Chapter 1

Antioxidants from Natural Sources

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Additional information is available at the end of the chapter

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Abstract

Antioxidants are the defense system of the body against the damage of reactive oxygen species, which is normally produced during the various physiological processes in the body. There are various sources of these antioxidants like endogenous antioxidant present in the body and exogenous food source. In recent decades, alternate of synthetic food antioxidants by natural ones has fostered interest on vegetable sources and the screening of inexpensive raw materials particularly from the agriculture for identifying new antioxidants. Polyphenols are the significant plant compounds with antioxidant activity, though not the only ones. Some but not only restricted to biological properties such as anticarcinogenicity, antimutagenicity, antiallergenicity, and antiaging activity have been reported for natural and synthetic antioxidants. Among the sources of natural antioxidants, the most important are those coming from routinely consuming vegetables and fruits; however, antioxidant from other plant and agriculture waste should not be ignored.

Keywords: antioxidants, vegetables, fruits, plants, herbs

1. Introduction

The formations of oxygen reactive forms as a result of rigorous oxidative processes taking place in human organism are the potent precursors of systemic cells and tissues damage. Antioxidants being an inhibitor of the oxidation process remove these free-radical intermediates by oxidized themselves [1], even at quite diminutive concentration, and thus have assorted physiological function in the body to stop these oxidation reactions ultimately protecting the body from harmful chain reactions [2]. Thus, they have reviewed by many researchers as nature's answer to physiological and environmental stress, atherosclerosis, aging, and cancer [3]. Body's endogenous defense system against these free radicals plays an imperative role, which can further supported by the supplementation of antioxidants in the diet. Generally, antioxidants can be divided into two major categories such as synthetic and natural. The main targeted site of these free radicals damage and defensive approach of antioxidants in the body is at the cellular level. Based up on this, these antioxidants can also be classified as enzymatic and nonenzymatic antioxidants. Enzymatic antioxidants primarily include glutathione peroxidase, catalase, and superoxide dismutase. There are also several other enzymes in the body that contribute to the total antioxidant capacity, which reflects in the serum [4]. Nonenzymatic antioxidants contain several subdivisions mainly vitamins such as A, E, C, and to lesser extent vitamin D, enzyme cofactors (Q10), peptides and some minerals (zinc and selenium). The major ingredients from the natural sources are polyphenolic compounds, which are reported to have significant antioxidant potential [5]. A detailed classification and subclassification has been displayed in **Figure 1**.

Natural antioxidants are primarily phenolics that may occur in all parts of plants [6], such as fruits, vegetables, nuts, seeds, leaves, roots, and barks. In the recent past, some toxicological studies regarding the use of synthetic antioxidants have shown their unwanted or adverse effects. These reports have urged the researchers to focus their study on exploring the natural sources with reasonable antioxidant potential [7]. Moreover, the availability and economy are significant concerns too in the context of using these natural antioxidants. The antioxidants from the nature can be categorized into the various subclassifications. However, two major categories are like antioxidants from commonly consumed or routine natural diets (e.g., vegetables, fruits, cereals, and beans) and secondly from plant or herb source that have fair antioxidant

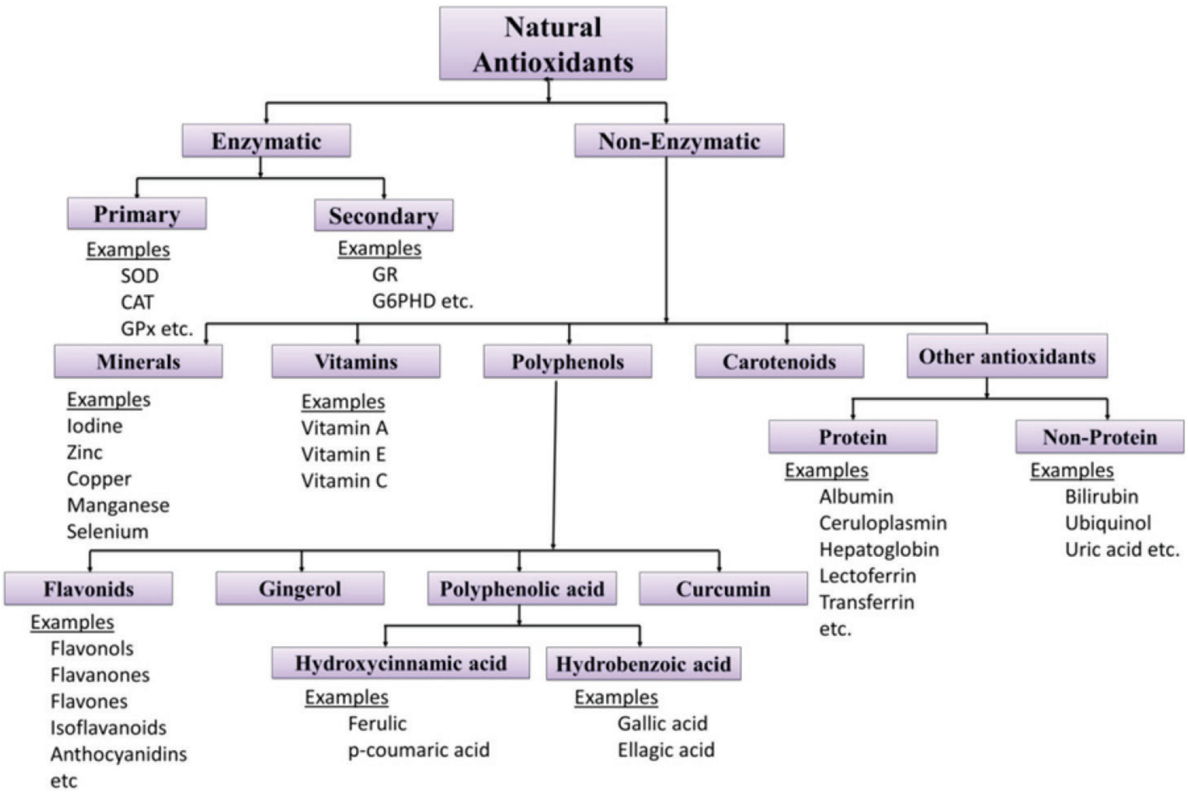

Figure 1. Classification and subclassification of antioxidants found in natural sources.

potential but are not the routine dietary source (e.g., medicinal plants and wild herbs). Among these, the routine dietary sources are very important as these can be easily available and more suitable for the dietary interventions. The need is to identify and generate awareness about these sources, which can be rated from top to down regarding antioxidant potential. The people who are habitual of consuming these vegetables and fruits in their routine meal are reported to be less affected by various chronic diseases [8], and studies have also endorsed the long-term healthy impact of consuming these nature-origin diets. Most common dietary supplements are comprised of vitamins C and E from synthetic as well as natural sources. Vitamin C is rich in the citrus fruits, which is a renowned fact, so fruits such as orange, lemon, blueberries, strawberries, grapes, prunes, and plums; red beans; spinach; kale; broccoli flowers; and alfalfa sprouts have good amount of antioxidants [9]. Fortunately, these are the part of our routine diet; however, their availability pertaining to the geographical distribution as well as cultivation is an important factor. Though international trading made them available throughout the world and even in the off season as well, the consumption of seasonal and fresh fruits is always encouraged. Vitamin E is a fat-soluble vitamin and exerts its antioxidant effect by reducing fat oxidation in the body [10]. Synthetic form of this vitamin is comprised of α-tocopherol, which is widely used as food supplement. The natural form of this vitamin contains mixed tocopherols almost having eight isomeric forms of α-tocopherol. The availability of these mixed tocopherols enhances the percent absorption of vitamin E from the natural sources in the human body.

An enormous growth has been observed in the vitamin supplement market during the past decade. It is estimated worth $68 billion with the US renders to be major shareholder, i.e., around 30%. A $421 million for just vitamin E and $361 million for vitamin C business has been recorded from Europe. Moreover, according to a report from Business insight, an annual growth of 4.5% in US vitamin and mineral market, i.e., almost $30 billion in the first half of this decade, was forecasted [11].

The targeted approach of the researchers around the world to date is to find natural sources of antioxidants, which will be inexpensive and closer to the nature. These findings will be the superior substitute of synthetic supplements in food, pharmaceutical, and cosmetic industries [12]. Though significant harmful effects of synthetic supplements have not been reported to date, a common concept of closer to nature is obviously a better approach in the supplementation. The coming decade will be the era of natural products, and exploration of natural antioxidants will be the prime focus of the researchers [11].

The main objective of the current chapter is to overview and summarize the natural sources with antioxidant potential. The summarized data will be a useful information for the professional and nonprofessional readers to gather a fair information regarding dietary and non-dietary sources in the nature, which can be the part of the routine diet to enhance the antioxidant capability of the body.

2. Natural antioxidants

The nature is always a significant and rich source of countless ingredients that can be served as health-promoting agents. Many of these natural sources include routinely used fruits, vegetables, herbs, spices, and edible mushrooms that can be the part of routine diet. In addition to that, there is a huge list of medicinal plants reported to have extensive health-boosting potentials. One of the most beneficial effects from these natural sources is due to their potential antioxidant properties. Regarding the antioxidant capability, the researchers have focused their studies to explore the most potential sources along with their active ingredients. The researchers have added some marine sources such as algae and seagrass as well in the list of these natural sources. The recent studies have also explored the role of naturally occurring microbiome in the gut in the body antioxidant pool denoted as good bugs. These good bugs can also be used as supplement called as probiotics. Thus, generated literature is a big data bank for the researchers of the field and beneficial information for the general reader as well. There is a need to summarize this enormous data bank based upon the identification of most potential sources, which will make the literature feasible for the professional and nonprofessional readers at the same time. This chapter will elaborate the various natural sources of antioxidants that hopefully help to prioritize the beneficial amendments in dietary composition.

