sprouts and leaves	Barley, tea
6. Barks and roots	Cichorium intybus L.
7. Vegetables and fruits	Carrot, parsley, grapes, berries, peaches, apples, plums...
8. Spices and herbs	Rosemary, Sage, Basil, Thyme, Calendula..
II. Marine products	Oysters, scallops
III. Maillard reaction	Melanoidine
IV. Fermentation products	Tempeh, Natto, Miso, Tofu

absorption of microwave energy (which arises from the promotion of the unpaired electron to a higher energy level) when the samples are placed in a variable magnetic field. The position in the magnetic field of this absorption (*g factor*) and the structure, number and splittings (*hyperfine coupling constants*) between the absorption bands (which are usually recorded as their first derivatives) give valuable information as to the nature and structure of the radical(s) present in the system.

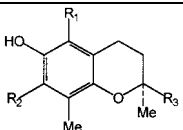
The study of unstable free radicals involves a procedure known as "spin trapping". Using the spin trap i.e. nitroso or nitron compounds, it is possible to convert reactive free radicals, which are short-lived even at low concentrations, to stable nitroxide radicals (adducts) with spectral hyperfine splittings that reflect the nature and structure of these radicals [18–19].

The chemical reactivity of plant extracts and individual organic compounds that react as antioxidants has been characterized using *in vitro* model systems based on the scavenging of reactive oxygen species or stable free radicals. Typical reactive oxygen species-generating systems employ UV light, radiation, pulse radiolysis, the hypoxanthine-xanthine oxidase system or metal ions (Fenton chemistry). The substrate for oxidation in these reactive oxygen species-generating systems are frequently lipids contained in tissue homogenates, liposomes, micelles, ghost cell membranes, or simple and complex, lipid systems such as methyl linoleate or low-density lipoprotein (LDL). Conjugated dienes and oxygen consumption are typical markers for defining the extent of oxidation. Stable free radicals that have been used to evaluate tea antioxidants include the radical cation of the compound 2,2'-azino-bis(3-ethylbenzothiazoline)-6-sulfonic acid (ABTS), the diphenyl-2-picrylhydrazyl radical (DPPH) and the galvinoxyl radical.

### Tocopherols and tocotrienols

The tocopherols and tocotrienols (Table 2), collectively known as vitamin E, are lipid-soluble natural antioxidants, often present as minor components of

Table 2. Tocopherols and tocotrienols

			
Vitamin E	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>
α-tocopherol (1)	Me*	Me	(CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CH(Me)) <sub>3</sub> Me
β-tocopherol (2)	Me	H	
γ-tocopherol (3)	H	Me	
δ-tocopherol (4)	H	H	
α-tocotrienol (5)	Me	Me	(CH <sub>2</sub> CH <sub>2</sub> CH=C(Me)) <sub>3</sub> Me
β-tocotrienol (6)	Me	H	
γ-tocotrienol (7)	H	Me	
δ-tocotrienol (8)	H	H	

\* Methyl group

vegetable oils such as palm, rice bran, wheat germ, barley, coconut, corn and rubber seed oil. Most vegetable oils provide α-tocopherol (1), but palm oil is unique in that respect. It contains relatively high concentrations of the tocotrienols (5, 7 and 8) accounting for about 72–80% of the total vitamin E content (600–1000 ppm) [20].

Tocopherols and tocotrienols react with chain-propagating free radicals, especially peroxy radicals, with the formation of relatively stable phenoxyl radicals. The phenoxyl radicals are conjugatively stabilized and they react rapidly with another peroxy radical to give a stable adduct (Fig. 4) [21].

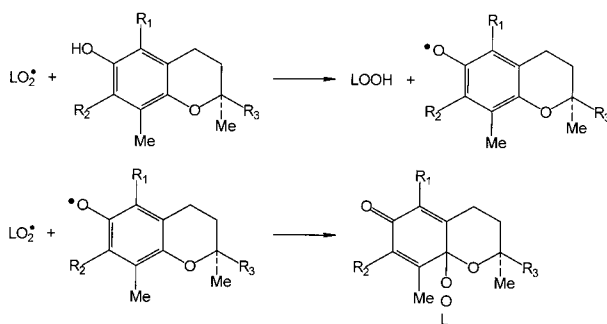


Figure 4. Scavenging effect of vitamin E on a peroxy radical

### Ascorbic acid

Ascorbic acid is a ubiquitous constituent of all green plants, with the exception of dormant seeds, and it is not difficult to obtain an adequate supply in the daily diet. Relatively high amounts of ascorbic acid are found in strawberries, citrus fruits and various vegetables, although the availability of ascorbic acid in these foodstuffs is influenced by numerous factors. Over 85% of the daily dietary intake of ascorbic acid is derived from fruit and fruit juices, vegetables and their products; 27 mg from fruit, 20 mg from vegetables (>85% of all).

In general, three main types of biological activity can be defined for ascorbic acid: its function as an enzyme cofactor, as a radical scavenger and as a donor/acceptor in electron transport, either across the plasma membrane or in chloroplasts.

### Phenolic compounds

Phenolic compounds form one of the main classes of secondary metabolites with a large range of structures and functions, but generally possess an aromatic ring bearing one or more hydroxyl substituents [22–23].

The phenolic flavonoids have a diphenylpropane (C<sub>6</sub>C<sub>3</sub>C<sub>6</sub>) skeleton. The family includes monomeric flavanols, flavanones, anthocyanidins, flavones and flavonols. Some dietary sources of flavonoids are presented in Table 3.

Table 3. Some dietary sources of flavonoids

Flavanol	
Epicatechin Catechin	green and black teas red wine
Epigallocatechin Epicatechin gallate Epigallocatechin gallate	
Flavanone	
Naringenin	peel of citrus fruits
Taxifolin	citrus fruits
Flavonol	
Kaempferol	endive, leek, broccoli, radish, grapefruit, black tea
Quercetin	onion, lettuce, broccoli, cranberry, apple skin, berries, olive tea, red wine
Myricetin	cranberry, grapes, red wine
Flavone	
Chrysin	fruit skin
Apigenin	celery, parsley
Anthocyanidins	
Malvidin	red grapes, red wine
Cyanidin	cherry, raspberry, strawberry, grapes
Apigenidin	coloured fruit and peels
Phenyl propanoids	
Ferulic acid	wheat, corn, rice, tomatoes, spinach cabbage, asparagus
Caffeic acid	white grapes, white wine, olives, olive oil, spinach, cabbage, asparagus, coffee
<i>p</i> -Coumaric acid	white grapes, white wine, tomatoes, spinach, cabbage, asparagus
Chlorogenic acid	apples, pears, cherries, plums, peaches, apricots, blueberries, tomatoes, anis

Phenolic antioxidants (Ar-OH) inhibit lipid oxidation by trapping lipid oxygen radicals such as peroxy or alkoxy radicals [24]:



However, the mechanisms of their radical scavenging, as well as the physico-chemical properties (acid-base, redox properties) which determine the activities of these phenolic compounds, are scarcely known.

Another proposed mechanism of antioxidative activity of phenolic compounds is that the antioxidant-derived aroxy radicals (ArO<sup>•</sup>) react directly

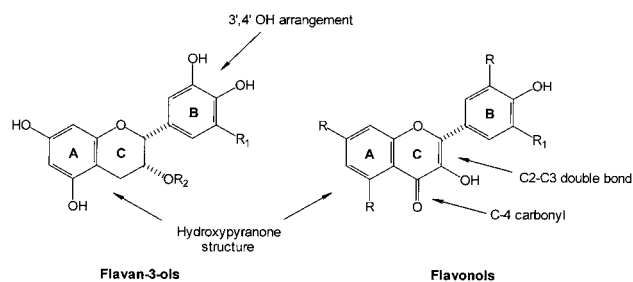
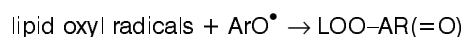


Figure 5. Structural features of flavonoids important to antioxidant chemistry

with lipid oxyl radicals and form stable products with quinone structures, LOO-AR(=O) [25]:



More recent studies have dealt with the extent to which phenols react as radical scavengers. The conclusion drawn was that the three criteria (Fig. 5) for effective radical scavenging are:

- the presence of an *o*-dihydroxy structure in the B ring, which confers higher stability to the radical form and participates in electron delocalization;

- the 2,3 double bond in conjugation with a 4-oxo function in the C ring is responsible for electron delocalization from the B ring - the antioxidant potency is related to structure in terms of electron delocalization of the aromatic nucleus. When these compounds react with free radicals, the phenoxyl radicals produced are stabilized by the resonance effect of the aromatic nucleus;

- the 3- and 5-OH groups with a 4-oxo function in the A and C rings are required for maximum radical scavenging potential.