Fruits and vegetables are highly recommended dietary contents, widely known for their health-promoting effects and nutritious values. They got an essential place as conventional foods in the history because of their excessive amount of minerals, specifically electrolytes; vitamins, specifically vitamins C and E; while various current studies are revealing their phytochemical contents, having antioxidant capabilities [13]. These antioxidants scavenge the oxidants or free radicals produced as a result of several degenerative and disease processes such as diabetes, cancers, and cardiovascular disorders. So, regular consumption of fruits and vegetables may reduce the risk of mortality associated with these diseases [14]. Most of the natural antioxidants convert the lipid radicals into more stable products by breaking the chain. Antioxidants obtained from vegetables and fruits are mostly of phenolic structure, which may include vitamins, minerals, and polyphenols [15]. Antioxidant minerals, such as iron, zinc, selenium, copper, and manganese, act as cofactor of many antioxidant enzymes, absence of which may certainly disturb the activity of their enzymatic scavenging activity [16]. The antioxidant capability of different fruits is being presented in **Table 1**.

2.1. Types of antioxidants from fruits and vegetables

Polyphenols, present in fruits and vegetables, is a group of several low- and high-molecular-weight compounds having antioxidant properties that prevent lipid oxidation [17]. Most of them are conjugates of mono and polysaccharides connected with one or more groups of phenol rings or may also present as functional derivatives such as esters and methyl esters [18]. This major class of natural antioxidants can be obtained from teas, particularly green and red teas, as well as fruits such as grapes [19]. However, polyphenols from teas have more significant than in fruits because of their bioavailability in blood. Approximately 15–20% polyphenols are absorbed in human blood from their consumed amount. This absorption is enhanced when there are no sugar molecules attached with them. So, teas have more absorption of polyphenols than in fruits because of high sugar content in fruits [20].

Flavonoids, another important antioxidant content, is a subclass of polyphenols present abundantly in most of the foods, such as potatoes, wheat, tomatoes, red berries, peaches,

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No	English name	Antioxidant contents	Concentration (ORAC value)	References
1.	Beet root	Betalains		[146]
2.	Guava	β-Carotene, lycopene, vitamin C, ellagic acid, anthocyanin		[147]
3.	Pears	Ascorbic acid, flavonoids (quercetin, isorhamnetin, myricetin, kaempferol, and luteolin), betalains, taurine, total carotenoids and total phenolics	135 (mmol TE/g)	[148]
4.	Pomegranate	Vitamin C and polyphenols	1245 (mmol TE/g)	[149]
5.	Papaya	Quercetin and β-sitosterol	300 (mmol TE/g)	[150]
6.	Water melon	Lycopene, β-carotene, vitamin C	100	[151]
7.	Apple	Proanthocyanidins, flavonoids (kaempferol, quercetin, and naringenin derivatives); phenolic acids (protocatechuic, caffeoylquinic, and hydroxycinnamic acid derivatives); hydroxychalcones (phloretin and 3-hydroxyphloretin derivatives); and isoprenoid glycosides (vomifoliol derivatives) Flavanols, flavonols, dihydrochalcones, and hydroxycinnamates	16.78 a ± 0.25 (mmol TE/g) 1508 ± 44 (μmol/100 g)	[152] [153]
8.	Plum	Proanthocyanidins, flavonoids (kaempferol, quercetin, and naringenin derivatives); phenolic acids (protocatechuic, caffeoylquinic, and hydroxycinnamic acid derivatives); hydroxychalcones (phloretin and 3-hydroxyphloretin derivatives); and isoprenoid glycosides (vomifoliol derivatives)	14.55 c ± 0.21 (mmol TE/g) 94.8 (mmol TE/g)	[152] [154]
9.	Guava	β-Carotene, lycopene, vitamin C, ellagic acid, anthocyanin		
10.	Beet root	Betalains, vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	4100 (dry extract) 115 (μmol TE/g)	[146] [155]
11.	Pea	Vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	19 (μmol TE/g)	[155]
12.	Carrot	Vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	60 (μmol TE/g)	[155]
13.	White cabbage	Vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	61 (μmol TE/g)	[155]
14.	Tomato	Vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	67 (μmol TE/g)	[155]
15.	White onion	Vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	85 (μmol TE/g)	[155]
16.	Cauliflower	Vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	102 (μmol TE/g)	[155]
17.	Spinach	Vitamins C and E, carotenoids, flavonoids, and thiol (SH) compounds	152 (μmol TE/g)	[155]

Table 1. Some important fruits having antioxidant constituents.

and almonds [21]. Anthocyanin is a subcategory of flavonoids (**Figure 1**) which is present in berries and red wine. It is a potent antioxidant with decreased bioavailability as compared to other flavonoids [19]. Polyphenols show their antioxidant properties by preventing the oxidation of low-density lipoproteins (LDL), thus preventing plaque formation [22]. Some types of polyphenols have also been found to inhibit the oxidation of some important enzymes and thus preserve their proper functioning [23]. Carotenoids are another major class of phytochemicals antioxidants from fruits and vegetables after polyphenols. They mostly found in vegetables, such as potatoes, carrots, papayas, and apricots [21].

Among the vitamins obtained from fruits and vegetables, acting as antioxidants, vitamin C, also known as ascorbic acid, is a very potent water-soluble antioxidant commonly found in citrus fruits and vegetables such as oranges, lemons [24], and tomatoes [21]. It is recommended that the fruits and vegetables containing vitamin C should be taken in small divided doses instead of having a large dose simultaneously because vitamin C shows less absorption when given in large quantities [25].

Another vitamin with antioxidant properties is vitamin E, which is related to tocopherol family of antioxidant. It is a fat-soluble, nonpolar vitamin found naturally in lipid-rich fruits and vegetables, such as olives, sunflower, and nuts [21]. Vitamin E shows higher bioavailability than vitamin C, which is perhaps due to its fat solubility and can be further enhanced when taken with fatty foods [25].

2.2. Antioxidants from fruits and vegetables wastes

Fruits and vegetable waste material is produced during their cultivation, industrial management, processing, preservation, and distribution [26]. In the past few decades, researchers have been struggling to device the methods to recycle these wastes to get therapeutic benefits [27]. The vegetables and fruit waste material includes peelings, trimming, shells, seeds, stems, and pulp residues that remained after extraction of juices and starch or sugar preparation. This waste constitutes about 25–30% [28]. According to a research, greater amounts of phenols and ascorbic acids have been reported in these waste scalps than their pulp [29] and in unripe form than their ripened form [30]. Most of the fruit peels contain 2–27 times greater amount of antioxidants than their pulp [31]. According to Someya et al., banana pulp possesses 232 mg/100 g of phenolic components, and this amount is just 25% of the amount present in banana peels [32]. *Cucumis sativus* (Cucumber) peel has been reported as a good source of flavonoids, which is considered as a potential antioxidant [33]. Many bioactive substances may be recovered from theses wastes to prepare foods in food processing and therapeutic preparations [34]. A significant amount of bioactive phytochemicals, having strong antioxidant properties, can be obtained from the tomato wastes, which include carotenes, tocopherols, terpenes, sterols, and polyphenols. These natural antioxidants obtained from food waste may be used to formulate functional foods or can be used as food additives [35].

A lot of antioxidants, such as carotenoids, phenolic compounds, vitamin C, and dietary fibers, are found in mango peel. These compounds have reported activity against many degenerative diseases, such as Alzheimer's disease, cataracts, cancer, and Parkinson's disease [36]. The wastes of wine-making industry include degradable solids such as skin, stem, and seeds, which contain many antioxidants that have shown to prevent many degenerative processes and possess health-promoting effects [37]. Pujol et al. [38] reported that the coffee wastes from the coffee industry contains approximately 6% polyphenols and about 4% tannins. Antioxidant ingredients from various sources of fruit waste have been presented in **Table 2**.

No	Fruit	Residue	Antioxidant	Reference
1.	Banana	Unripe (green) fruit and peel	Phenols and flavonoids	[156, 157]
2.	Mango	Peel, kernel	Gallic acid, ellagic acid, gallates, gallotannins, condensed tannins	[158, 159]
3.	Water melon	Peel, rinds	Citrulline, lycopene, flavonoids, and phenols	[160, 161]
4.	Cucumber	Peel	Flavonoids and phenols	[33]
5.	Potato	Peel	Chlorogenic acid, caffeic acid, ferulic acid, and phenols	[162, 163]
6.	Coffee	Coffee ground and residue	Polyphenols, tannins, and gallic acids	[164, 38]
7.	Apple	Peel	Epicatechin, catechins, anthocyanins, quercetin glycosides, chlorogenic acid, hydroxycinnamates, phloretin glycosides, and procyanidins	[165]
8.	Grapes	Skin and seeds	Coumaric acid, caffeic acid, ferulic acid, chlorogenic acid, cinnamic acid, neochlorogenic acid, p-hydroxybenzoic acid, protocatechuic acid, vanillic acid, gallic acid, proanthocyanidins, quercetin 3-o-gluuronide, quercetin, and resveratrol	[166, 167]
9.	Guava	Skin and seeds	Catechin, cyanidin 3-glucoside, galangin, gallic acid, homogentisic acid, and kaempferol	[168]
10.	Pomegranate	Peel and pericarp	Gallic acid, cyanidin-3,5-diglucoside, cyanidin-3-diglucoside, and delphinidin-3,5-diglucoside	[169, 170]
Vegetables				
11.	Carrot	Peel	Phenols, β-carotene	[171]
12.	Cucumber	Peel	Phenols, flavonoids, pheophytin, phellandrene, caryophyllene	[33, 160]
13.	Potato	Peel	Gallic acid, caffeic acid, vanillic acid, chlorogenic acid, ferulic acid, and phenols	[160, 162, 163]
14.	Tomato	Skin and pomace	Carotenoids	[172]

Table 2. Antioxidants from some fruits and vegetable wastes.

2.3. Mushrooms as antioxidant

In the nutrition world, mushrooms are delegated vegetables; however, they are not actually plants. They have a place with the kingdom of fungi. In spite of the fact that they are not vegetables, mushrooms give imperative supplements. Mushrooms are considered as healthfully utilitarian sustenance and also source of valuable medicines [39, 40]. Numerous consumable mushrooms (for the most part Basidiomycetes) are great wellsprings of important nutritive components including carbohydrates, for example, β-glucans; lipids; B-vitamins, such as niacin, flavin, and pyridoxine; phenolics, like tocopherols; organic acids, for example, malate ascorbate, fumarate, and shikimate; monoterpenoid and diterpenoid; proteins, for example, hydrophobins; and trace components, for example, selenium [41–43]. These components are established as to be responsible for immunomodulatory, antimicrobial, antitumor, antihypertensive, hepatoprotective, and antioxidant activities of mushrooms [44, 45].

The amount of mushrooms on Earth is assessed at 140,000 yet might be just 10% (approximately 15,000 species) are known [43, 46]. Out of approximately 15,000 known species, 2,000 are found safe for human utilization, and around 650 of these contain therapeutic properties [47]. There are a number of mushrooms including *Agaricus bisporus* [48] *Lentinus edodes* [49], *Armillaria mellea* [50], *Auricularia auricula* [51], *Boletus edulis* [52], *Ganoderma applanatum* [53], *Grifola frondosa* [54], *Hypsizigus marmoreus* [55], *Pleurotus* sp. [56], *Schizophyllum commune* [57], *Termitomyces* sp. [58], and *Tricholoma* sp. [59] that possess antioxidant properties. The antioxidant properties of mushrooms are mainly due to their phenolic compound [52, 48]. Phenolic acid is the chief phenolic component present in the mushrooms. There are an assortment of phenolic compounds recognized in wild mushrooms, including cinnamic acid, protocatechuic, *p*-hydroxybenzoic, *p*-coumaric acids, gallic acid, vanillin, rutin, and quercetin [60]. Polysaccharides are one of the major components in the mushroom. In recent studies, it has been revealed that they contain the antioxidant property [61]. Scavenging properties of polysaccharides are impacted by chemical properties such as atomic weight, level of branching, monosaccharide types, and proportion of monosaccharides, intermolecular relationship of polysaccharides, and alteration of polysaccharides. Among the monosaccharides, rhamnose is the most critical determinant factor related to scavenging properties of mushroom [62].

2.3.1. Agaricus bisporus

A. bisporus, also known as white button mushroom native to grasslands in Europe and North America, cultivated in more than 70 countries [63], possesses polysaccharides and antioxidants including vitamin C, D, B_{12}; folates; and polyphenols [48]. The phenolic composition of methanolic extract from *A. bisporus* is investigated by HPLC. Polysaccharides and phenolic compounds such as gallic acid, rutin, caffeic acid, and catechin found in the mushroom are responsible for its scavenging activity [64]. Mushrooms being routinely used as dietary ingredient made them a significant natural antioxidant source.

2.3.2. Armillaria mellea

A. mellea is a culinary-medicinal honey mushroom, used as an admired element in the traditional Chinese medicine. The mushroom is pathogenic and is found worldwide in temperate, boreal, and tropical forests [65]. It grows on living trees and on dead and rotting sustenance material [66]. Polysaccharides obtained from wild sporophores and refined products of *A. mellea* have scavenging properties [67]. Two polysaccharides, AkPS1V-1 and AkPS1V-2, from the alkaline extract of the mushroom have been isolated and reported for their antioxidant activity [68]. Moreover, their ascorbic acid and phenolic components have been reported for their scavenging impact on superoxide anions [69]. Overall, it is reported to have a fair antioxidant capacity to be used as food oxidation-reducing substance.

2.3.3. *Auricularia auricula*

A. auricula is an edible mushroom, found worldwide, belongs to the family Auriculaceae, commonly known as tree-tea or wood-ear. The mushroom contains high quantity of carbohydrates including polysaccharides, proteins, minerals, and phenolic substances [69, 70]. Polysaccharides of the mushroom have antioxidant activity [71] by the inhibition of lipid peroxidation and have effective hydroxyl radical scavenging activity [72]. In the case of lipid peroxidation, IC_{50} values of ethanolic, crude, and boiled extracts of *A. auricula* are 398, 310, and 572 μg/ml, respectively, and in the case of hydroxyl radical scavenging activity, 373, 403, and 510 μg/ml, respectively [72]. Khaskheli et al. isolated two polysaccharides from fruiting body of *A. auricula* and evaluated potential antioxidant activity of these polysaccharides [71]. Among its various extracts, the boiled extract, which is also convenient, proves to be more effective antioxidant.

2.3.4. *Boletus edulis*

B. edulis belongs to the Boletus species of mushroom widely distributed in the holarctic across Asia, Europe, and North America, commonly known as porcino and penny bun [73]. Other edible mushrooms of boletus species including *B. aereus, B. reticulate*, and *B. edulis* have good antioxidant properties. Total phenol contents of *B. edulis* is higher that shows the scavenging activity [74]. *B. auranticus* (EC50 0.016 mg/ml) exhibits higher total phenol contents as well as hydroxyl radical-scavenging activity than *B. edulis*. However, reducing power of *B. edulis* is higher. *B. edulis* extricate averts lipid peroxidation [75]. Antioxidant activity of *B. edulis* is attributed to its polysaccharides found in the fruiting bodies that are reported to have chelating action and inhibitory impacts on superoxide radical and hydroxyl radical [67]. Vieira et al. [76] investigate the *B. edulis* antioxidant activity with the combination of another edible mushroom *Marasmius oreades*. They investigated different parameter to observe the antioxidant capacity of the both mushroom species mixture, and they observed the good antioxidant activity in synergism. These results show that on various occasions, the addition of more than one mushroom as a combination gives more effective results than alone.

2.3.5. *Ganoderma lucidum*

Ganoderma lucidum is also commonly known as Lingzhi, a basidiomycete fungus, native to China and grows in mountain woods with humid and dim-light conditions, in the rotten bark or root of tree. The mushroom is well known as medicinal mushroom and has been prescribed to prevent and treat different diseases [77]. *G. lucidum* contains polysaccharides, sterols, triterpenoids, nucleosides, and alkaloids [78]. *G. lucidum* is called as marvelous mushroom of immortality because it shows that the consumption of the mushroom can prolong life [77]. Shi et al. [79] separated four polysaccharides from *G. lucidum* and investigate their antioxidant property. They demonstrated that these four polysaccharides have scavenging activities in a concentration-dependent manner [79]. *G. applanatum* is known as shelf fungus and also belongs to *Ganoderma* species of the mushroom. *G. applanatum* exhibits the higher antioxidant property over *G. lucidum* and other two edible mushrooms including *L. edodes* and *Trametes versicolor* [80].

2.3.6. *Grifola frondosa*

G. frondosa, also known as Maitake, is a culinary as well as medicinal mushroom native to China, North America, and northeastern part of Japan but cultivated worldwide in several countries because of its useful effects [81]. The mushroom is progressively being perceived as a powerful wellspring of polysaccharide with sensational well-being and advanced potential. Total phenols, ascorbic acid, α-tocopherol, and flavonoids are the major scavenging agents present in the different *G. frondosa* extricates [82]. *G. frondosa* polysaccharides have critical inhibitory impacts on hydroxyl radical, superoxide radical, and 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical [83]. Their ferrous particles chelating activity is also strong [84]. Fan et al. [85] extracted five polysaccharides from the natural product group of *G. frondosa* by various separating techniques. Hot alkali extract of *G. frondosa* has the better antioxidant activity as compared to partially purified polysaccharides. It has the lower EC_{50} values of DPPH scavenging ability [86]. The study results enforce the variation of their antioxidant ingredients due to the seasonal and geographic displacements.

2.3.7. *Hypsizigus marmoreus*

H. marmoreus is an edible mushroom commonly found in East Asia including Korea, China, and Japan, widely known due to its antioxidant activity [87]. Phenols [88] and polysaccharides are the major bioactive components present in *H. marmoreus* that show the antioxidant activity by scavenging reactive oxygen species and strengthening its reducing power [55]. Liu et al. investigated the intracellular polysaccharides of *H. marmoreus* and revealed that these polysaccharides can be utilized as an antioxidant agent that improves adaptive immune reactions [89].