The biological, pharmacological and medicinal properties of the flavonoids have been extensively reviewed [26]. Flavonoids and other plant phenolics in addition to their free radical scavenging activity are reported to have multiple biological activities, including vasodilatory, anticarcinogenic, antiinflammatory, antibacterial, immune-stimulating, antiallergic, antiviral, and estrogenic effects, as well as being inhibitors of phospholipase A<sub>2</sub>, cyclooxygenase and lipoxygenase.

Black tea and green tea beverages both have a potent antioxidant capacity relative to Trolox (water-soluble form of vitamin E, Table 4). The antioxidant potentials of the tea catechins, on a molar basis, against radicals generated in the aqueous phase are, in order of decreasing effectiveness: epicatechin gallate ≈ epigallocatechin gallate > epigallocatechin > gallic acid > epicatechin catechin [27].

Djilas et al. [28] isolated some water-soluble tannins from *Osbeckia Chinensis* L. and examined their antioxidant activity in a methyl linoleate auto-oxidation system using ESR spectroscopy. The established order was: degalloylpunicacortein A < punicacortein = 2,3 - [(S)4,4',5,5',6,6'-hexahydroxydiphenyl]-D-glucopy-

Table 4. Reactive antioxidant potentials of vitamins, tea beverages, flavonoids, carotenes and xanthophylls

Antioxidant	Trolox equivalent antioxidant capacity (TEAC, mM)*
<b>Vitamins</b>	
Vitamin C	1.0 ± 0.02
Vitamin E	1.0 ± 0.03
<b>Tea beverage</b>	
Green tea (1000 ppm)	3.8 ± 0.03
Black tea (1000 ppm)	3.5 ± 0.03
<b>Flavan-3-ols</b>	
Epicatechin	2.5 ± 0.02
Epigallocatechin	3.8 ± 0.06
Epigallocatechin gallate	4.8 ± 0.06
Epicatechin gallate	4.9 ± 0.02
<b>Theaflavins</b>	
Theaflavin	2.9 ± 0.08
Theaflavin-3-monogallate	4.7 ± 0.16
Theaflavin-3'-monogallate	4.8 ± 0.19
Theaflavin-3,3'-digallate	6.2 ± 0.43
<b>Flavonols</b>	
Quercetin	4.7 ± 0.10
Kaempferol	1.3 ± 0.08
Rutin	2.4 ± 0.06
<b>Flavones</b>	
Apigenin	1.5 ± 0.08
Luteolin	2.1 ± 0.05
<b>Carotenes</b>	
Lycopene	2.9 ± 0.1 S
α-Carotene	1.3 ± 0.04
β-Carotene	1.9 ± 0.10
<b>Xanthophylls</b>	
β-Cryptoxanthin	2.0 ± 0.02
Zeaxanthin	1.4 ± 0.04
Lutein	1.5 ± 0.10

\* TEAC is the millimolar concentration of a Trolox solution having the antioxidant capacity equivalent to a 1.0 mM solution of the substance under investigation [27].

ranoside < 4,6 - [(S)-4,4',5,5',6,6' - hexahydroxydiphenoyl] - glucopyranoside < casuarin < casuarinin.

(-)-Epicatechin gallate and (-)-epigallocatechin gallate represent the strongest protection against lipid peroxidation in erythrocyte ghost prepared from human red blood cell membranes, and were also found to be more active than standard antioxidants [29].

LDL oxidation by macrophages or copper is inhibited by a variety of flavonoids including quercetin, morin and fisetin and by cinnamates in prunes.

Quercetin is also capable of protecting cells from the toxic effects of oxidized LDL, while rutin can act synergistically to protect endothelial cells. There is strong interest in the bioactivity of wine and grape juice which also inhibits copper catalysed LDL oxidation [30]. The phenol concentration (largely flavonoids) of red wines varied from 4 to 10 mM and in white wines from 0.4 to 0.7 mM. Frankel et al [31] correlated the inhibition of LDL oxidation with individual phenols. The antioxidant activity of white wine and juices was related to their flavanol and cinnamate contents, while that of red juices was related to their anthocyanin levels.

The flavonoids, eriocitrin, diosmin, hesperidin, and narirutin extracted from lemon fruit exhibited high antioxidative activity in the LDL oxidation system [30].