2.3.8. *Lentinus edodes*

L. edodes also known as shitake mushroom is the second most well-known consumable mushroom in the worldwide market and is usually cultivated in Indonesia, Taiwan, China, and Japan [90]. The mushroom is credited to its wholesome incentive as well as to conceivable potential for therapeutic applications [91]. *L. edodes* contains some important polysaccharides that have therapeutic activity. The mushroom is also a good source of vitamins, particularly vitamin B, including B1, B2, B5, B12, and provitamin D2. *L. edodes* extract has potent antioxidant effect due to the presence of bioactive compounds ergothioneine [92]. *L. edodes* has the ability to increase the total antioxidant capacity and reduce the total oxidative stress [91]. UV-C radiation can improve scavenging capacity of *L. edodes* [93]. Chen et al. [83] separated three types of polysaccharide from fruiting bodies of *L. edodes*, and they demonstrated the polysaccharides as potent antioxidant agents that can produce healthy immune response. The treatment of mushroom crude powder or its extract may also helpful to enhance its antioxidant capability.

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2.3.9. Pleurotus ostreatus

Pleurotus ostreatus is the third most cultivated mushroom worldwide after *A. bisporus* [94]. Its mycelia as well as fruiting bodies have well-known therapeutic effects due to its various biologically active compounds including phenols, flavonoids, and carotenoids [95] having strong antioxidant activity [96]. The methanol extract demonstrated the most grounded β-carotene-linoleic acid restraint when contrasted with alternate extracts. On the other hand, acetone has the strong reducing power than alternate concentrates.

2.3.10. Schizophyllum commune

S. commune is a standout among the usually discovered fungus and can be separated from all landmasses, aside from Antarctica. *S. commune* has been accounted for to be a pathogen of people and trees; however, it principally receives a saprobic way of life by causing white rot. The antioxidant activity of *S. commune* is due to polysaccharides and polyphenols components [97].

2.4. Medicinal plants and spices having antioxidants

2.4.1. Allium sativum

A. sativum commonly known as garlic is a species belongs to family Alliaceae commonly cultivated in India [98]. It is a perpetual herb with a tall, erect blooming stem that grows up to 3 feet. Garlic has been utilized all through history for both culinary and therapeutic purposes. *A. sativum* is an adaptable herb that contains various trace elements, vitamins, and minerals. The total phenolic compound of the garlic has the antioxidant activity [99]. As an antioxidant, garlic has the strongest DPPH-scavenging ability [100]. Aged garlic extract has significantly eminent total phenolic substance than raw garlic extract [101]. It has been noticed that as the plant gets older, more the antioxidant potential it will gain.

2.4.2. Capsicum annuum

Capsicum annuum (red pepper) is native to southern North America and northern South America and was introduced in Asia in sixteenth century from South America [102]. It contains a wide cluster of phytochemicals with their radical-scavenging properties [103]. The spice contains carotenoids, flavonoids, tocopherols, free sugars, capsaicinoids, L-ascorbic acid, and organic acids [104]. At the ripe stage, hot-dried peppers have a high bioactive substances that show huge free radical-scavenging properties such as polyphenols and carotenoids [103].

2.4.3. Curcuma longa

Curcuma longa is a well-known spice that has a place in the Zingiberaceae family and is a lasting herb that measures up to 1 m high with a short stem. It is circulated all through tropical and subtropical locales of the world, being generally developed in Asiatic nations [105], primarily in India and China. In Pakistan and India, it is prevalently known as Haldi. As a powder, called turmeric, it has been in continual use as a flavor enhancer in both veggies lover and non-vegan foods. Essential oil of fresh rhizomes has higher scavenging properties [106]. The phenolic compounds of *C. longa* are the primary contributor of antioxidant activity [107].

2.4.4. *Eugenia caryophyllus*

Eugenia caryophyllus commonly known as clove is a medium-size tree (8-12 m) that belongs to family Myrtaceae. *E. caryophyllus* has been utilized for a considerable length of time as nourishment additive and for some therapeutic purposes as well [108]. Clove is local of Indonesia yet these days also cultivated in some other countries including Brazil in the province of Bahia. This plant is one of the wealthiest sources of phenolic compounds, for example, gallic acid eugenol and eugenol acetate [108]. *E. caryophyllus* leaf essential oil and its main constituent eugenol possess high antioxidant activity [109]. Among various extracts, the methanolic extract has higher scavenging activity than acetone and chloroform extracts [110].

2.4.5. *Geranium sanguineum*

Geranium sanguineum, usually called as bloody cranesbill, is a herbaceous plant that belongs to family Geraniaceae. It is local from Asia and Europe and is developed as a garden subject. In Pakistan, India, Sri Lanka, Indonesia, and Zanzibar, it is cultivated on large scale. It is found naturally in Madagascar, Brazil, Sri Lanka, Tanzania, and West Indies [111]. Methanol extract of *G. sanguineum* has the free radical-scavenging property [112].

2.4.6. *Pistacia lentiscus*

Pistacia lentiscus is extensively used in folk medicine by rural populations in Algeria. The herb is imperative due to its therapeutic uses. Ethanol, ethyl acetate, aqueous, hexane, aqueous/hexane, and chloroform extracts from the leaves of *P. lentiscus* have the radical-scavenging activity [113]. *P. lentiscus* have exceptional reducing power and strong radical-scavenging activity against DPPH [113, 114].

2.4.7. *Salvia officinalis*

Salvia officinalis, also known as garden sage, belongs to family Lamiaceae and possesses strong antioxidant property [115]. The plant is grown and cultivated in some parts of Iran. The leaves of the plant are utilized as a part of Iranian folk medicine. The antioxidant activity of the plant is due to the presence of polyphenol constituents [116]. Dried sage leaves infusion with boiling water (sage tea) is the most typical form of preparation. Sage tea contains polyphenolic constituents that possess antioxidant property and other therapeutic effects [117].

2.4.8. *Uncaria tomentosa*

Uncaria tomentosa is generally known as cat's claw and belongs to the family Rubiaceae. Its native is Amazon rainforest and other tropical territories of Central and South America. For centuries, the plant has been utilized as a part of customary practices in South America particularly in Peru. Due to its anti-inflammatory and radical-scavenging activities, the plant has been used to treat rheumatic diseases and cancer [118]. Decoctions prepared from the bark of *U. tomentosa* are generally utilized as a part of the conventional Peruvian medicine for the treatment of many diseases [119]. The bark decoctions have strong ability to decrease the free radicals diphenylpicrylhydrazyl, hydrogen peroxide, and hypochlorous acid [119].

2.4.9. Leea indica

Leea indica belongs to the family Vitaceae and has been traditionally used as natural folk medicine in Malaysia. In the leaves of *L. indica*, 23 known chemical compounds are identified [120]. The identified compounds include 11 hydrocarbons, 3 phthalic acid esters, phthalic acid, gallic acid, ursolic acid, solanesol, farnesol, β-sitosterol, lupeol, and 1-eicosanol [120]. Among these, total phenolic compounds possess the antioxidant activity [121].

2.4.10. Polyalthia cerasoides

Polyalthia cerasoides belongs to the family Annonaceae and is a medicinal plant used in Thai native medicine. The roots of *P. cerasoides* are used for therapeutic purposes that contain alkaloid, bidebiline, three known sesquiterpenes, four known isoquinoline, and other compounds such as laudanosine, codamine, laudanidine, and reticuline [122]. The extract has the highest phenolic compound and high reactive oxygen species-scavenging activity [123, 124].

2.5. Antioxidants from marine sources

Marine ecosystem has been reported as a potential source of biodiversity and chemical activities. The organisms living in marine environment are gaining the attention of industries such as pharmaceuticals, nutraceuticals, and cosmetics because of possessing various interesting and useful chemical compounds [125]. Marine biotechnologists are trying to produce the tool for the utilization of marine biodiversity for the production of cheap source of pharmaceutical products and functional foods [126]. Seaweeds and sponges are considered as the richest source of bioactive compounds having the antimicrobial and antioxidant activities [127]. Seaweeds and sponges with their associated bacteria have been found to possess various health-promoting and disease prevention effects due to their phenolic compounds, polysaccharides, and useful organic acids [128]. These are supposed to be the most protective group of foods against environmental pollutants and radiation [129]. Among various other useful compounds, the marine organisms also contain polyphenolic compounds that are responsible for antioxidant activity including flavonoids, benzoic acid, cinnamic acid, gallic acid, quercy, and phlorotannins [130]. Nonanimal sulfated polysaccharides are reported to have antioxidant activities [131], which can be obtained from marine algae and other marine organisms from the phaeophyta group [132].

A large number of different species of algae and microalgae have been studied for the use of their bioactive contents as functional food components. Algae comprised of a huge and complex group of photosynthetic organisms with simple reproductive organs, which can be multicellular, known as macroalgae and unicellular called as microalgae. Algae grow in extremes of environmental conditions such as light, temperature, and salinity, which results in the production of a large number of reactive oxygen species (ROS). To cope with these ROS, algae produce various secondary metabolites with many antioxidant activities such as phycobilins, polyphenols, carotenoids, and vitamins [133].

People living in coastal areas use many types of seaweed, both as fresh and dry forms, as a natural source of food, and from the research, it is known that these seaweeds contain a large amount of proteins, minerals, and vitamins. Although the composition of these seaweeds varies according to their species, geographical distribution, temperature, and seasonal variation, the overall nutritional value remains the same. Many compounds from marine algae possess anticancer activity, and recently, seaweeds have gained attention as a rich source of antioxidants [134]. Many of the secondary metabolites produced by marine organisms reflect the presence of chloride and bromide ions in seawater. Marine halogenated compounds assemble a large number of other useful compounds such as indoles, peptides, terpenes, phenols, acetogenins, and volatile halogenated hydrocarbons. This protective effect suggests the presence of antioxidant compounds that show their antioxidant activity as free radical scavengers, hydrogen-donating compounds, single oxygen quenchers, and metal ion chelators. Many biological compounds have previously isolated from some other marine organisms such as fish, crustaceans, and their byproducts [135].

Seaweeds also create a suitable environment to a large number of bacteria that live on their surface having much more diversity of microorganisms as compared to other multicellular organisms [136]. These associated microorganisms have a protective effect on the seaweeds from pathogen, and they produce a large number of bioactive compounds of biomedical importance [137]. Exopolysaccharides produced by these bacterial species are used as an ingredient in food, petroleum, and pharmaceutical industries and emulsification of crude oil, vegetables, mineral oils, and bioremediation agents in environment management systems [138].

Fish protein hydrolysate (FPH), which is prepared from various marine organisms such as mackerel, tuna, Alaska Pollock, and yellowfin sole, has also been reported to have antioxidant activity [139–141]. Many types of peptides are obtained from fish muscle, bone, skin, and other tissues. All of these amino acids can scavenge-free radicals, but the most powerful scavenging activity attributes to those who can easily donate hydrogen atoms. These amino acids are cystine and methionine, which have nucleophilic sulfur-containing side chains or tryptophan, tyrosine, and phenylalanine, which have aromatic side chains. Peptide size and amino acid composition are important for the FPH because it determines its antioxidant nature [142].

An in vitro study on phycocyanin, a pigment obtained from blue-green algae, reveals its antioxidant activity. It was evaluated in vitro by the use of luminol-enhanced chemiluminescence (LCL). Luminol reacts with oxygen (O^{-2}), alkoxyl ($RO^{\cdot}$), and hydroxyl ($OH^{\cdot}$) radicals and shows a luminous signal measurable before and after antioxidant addition. This antioxidant activity was also confirmed in vivo by induction of inflammation in mice paw with glucose oxidase. The edema caused by inflammation was reduced, and the luminous signal indicated that the phycocyanin can scavenge $OH^{\cdot}$ and $RO^{\cdot}$ [143]. Algal antioxidants are also used in the cosmeceutical industries as antiaging agents [144]. A carotenoid pigment known as astaxanthin, found in microalga *Haematococcus pluvialis*, is reported to have anti-inflammatory, immunomodulatory, and antioxidant activities [145].

3. Conclusion

An increasing interest has been observed from the past decade in exploring the natural ingredients to be used in the food and food products. The researchers from all over the world are focusing on the alternate sources other than the synthetic one, which will be more safe and convenient as dietary component. Although there are no such harmful reports have been observed regarding the use of synthetic antioxidants however the consumer's interest is also compelling toward the nature close products. Moreover, the synthetic antioxidants and preservatives in the food may lead to lipid peroxidation and deterioration of food flavor and quality. The use of natural herbs, spices, and plant ingredients is in practice from the ancient times and still practiced in the traditional food preparation as preservative, aroma, and flavor. This chapter is an effort to overview the potentials of various natural sources having reasonable antioxidant potential. The literature reports compiled here will be beneficial to identify the significance of various natural sources based on their antioxidant capacity, active ingredients, and geographic availability. This chapter reveals that people can prioritize their dietary habits based on the antioxidant potential and cost-effectiveness of the available source because 70–80% of the world population cannot afford the modern supplement and medicines.

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References

[1] Brewer M. Natural antioxidants: Sources, compounds, mechanisms of action, and potential applications. Comprehensive Reviews in Food Science and Food Safety. 2011;**10**(4):221-247

[2] Miguel MG. Antioxidant and anti-inflammatory activities of essential oils: A short review. Molecules. 2010;**15**(12):9252-9287

[3] Valko M et al. Free radicals and antioxidants in normal physiological functions and human disease. The International Journal of Biochemistry & Cell Biology. 2007;**39**(1):44-84

[4] Anwar H et al. Effect of protein, probiotic, and symbiotic supplementation on serum biological health markers of molted layers. Poultry Science. 2012;**91**(10):2606-2613

[5] Carocho M, Ferreira IC. A review on antioxidants, prooxidants and related controversy: Natural and synthetic compounds, screening and analysis methodologies and future perspectives. Food and Chemical Toxicology. 2013;**51**:15-25

[6] Asif M. Chemistry and antioxidant activity of plants containing some phenolic compounds. Chemistry International. 2015;**1**(1):35-52

[7] Ramalakshmi K, Kubra IR, Rao LJM. Antioxidant potential of low-grade coffee beans. Food Research International. 2008;**41**(1):96-103

[8] Dembinska-Kiec A et al. Antioxidant phytochemicals against type 2 diabetes. British Journal of Nutrition. 2008;**99**(E-S1):ES109-ES117

[9] Cao G et al. Serum antioxidant capacity is increased by consumption of strawberries, spinach, red wine or vitamin C in elderly women. The Journal of Nutrition. 1998; **128**(12):2383-2390

[10] Salinthone S et al. α-Tocopherol (vitamin E) stimulates cyclic AMP production in human peripheral mononuclear cells and alters immune function. Molecular Immunology. 2013;**53**(3):173-178

[11] Shebis Y et al. Natural antioxidants: Function and sources. Food and Nutrition Sciences. 2013;**4**(06):643

[12] Binic I et al. Skin ageing: Natural weapons and strategies. Evidence-based Complementary and Alternative Medicine. 2013;**2013**

[13] Slavin JL, Lloyd B. Health benefits of fruits and vegetables. Advances in Nutrition. 2012;**3**(4):506-516

[14] Nahak G, Suar M, Sahu RK. Antioxidant potential and nutritional values of vegetables: A review. Research Journal of Medicinal Plant. 2014;**8**(2):50-81

[15] Hurrell RF. Influence of vegetable protein sources on trace element and mineral bioavailability. The Journal of Nutrition. 2003;**133**(9):2973S-2977S

[16] Sonia N, Mini C, Geethalekshmi P. Vegetable peels as natural antioxidants for processed foods–a review. Agricultural Reviews. 2016;**37**(1):35-41

[17] Parr AJ, Bolwell GP. Phenols in the plant and in man. The potential for possible nutritional enhancement of the diet by modifying the phenols content or profile. Journal of the Science of Food and Agriculture. 2000;**80**(7):985-1012

[18] Baxter H, Harborne JB, Moss GP. Phytochemical Dictionary: A Handbook of Bioactive Compounds from Plants. Philadelphia (PA), USA: CRC Press; 1998

[19] Carr AC, Zhu B-Z, Frei B. Potential antiatherogenic mechanisms of ascorbate (vitamin C) and α-tocopherol (vitamin E). Circulation Research. 2000;**87**(5):349-354

[20] Quintavalla S, Vicini L. Antimicrobial food packaging in meat industry. Meat Science. 2002;**62**(3):373-380

[21] Urquiaga I, Leighton F. Plant polyphenol antioxidants and oxidative stress. Biological Research. 2000;**33**(2):55-64

[22] Shahidi F. Antioxidants in food and food antioxidants. Molecular Nutrition & Food Research. 2000;**44**(3):158-163

[23] Pinho O et al. Quantification of synthetic phenolic antioxidants in liver pâtés. Food Chemistry. 2000;**68**(3):353-357

[24] McGhie TK, Walton MC. The bioavailability and absorption of anthocyanins: Towards a better understanding. Molecular Nutrition & Food Research. 2007;**51**(6):702-713

[25] Daniel J. Metabolic aspects of antioxidants and preservatives. Xenobiotica. 1986;**16**(10-11): 1073-1078

[26] Mirabella N, Castellani V, Sala S. Current options for the valorization of food manufacturing waste: A review. Journal of Cleaner Production. 2014;**65**:28-41

[27] Rudra SG et al. Food industry waste: Mine of nutraceuticals. International Journal of Science, Environment and Technology. 2015;**4**(1):205-229

[28] Ajila C et al. Mango peel powder: A potential source of antioxidant and dietary fiber in macaroni preparations. Innovative Food Science & Emerging Technologies. 2010; **11**(1):219-224

[29] Goulas V, Manganaris GA. Exploring the phytochemical content and the antioxidant potential of citrus fruits grown in Cyprus. Food Chemistry. 2012;**131**(1):39-47

[30] Fatemeh S et al. Total phenolics, flavonoids and antioxidant activity of banana pulp and peel flours: Influence of variety and stage of ripeness. International Food Research Journal. 2012;**19**(3):1041-1046

[31] Guo C et al. Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay. Nutrition Research. 2003;**23**(12):1719-1726

[32] Someya S, Yoshiki Y, Okubo K. Antioxidant compounds from bananas (Musa Cavendish). Food Chemistry. 2002;**79**(3):351-354

[33] Agarwal M et al. Extraction of polyphenol, flavonoid from Emblica officinalis, Citrus Limon, Cucumis sativus and evaluation of their antioxidant activity. Oriental Journal of Chemistry. 2012;**28**(2):993