Using ESR spectroscopy and the spin trapping method, Milic et al. [14] showed that phenolic acids reacted with the methyl esters of sunflower oil and scavenged an alkoxy radical. The results obtained on the scavenging effects of phenolic acids indicated that the compounds reacted directly with a lipid oxygen radical and donate a hydrogen atom, involving the termination of a radical chain reaction. The oxygen-centered antioxidant radicals, alkoxy radicals (ArO<sup>•</sup>), are insufficiently reactive and they can disappear by several mechanisms. The scavenging activity of the phenolic compounds was estimated by the percentage of decrease of the relative intensity (RI) of the signal of the PBN-alkoxy radical adduct with reference to the control without phenolic compounds (the ESR line intensity is 100%). This activity depends on the structure of the molecules, number and position of the hydroxyl group in the molecules, and it increases in the order gallic > caffeic > chlorogenic > vanillic > salicylic acids.

The influence of different amounts of vanillic, salicylic, gallic, chlorogenic and caffeic acids on the intensity of the signal in the ESR spectra of the spin adduct of the lipid alkoxy radical is presented in Figure 6.

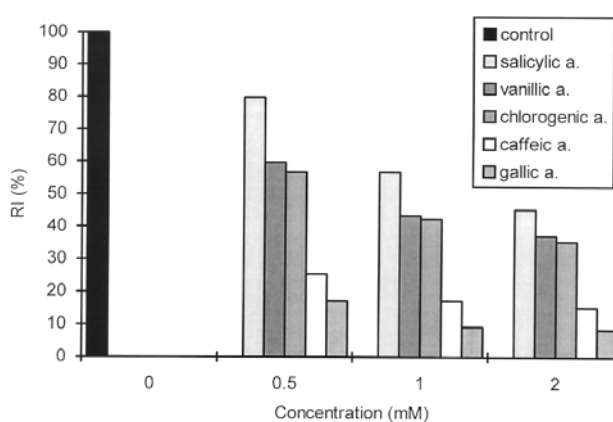


Figure 6. The influence of different amounts of vanillic, salicylic, gallic, chlorogenic and caffeic acids on the relative intensity of the signal in the ESR spectra of the spin adduct of a lipid alkoxy radical

On comparing the inhibitory effect of individual flavonoids during thermal or catalytical lipid oxidation [32], it may be concluded that the inhibitory and stabilizing effects of these compounds, as well as of phenolic acids, are conditioned by their structure and concentration. The following order of inhibitory activities has been established: myricetin > quercetin > morin  $\approx$  kaempferol  $\approx$  fisetin  $\approx$  luteolin > rutin > diosmin > apigenin > naringenin.

The antioxidants in soybean have also been frequently studied, mainly the isoflavones genistein, daidzein, and glycitein, which are active in this order, according to Pratt [33] and Sakač [34], but their activities are weaker than that of quercetin. The isoflavones, genistein, genistin and daidzein, isolated from the hexane, ethanol and ethyl acetate extracts of soybean grain, showed strong anti oxidative effects during the thermal and catalytic oxidation of methyl linoleate [35].

The presence of strong antioxidant potential in sprouts of sesame seed and in young barley leaves has been reported as an increase in the phenolic components such as flavones [36].

Bark and root are usually abundant in polyphenolic antioxidants, among them, ellagic acid is widely present in bark and medicinal plants and it exhibits very strong antioxidant and antimutagen activities [37].

Spices and herbs are also abundant sources of effective antioxidants. On the one hand, herbals have always been traditionally used, i.e. as species for teas and as medicine and on the other herbals, and especially herbal extracts, are experiencing a revival in modern phytotherapy.

Plants of the *Perilla* family (rosemary, sage, thyme, etc.) are especially abundant in various antioxidants from petroleum ether soluble and insoluble extracts [38]. Recently many new antioxidants have been isolated from various kinds of spices by Nakatani et al. [39]. Also red chili and cinnamon leaves have shown a high antioxidative effect in food.

Milić et al. [40] have shown that the ethyl acetate, n-butanol and chloroform extracts of sage reduce the concentration of hydroxyl radicals during the Fenton reaction and of peroxy radicals during lipid oxidation. The flavonoids apigenin, apigen-7-O- $\beta$ -glucosides and luteolin contributed to the antioxidative activity of the investigated extracts.

Plants also contain high amounts of tannins, triterpenes and flavonoids. Phenolic acid and tannins in natural products are known to possess high antioxidant and antiradical activity.