[34] Baiano A. Recovery of biomolecules from food wastes—A review. Molecules. 2014; **19**(9):14821-14842

[35] Kalogeropoulos N et al. Bioactive phytochemicals in industrial tomatoes and their processing byproducts. LWT- Food Science and Technology. 2012;**49**(2):213-216

[36] Ayala-Zavala J et al. Antioxidant enrichment and antimicrobial protection of fresh-cut fruits using their own byproducts: Looking for integral exploitation. Journal of Food Science. 2010;**75**(8)

[37] Teixeira A et al. Natural bioactive compounds from winery by-products as health promoters: A review. International Journal of Molecular Sciences. 2014;**15**(9):15638-15678

[38] Pujol D et al. The chemical composition of exhausted coffee waste. Industrial Crops and Products. 2013;**50**:423-429

[39] Pan H et al. Purification and identification of a polysaccharide from medicinal mushroom Amauroderma rude with immunomodulatory activity and inhibitory effect on tumor growth. Oncotarget. 2015;**6**(19):17777

[40] Rahman T, Choudhury M. Shiitake mushroom: A tool of medicine. Bangladesh Journal of Medical Biochemistry. 2013;**5**(1):24-32

[41] Ruthes AC, Smiderle FR, Iacomini M. Mushroom heteropolysaccharides: A review on their sources, structure and biological effects. Carbohydrate Polymers. 2016;**136**:358-375

[42] Cashman KD et al. Effect of ultraviolet light–exposed mushrooms on vitamin D status: Liquid chromatography–tandem mass spectrometry reanalysis of Biobanked sera from a randomized controlled trial and a systematic review plus meta-analysis-3. The Journal of Nutrition. 2016;**146**(3):565-575

[43] Khatua S, Paul S, Acharya K. Mushroom as the potential source of new generation of antioxidant: A review. Research Journal of Pharmacy and Technology. 2013;**6**(5):496-505

[44] Valverde ME, Hernández-Pérez T, Paredes-López O. Edible mushrooms: Improving human health and promoting quality life. International Journal of Microbiology. 2015;**2015**

[45] Taofiq O et al. The contribution of phenolic acids to the anti-inflammatory activity of mushrooms: Screening in phenolic extracts, individual parent molecules and synthesized glucuronated and methylated derivatives. Food Research International. 2015;**76**:821-827

[46] Wasser S. Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides. Applied Microbiology and Biotechnology. 2002;**60**(3):258-274

[47] Rai M, Tidke G, Wasser SP. Therapeutic Potential of Mushrooms. 2005

[48] Liu J et al. In vitro and in vivo antioxidant activity of ethanolic extract of white button mushroom (Agaricus bisporus). Food and Chemical Toxicology. 2013;**51**:310-316

[49] Han S-R, Kim M-J, Oh T-J. Antioxidant activities and antimicrobial effects of solvent extracts from Lentinus edodes. Journal of the Korean Society of Food Science and Nutrition. 2015;**44**(8):1144-1149

[50] Lai M-N, Ng LT. Antioxidant and antiedema properties of solid-state cultured honey mushroom, Armillaria mellea (higher Basidiomycetes), extracts and their polysaccharide and polyphenol contents. International Journal of Medicinal Mushrooms. 2013;**15**(1)

[51] Khaskheli SG et al. Characterization of Auricularia auricula polysaccharides and its antioxidant properties in fresh and pickled product. International Journal of Biological Macromolecules. 2015;**81**:387-395

[52] Vamanu E, Nita S. Antioxidant capacity and the correlation with major phenolic compounds, anthocyanin, and tocopherol content in various extracts from the wild edible *Boletus edulis* mushroom. BioMed Research International. 2013;**2013**

[53] Ferreira IC et al. Chemical features of *Ganoderma polysaccharides* with antioxidant, antitumor and antimicrobial activities. Phytochemistry. 2015;**114**:38-55

[54] Postemsky P, Curvetto N. Enhancement of wheat grain antioxidant activity by solid state fermentation with *Grifola* spp. Journal of Medicinal Food. 2014;**17**(5):543-549

[55] Liu M et al. Antioxidant and hepatoprotective activities of mycelia selenium polysaccharide by *Hypsizigus marmoreus* SK-02. Biological Trace Element Research. 2016; **172**(2):437-448

[56] Arbaayah H, Kalsom UY. Antioxidant properties in the oyster mushrooms (Pleurotus spp.) and split gill mushroom (*Schizophyllum commune*) ethanolic extracts. Mycosphere. 2013;**4**(4):661-673

[57] Dulay RMR et al. Antioxidant activity and total phenolic content of *Volvariella volvacea* and *Schizophyllum commune* mycelia cultured in indigenous liquid media. Mycosphere. 2016;**7**(2):131-138

[58] Mitra P, Mandal NC, Acharya K. Polyphenolic extract of *Termitomyces heimii*: Antioxidant activity and phytochemical constituents. Journal für Verbraucherschutz und Lebensmittelsicherheit. 2016;**11**(1):25-31

[59] You L et al. Structural characterisation of polysaccharides from Tricholoma matsutake and their antioxidant and antitumour activities. Food Chemistry. 2013;**138**(4):2242-2249

[60] Barros L et al. Phenolic acids determination by HPLC–DAD–ESI/MS in sixteen different Portuguese wild mushrooms species. Food and Chemical Toxicology. 2009; **47**(6):1076-1079

[61] Wang J-H et al. Physicochemical properties and antioxidant activities of polysaccharide from floral mushroom cultivated in Huangshan Mountain. Carbohydrate Polymers. 2015;**131**:240-247

[62] Lo TC-T et al. Correlation evaluation of antioxidant properties on the monosaccharide components and glycosyl linkages of polysaccharide with different measuring methods. Carbohydrate Polymers. 2011;**86**(1):320-327

[63] Capelli A. Fungi Europaei, Agaricus L. Saronno, Italy: Libreria Editrice Biella Giovanna; 1984

[64] Abah S, Abah G. Antimicrobial and antioxidant potentials of *Agaricus bisporus*. Advances in Biological Research. 2010;**4**(5):277-282

[65] Kile GA, McDonald GI, Byler JW. Ecology and disease in natural forests. Agriculture handbook (USA); 1991

[66] Zeković Z, Vidović S, Mujić I. Selenium and zinc content and radical scavenging capacity of edible mushrooms *Armilaria mellea* and *Lycoperdon saccatum*. Croatian Journal of Food Science and Technology. 2010;**2**(2):16-21

[67] Zhang A et al. Chemical analysis and antioxidant activity in vitro of polysaccharides extracted from boletus edulis. International Journal of Biological Macromolecules. 2011;**49**(5):1092-1095

[68] Siu K-C et al. Molecular properties and antioxidant activities of polysaccharides isolated from alkaline extract of wild Armillaria ostoyae mushrooms. Carbohydrate Polymers. 2016;**137**:739-746

[69] Lung M-Y, Chang Y-C. Antioxidant properties of the edible basidiomycete Armillaria mellea in submerged cultures. International Journal of Molecular Sciences. 2011;**12**(10): 6367-6384

[70] Sun Y et al. Structural elucidation and immunological activity of a polysaccharide from the fruiting body of Armillaria mellea. Bioresource Technology. 2009;**100**(5):1860-1863

[71] Khaskheli AA et al. Monitoring the Rhizopus oryzae lipase catalyzed hydrolysis of castor oil by ATR-FTIR spectroscopy. Journal of Molecular Catalysis B: Enzymatic. 2015;**113**:56-61

[72] Acharya K et al. Antioxidant and nitric oxide synthase activation properties of *Auricularia auricula*. Indian Journal of Experimental Biology. 2004;**42**:538-540

[73] Dentinger BT, Suz LM. What's for dinner?: Undescribed species in commercial porcini from China. PeerJ. 2014 PrePrints

[74] Palacios I et al. Antioxidant properties of phenolic compounds occurring in edible mushrooms. Food Chemistry. 2011;**128**(3):674-678

[75] Vidović SS et al. Antioxidant properties of selected boletus mushrooms. Food Biophysics. 2010;**5**(1):49-58

[76] Vieira V et al. Insights in the antioxidant synergistic effects of combined edible mushrooms: Phenolic and polysaccharidic extracts of *Boletus edulis* and *Marasmius oreades*. Journal of Food and Nutrition Research. 2012;**51**:109-112

[77] Bishop KS et al. From 2000 years of *Ganoderma lucidum* to recent developments in nutraceuticals. Phytochemistry. 2015;**114**:56-65

[78] Xu Z et al. Ganoderma lucidum polysaccharides: Immunomodulation and potential anti-tumor activities. The American Journal of Chinese Medicine. 2011;**39**(01):15-27

[79] Shi M, Zhang Z, Yang Y. Antioxidant and immunoregulatory activity of *Ganoderma lucidum* polysaccharide (GLP). Carbohydrate Polymers. 2013;**95**(1):200-206

[80] Kozarski M et al. Antioxidative activities and chemical characterization of polysaccharide extracts from the widely used mushrooms *Ganoderma applanatum*, *Ganoderma lucidum*, *Lentinus edodes* and *Trametes versicolor*. Journal of Food Composition and Analysis. 2012;**26**(1-2):144-153

[81] Kodama N, Komuta K, Nanba H. Can maitake MD-fraction aid cancer patients? Alternative Medicine Review. 2002;**7**(3):236-239

[82] Yeh J-Y et al. Antioxidant properties and antioxidant compounds of various extracts from the edible basidiomycete *Grifola frondosa* (Maitake). Molecules. 2011;**16**(4):3197-3211

[83] Chen H et al. Antioxidant activities of polysaccharides from *Lentinus edodes* and their significance for disease prevention. International Journal of Biological Macromolecules. 2012;**50**(1):214-218

[84] Chen G-t et al. Isolation, purification and antioxidant activities of polysaccharides from Grifola frondosa. Carbohydrate Polymers. 2012;**89**(1):61-66

[85] Fan Y et al. Physical characteristics and antioxidant effect of polysaccharides extracted by boiling water and enzymolysis from *Grifola frondosa*. International Journal of Biological Macromolecules. 2011;**48**(5):798-803

[86] Klaus A et al. Biological potential of extracts of the wild edible Basidiomycete mushroom *Grifola frondosa*. Food Research International. 2015;**67**:272-283

[87] Xie Q, Yan P, Chi Z. Antioxidant activity of exopolysaccharide from fermented kelp waste by *Hypsizygus marmoreus*. Science and Technology of Food Industry. 2011;**32**:115-117

[88] Chowdhury MMH, Kubra K, Ahmed SR. Screening of antimicrobial, antioxidant properties and bioactive compounds of some edible mushrooms cultivated in Bangladesh. Annals of Clinical Microbiology and Antimicrobials. 2015;**14**(1):8

[89] Liu H et al. Production and antioxidant activity of intracellular polysaccharide by *Hypsizigus marmoreus* SK-01. BioResources. 2012;**7**(4):5879-5893

[90] Pettipher GL. Cultivation of the shiitake mushroom (Lentinus edodes) on lignocellulosic waste. Journal of the Science of Food and Agriculture. 1988;**42**(3):195-198

[91] Nisar J et al. Shiitake culinary-medicinal mushroom, *Lentinus edodes* (Agaricomycetes): A species with antioxidant, Immunomodulatory, and Hepatoprotective activities in Hypercholesterolemic rats. International Journal of Medicinal Mushrooms. 2017

[92] Zembron-Lacny A et al. Effect of shiitake (Lentinus edodes) extract on antioxidant and inflammatory response to prolonged eccentric exercise. Journal of Physiology and Pharmacology. 2013;**64**(2):249-254

[93] Jiang T et al. Influence of UV-C treatment on antioxidant capacity, antioxidant enzyme activity and texture of postharvest shiitake (*Lentinus edodes*) mushrooms during storage. Postharvest Biology and Technology. 2010;**56**(3):209-215

[94] Sánchez C. Cultivation of *Pleurotus ostreatus* and other edible mushrooms. Applied Microbiology and Biotechnology. 2010;**85**(5):1321-1337

[95] Jayakumar T, Thomas P, Geraldine P. In-vitro antioxidant activities of an ethanolic extract of the oyster mushroom, *Pleurotus ostreatus*. Innovative Food Science & Emerging Technologies. 2009;**10**(2):228-234

[96] Anandhi R et al. Antihypercholesterolemic and antioxidative effects of an extract of the oyster mushroom, *Pleurotus ostreatus*, and its major constituent, chrysin, in triton WR-1339-induced hypercholesterolemic rats. Journal of Physiology and Biochemistry. 2013;**69**(2):313-323

[97] Klaus A et al. Antioxidative activities and chemical characterization of polysaccharides extracted from the basidiomycete *Schizophyllum commune*. LWT- Food Science and Technology. 2011;**44**(10):2005-2011

[98] Bhonde S, Prakash H. Garlic Cultivation in India. Nashik, India: National Horticultural Research and Development Foundation; 2006

[99] Lu X et al. Determination of total phenolic content and antioxidant activity of garlic (*Allium sativum*) and elephant garlic (*Allium ampeloprasum*) by attenuated total reflectance-Fourier transformed infrared spectroscopy. Journal of Agricultural and Food Chemistry. 2011;**59**(10):5215-5221

[100] Rahman M, Fazlic V, Saad. Antioxidant properties of raw garlic (*Allium sativum*) extract. International Food Research Journal. 2012;**19**(2):589-591

[101] Park J-H, Park YK, Park E. Antioxidative and antigenotoxic effects of garlic (Allium sativum L.) prepared by different processing methods. Plant Foods for Human Nutrition. 2009;**64**(4):244

[102] Latham E. The Colourful World of Chillies. New Zealand: Stuff. co. nz.; 2009

[103] Hervert-Hernández D, Sáyago-Ayerdi SG, GONi I. Bioactive compounds of four hot pepper varieties (*Capsicum annuum* L.), antioxidant capacity, and intestinal bioaccessibility. Journal of Agricultural and Food Chemistry. 2010;**58**(6):3399-3406

[104] Kim JS et al. Phytochemicals and antioxidant activity of fruits and leaves of paprika (*Capsicum annuum* L., var. special) cultivated in Korea. Journal of Food Science. 2011;**76**(2)

[105] Ferreira FD et al. Inhibitory effect of the essential oil of *Curcuma long*a L. and curcumin on aflatoxin production by *Aspergillus flavus* link. Food Chemistry. 2013;**136**(2):789-793

[106] Singh G et al. Comparative study of chemical composition and antioxidant activity of fresh and dry rhizomes of turmeric (*Curcuma longa* Linn.). Food and Chemical Toxicology. 2010;**48**(4):1026-1031

[107] Maizura M, Aminah A, Wan Aida W. Total phenolic content and antioxidant activity of kesum (*Polygonum minus*), ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) extract. International Food Research Journal. 2011;**18**(2)

[108] Cortés-Rojas DF, de Souza CRF, Oliveira WP. Clove (*Syzygium aromaticum*): A precious spice. Asian Pacific Journal of Tropical Biomedicine. 2014;**4**(2):90-96

[109] Teixeira B et al. Chemical composition and bioactivity of different oregano (Origanum vulgare) extracts and essential oil. Journal of the Science of Food and Agriculture. 2013;**93**(11):2707-2714

[110] Hemalatha R et al. Phytochemical composition, GC-MS analysis, in vitro antioxidant and antibacterial potential of clove flower bud (*Eugenia caryophyllus*) methanolic extract. Journal of Food Science and Technology. 2016;**53**(2):1189-1198

[111] Bhowmik D et al. Recent trends in Indian traditional herbs *Syzygium aromaticum* and its health benefits. Journal of Pharmacognosy and Phytochemistry. 2012;**1**(1):13-23

[112] Nikolova M, Tsvetkova R, Ivancheva S. Evaluation of antioxidant activity in some Geraniacean species. Botanica Serbica. 2010;**34**(2):123-125

[113] Atmani D et al. Antioxidant capacity and phenol content of selected Algerian medicinal plants. Food Chemistry. 2009;**112**(2):303-309

[114] GHENIMA AI et al. In vitro evaluation of biological activities of *Pistacia lentiscus* aqueous extract. International Journal of Pharmacy and Pharmaceutical Sciences. 2015;**7**(11):133-139

[115] Roby MHH et al. Evaluation of antioxidant activity, total phenols and phenolic compounds in thyme (*Thymus vulgaris* L.), sage (*Salvia officinalis* L.), and marjoram (*Origanum majorana* L.) extracts. Industrial Crops and Products. 2013;**43**:827-831

[116] Hamrouni-Sellami I et al. Total phenolics, flavonoids, and antioxidant activity of sage (*Salvia officinalis* L.) plants as affected by different drying methods. Food and Bioprocess Technology. 2013;**6**(3):806-817

[117] Walch SG et al. Antioxidant capacity and polyphenolic composition as quality indicators for aqueous infusions of *Salvia officinalis* L.(sage tea). Frontiers in Pharmacology. 2011;**2**:79

[118] Dreifuss AA et al. Antitumoral and antioxidant effects of a hydroalcoholic extract of cat's claw (*Uncaria tomentosa*)(Willd. Ex Roem. & Schult) in an in vivo carcinosarcoma model. Journal of Ethnopharmacology. 2010;**130**(1):127-133

[119] Gonçalves C, Dinis T, Batista MT. Antioxidant properties of proanthocyanidins of Uncaria tomentosa bark decoction: A mechanism for anti-inflammatory activity. Phytochemistry. 2005;**66**(1):89-98

[120] Srinivasan G, Ranjith C, Vijayan K. Identification of chemical compounds from the leaves of Leea indica. Acta Pharmaceutica. 2008;**58**(2):207-214

[121] Reddy NS et al. Phenolic content, antioxidant effect and cytotoxic activity of Leea indica leaves. BMC Complementary and Alternative Medicine. 2012;**12**(1):128

[122] Kanokmedhakul S, Kanokmedhakul K, Lekphrom R. Bioactive constituents of the roots of *Polyalthia cerasoides*. Journal of Natural Products. 2007;**70**(9):1536-1538

[123] Ravikumar Y et al. Antioxidant, cytotoxic and genotoxic evaluation of alcoholic extract of *Polyalthia cerasoides* (Roxb.) Bedd. Environmental Toxicology and Pharmacology. 2008;**26**(2):142-146

[124] Treeratanapiboon L et al. Bioactive 4-hydroxycinnamide and bioactivities of Polyalthia cerasoides. EXCLI Journal. 2011;**10**:16