The different types of extracts of *Salvia officinalis*, *Rosmarinus officinalis*, *Myrtus communis*, *Petroselinum crispum*, *Agrimonia eupatoria* and *Artemisia absinthium* reduce lipid peroxidation and OH-radical production [41, 42]. A high portion of 1,8-cineol, camphor and

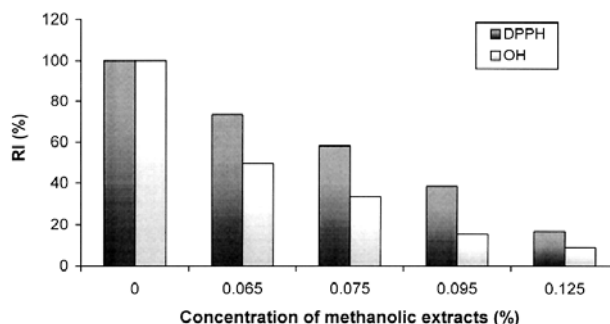


Figure 7. The scavenger effect of different concentrations of methanolic extracts of *Calendula officinalis* on stable DPPH-radicals and reactive hydroxyl radicals

borneol was found in rosemary and sage. High contents of  $\alpha$ - and  $\beta$ -thujone were determined in sage oil.

Phenolic substances in essential oil (eugenol, thymol, p-cymene, carvacrol, vanillin) were found to be strong inhibitors of oxidation of human LDL (low-density lipoproteins), the finding being important in the prevention of several human diseases, especially arterosclerosis [43].

The scavenger effect of different concentrations of methanolic extracts of *Calendula officinalis* on stable DPPH-radicals and reactive hydroxyl-radicals is presented in Fig. 7 [44, 45].

Methanolic extracts of *Calendula officinalis* show a good ability to scavenge DPPH and extremely reactive hydroxyl radicals (Fig. 6) and exhibit marked antioxidative activity [45,46].

### Maillard reaction products

Maillard reaction products (MRP) are widespread in processed foods and have received much attention as antioxidants. The results of an extensive study [47] have indicated that melanoidins and their precursors (pyrimidine and pyrazine cation radicals) have reducing and chelating properties and act as hydrogen donors or electron traps. The results of Đilas et al. [48] suggest that the MRP obtained by heating glucose and 2,3 and 4-aminobutanoic acid reduce the concentration of peroxy radicals during lipid oxidation.

### Carotenoids

Carotenoids form one of the most important classes of plant pigments and play a crucial role in defining the quality parameters of fruit and vegetables. Their role in the plant is to act as accessory pigments for light harvesting and in the prevention of photo-oxidative damage, as well as to play the role of attractants for pollinators. Their function as antioxidants in the plant shows interesting parallels with their potential role as antioxidants in foodstuffs and human organisms.

Carotenoids have diverse biological functions, the most important ones of which are summarised in Table 5 [49].

Table 5. Biological functions of carotenoids

Function	Carotenoids
Provitamin A activity	$\beta$ -carotene, $\alpha$ -carotene, $\beta$ -cryptoxanthin
Antioxidant	all carotenoids
Cell communication	$\beta$ -carotene, canthaxanthin, cryptoxanthin
Immune function enhancers	$\beta$ -carotene
UV skin protectants	$\beta$ -carotene, lycopene
Macula protection	lutein, zeaxanthin

$\beta$ -Carotene is an effective quencher of singlet oxygen and also functions as a radical-trapping antioxidant.

Some other active ingredients of beverages, vegetables, grains and fruits may also act as antioxidants and may protect human organisms. However, many of the natural antioxidants possess prooxidant activity, depending on the reaction conditions. This problem can be the topic of future investigations.

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## IZVOD

### ANTIOKSIDANTI U HRANI

(Pregledni rad)

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Slobodni radikali nastaju u ćelijama tokom normalnog aerobnog metabolizma i učestvuju u mnogim važnim biohemijskim reakcijama. Međutim, prekomerna produkcija slobodnih radikala i poremećaji u sistemima celularne i ekstracelularne antioksidativne zaštite dovode do mnogih patoloških promena u ljudskom organizmu.

U ovom preglednom radu detaljno su prikazani mehanizmi nastajanja slobodnih radikala tokom oksidacije lipida i sprečavanje njihovog toksičnog delovanja u prisustvu prirodnih antioksidanata. Takođe su opisane osnovne klase prirodnih antioksidanata (tokoferoli i tokotrienoli, flavonoidi i polifenoli, tanini, melanoidini, karotenoidi, askorbati) i hemizmi njihovog delovanja na stvaranje i stabilizaciju reaktivnih slobodnih radikala. Kao osnovni izvori prirodnih antioksidanata se navode: biljna ulja, semenke, čajevi, voće i povrće, začini i lekovito bilje.

Ključne reči: Prirodni antioksidanti

• Lipidna oksidacija • Slobodni radikali • ESR spektroskopija •

Key words: Natural antioxidants • Lipid oxidation • Free radicals • ESR spectroscopy •