[125] Tramper J et al. What to do in marine biotechnology? Biomolecular Engineering. 2003; **20**(4-6):467-471

[126] Selvan GP et al. Antagonistic activity of marine sponge associated Streptomyces sp. against isolated fish pathogens. Asian Pacific Journal of Tropical Disease. 2012; **2**:S724-S728

[127] Ngo D-H et al. Biological activities and potential health benefits of bioactive peptides derived from marine organisms. International Journal of Biological Macromolecules. 2012;**51**(4):378-383

[128] Wijffels RH. Potential of sponges and microalgae for marine biotechnology. Trends in Biotechnology. 2008;**26**(1):26-31

[129] Newman DJ, Cragg GM. Marine natural products and related compounds in clinical and advanced preclinical trials. Journal of Natural Products. 2004;**67**(8):1216-1238

[130] Al-Saif SSA-l et al. Antibacterial substances from marine algae isolated from Jeddah coast of Red Sea, Saudi Arabia. Saudi Journal of Biological Sciences. 2014;**21**(1):57-64

[131] Anand TP et al. Antimicrobial activity of marine bacteria associated with sponges from the waters off the coast of south East India. Microbiological Research. 2006;**161**(3):252-262

[132] Bultel-Poncé V et al. Metabolites from the sponge-associated bacterium *Micrococcus luteus*. Journal of Marine Biotechnology. 1998;**6**:233-236

[133] Manivannan K, Anantharaman P, Balasubramanian T. Antimicrobial potential of selected brown seaweeds from Vedalai coastal waters, Gulf of Mannar. Asian Pacific Journal of Tropical Biomedicine. 2011;**1**(2):114-120

[134] Devi GK et al. In vitro antioxidant activities of selected seaweeds from southeast coast of India. Asian Pacific Journal of Tropical Medicine. 2011;**4**(3):205-211

[135] Airanthi M, Hosokawa M, Miyashita K. Comparative antioxidant activity of edible Japanese brown seaweeds. Journal of Food Science. 2011;**76**:1

[136] López A et al. The effects of solvents on the phenolic contents and antioxidant activity of *Stypocaulon scoparium* algae extracts. Food Chemistry. 2011;**125**(3):1104-1109

[137] Wiese J et al. Diversity of antibiotic-active bacteria associated with the brown alga *Laminaria saccharina* from the Baltic Sea. Marine Biotechnology. 2009;**11**(2):287-300

[138] Penesyan A et al. Antimicrobial activity observed among cultured marine epiphytic bacteria reflects their potential as a source of new drugs. FEMS Microbiology Ecology. 2009;**69**(1):113-124

[139] Wu H-C, Chen H-M, Shiau C-Y. Free amino acids and peptides as related to antioxidant properties in protein hydrolysates of mackerel (Scomber austriasicus). Food Research International. 2003;**36**(9-10):949-957

[140] Jun S-Y et al. Purification and characterization of an antioxidative peptide from enzymatic hydrolysate of yellowfin sole (*Limanda aspera*) frame protein. European Food Research and Technology. 2004;**219**(1):20-26

[141] Je J-Y et al. Purification and characterization of an antioxidant peptide obtained from tuna backbone protein by enzymatic hydrolysis. Process Biochemistry. 2007;**42**(5):840-846

[142] Kim S-K, Wijesekara I. Marine-derived Nutraceuticals. Marine nutraceuticals: Prospects and Perspectives. Marine Drugs. 2013;**11**:1300-1303

[143] Romay C et al. Antioxidant and anti-inflammatory properties of C-phycocyanin from blue-green algae. Inflammation Research. 1998;**47**(1):36-41

[144] Cornish ML, Garbary DJ. Antioxidants from macroalgae: Potential applications in human health and nutrition. Algae. 2010;**25**(4):155-171

[145] Guerin M, Huntley ME, Olaizola M. *Haematococcus astaxanthin*: Applications for human health and nutrition. Trends in Biotechnology. 2003;**21**(5):210-216

[146] Georgiev VG et al. Antioxidant activity and phenolic content of betalain extracts from intact plants and hairy root cultures of the red beetroot *Beta vulgaris* cv. Detroit dark red. Plant Foods for Human Nutrition. 2010;**65**(2):105-111

[147] Nantitanon W, Yotsawimonwat S, Okonogi S. Factors influencing antioxidant activities and total phenolic content of guava leaf extract. LWT- Food Science and Technology. 2010;**43**(7):1095-1103

[148] Fernández-López JA et al. Determination of antioxidant constituents in cactus pear fruits. Plant Foods for Human Nutrition. 2010;**65**(3):253-259

[149] Yasoubi P et al. Total phenolic contents and antioxidant activity of pomegranate (*Punica granatum* L.) peel extracts. Journal of Agricultural Science and Technology. 2010;**9**:35-42

[150] Oloyede O et al. Antioxidative properties of ethyl acetate fraction of unripe pulp of *Carica papaya* in mice. The Journal of Microbiology, Biotechnology and Food Sciences. 2011;**1**(3):409

[151] Edwards AJ et al. Consumption of watermelon juice increases plasma concentrations of lycopene and β-carotene in humans. The Journal of Nutrition. 2003;**133**(4):1043-1050

[152] Navarro M et al. Polyphenolic characterization and antioxidant activity of *Malus domestica* and *Prunus domestica* cultivars from Costa Rica. Food. 2018;**7**(2):15

[153] Lotito SB, Frei B. Relevance of apple polyphenols as antioxidants in human plasma: Contrasting in vitro and in vivo effects. Free Radical Biology and Medicine. 2004; **36**(2):201-211

[154] Shukitt-Hale B et al. Plum juice, but not dried plum powder, is effective in mitigating cognitive deficits in aged rats. Nutrition. 2009;**25**(5):567-573

[155] Ou B et al. Analysis of antioxidant activities of common vegetables employing oxygen radical absorbance capacity (ORAC) and ferric reducing antioxidant power (FRAP) assays: A comparative study. Journal of Agricultural and Food Chemistry. 2002;**50**(11):3122-3128

[156] Mokbel MS, Hashinaga F. Antibacterial and antioxidant activities of banana (Musa, AAA cv. Cavendish) fruits peel. American Journal of Biochemistry and Biotechnology. 2005;**1**(3):125-131

[157] Nguyen TBT, Ketsa S, van Doorn WG. Relationship between browning and the activities of polyphenoloxidase and phenylalanine ammonia lyase in banana peel during low temperature storage. Postharvest Biology and Technology. 2003;**30**(2):187-193

[158] Arogba SS. Mango (*Mangifera indica*) kernel: Chromatographic analysis of the tannin, and stability study of the associated polyphenol oxidase activity. Journal of Food Composition and Analysis. 2000;**13**(2):149-156

[159] Puravankara D, Boghra V, Sharma RS. Effect of antioxidant principles isolated from mango (*Mangifera indica* L) seed kernels on oxidative stability of buffalo ghee (butter-fat). Journal of the Science of Food and Agriculture. 2000;**80**(4):522-526

[160] Zeyada NN, Zeitoum M, Barbary O. Utilization of some vegetables and fruit waste as natural antioxidants. Alex Journal of Food Science and Technology. 2008;**5**:1-11

[161] Erukainure O et al. Improvement of the biochemical properties of watermelon rinds subjected to *Saccharomyces cerevisae* solid media fermentation. Pakistan Journal of Nutrition. 2010;**9**(8):806-809

[162] Nara K et al. Antioxidative activity of bound-form phenolics in potato peel. Bioscience, Biotechnology, and Biochemistry. 2006;**70**(6):1489-1491

[163] Mahmood A, Greenman J, Scragg A. Orange and potato peel extracts: Analysis and use as *Bacillus substrates* for the production of extracellular enzymes in continuous culture. Enzyme and Microbial Technology. 1998;**22**(2):130-137

[164] Zuorro A, Lavecchia R. Spent coffee grounds as a valuable source of phenolic compounds and bioenergy. Journal of Cleaner Production. 2012;**34**:49-56

[165] Wolfe KL, Liu RH. Apple peels as a value-added food ingredient. Journal of Agricultural and Food Chemistry. 2003;**51**(6):1676-1683

[166] Negro C, Tommasi L, Miceli A. Phenolic compounds and antioxidant activity from red grape marc extracts. Bioresource Technology. 2003;**87**(1):41-44

[167] Maier T et al. Residues of grape (*Vitis vinifera* L.) seed oil production as a valuable source of phenolic antioxidants. Food Chemistry. 2009;**112**(3):551-559

[168] Deng G-F et al. Potential of fruit wastes as natural resources of bioactive compounds. International Journal of Molecular Sciences. 2012;**13**(7):8308-8323

[169] Noda Y et al. Antioxidant activities of pomegranate fruit extract and its anthocyanidins: Delphinidin, cyanidin, and pelargonidin. Journal of Agricultural and Food Chemistry. 2002;**50**(1):166-171

[170] Gil MI et al. Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing. Journal of Agricultural and Food Chemistry. 2000;**48**(10):4581-4589

[171] Chantaro P, Devahastin S, Chiewchan N. Production of antioxidant high dietary fiber powder from carrot peels. LWT- Food Science and Technology. 2008;**41**(10):1987-1994

[172] Strati IF, Oreopoulou V. Effect of extraction parameters on the carotenoid recovery from tomato waste. International Journal of Food Science and Technology. 2011;**46**(1):23-29