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Review Article

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Study on antioxidant activity in fruits and vegetables – A Review

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Abstract

Fruits and vegetables are very good sources of antioxidants those consist of many different antioxidant components. The antioxidant activity can be varied among fruits and vegetables. Each fruits and vegetables containing different kind of antioxidants as well as this can be varied among the species to species as well as climates. There are several in vitro methods to evaluate the antioxidant activity of fruits and vegetables. This review was carried out to study the antioxidant activity of fruits and vegetables and how it varies with the climate conditions.

Keywords: Antioxidant activity, Phenolic compounds, Fruits, Vegetables, Climate

Introduction

There are various normal reactions within our bodies that produced free radicals as byproducts. Some of these reactions are generation of calories, the degradation of lipids, the catecholamine response under stress, and inflammatory processes.
An antioxidant can be defined as any substance which significantly delays or prevents oxidation of oxidizable substrate when present at low concentration compared to that of an oxidizable substrate. There are two groups named as natural enzymatic antioxidants and non-enzymatic ones.Superoxide dismutase, catalases are natural enzymatic antioxidants that are located mostly in peroxisomes. Vitamin E, Vitamin C, BHT, BHA, carotenoids, glutathione and derivatives, phenolic compounds, flavonoids and alkaloids are natural and synthetic antioxidants.

Through our diet, we can open ourselves to more antioxidants that it is extremely easiest and best way. Consuming fruits and vegetables, we can reduce the risk of oxidative damages to cells. Fruits and vegetables are very good source of natural antioxidants which consist of many different antioxidant components. Hence those are alluded to as "super foods" or "functional foods". These antioxidants are carotenoids, vitamins, phenolic compounds, flavonoids, dietary glutathione and endogenous metabolites. These function as free radical scavengers, singlet and triplet oxygen quenchers, enzyme inhibitors, peroxide decomposers and synergists. Eg: Carotenoids demonstrate photoprotection that originates from their ability to quench and inactivate reactive oxygen species.

Common antioxidants in fruits and vegetables.

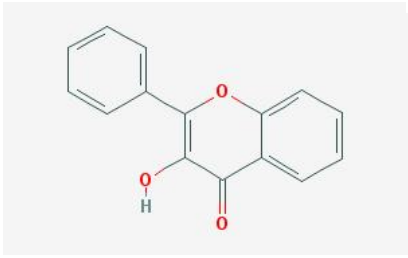
Phenolic compounds

These are secondary metabolites commonly found in plants and are very useful in the defense mechanisms against pathogens and radiation and directly involve in antioxidant activity. These are of major concern in the

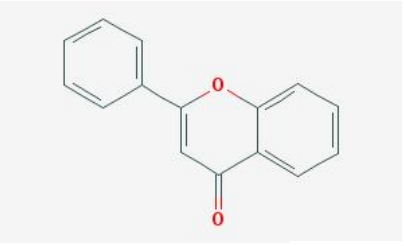
food industry because they retard oxidative degradation of lipids and hence improve the quality and nutritional value of foods like wise its' nutrional value. These substances are produced through phenyl propanoid pathway and shikimic acid pathway. Flavonoids are a group of phenolic compounds and they can be categorized into six groups such as flavones, flavanols, flavanones,flavan-3-ols,isoflavones and anthocyanidin compounds. Phenolic compounds have antitumor, antimicrobial and anti-inflammation properties.Some flavonoids have high antioxidant activity than vitamin C,gluthione and beta carotene.

Rather than phenolic compounds there are several antioxidants in plants such as fat soluble vitamins(alpha tocopherol),water soluble vitamins(ascorbic acid) and enzymes such as gluthione reductase, catalase and superoxide dismutase.

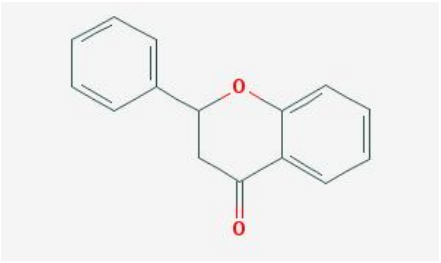
According to the previous studies extracts from beet root pomace have considerable amounts of phenolic compounds. (Jasna et al.,2011) The present studies have shown that the extract of *Mellilotus officinalis*, which contain highest amount of flavonoid and phenolic compounds, exhibited the greatest antioxidant activity. (Pourmorad et al., 2006)



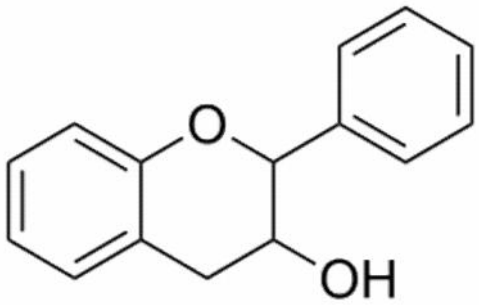
Flavones



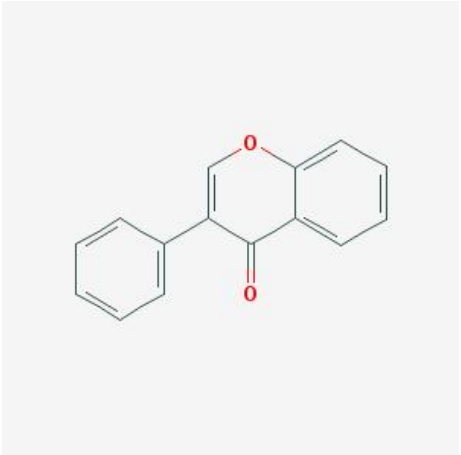
Flavonol



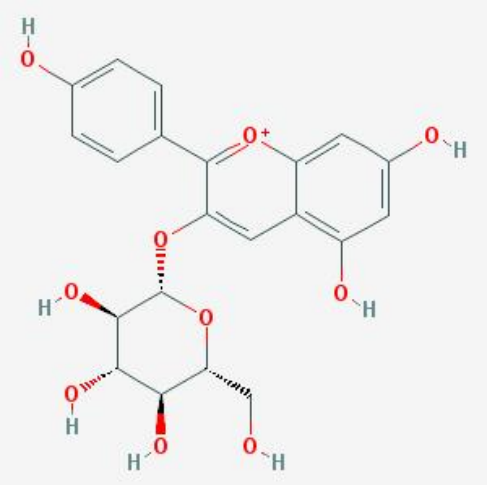
Flavanone



Flavan-3-ols

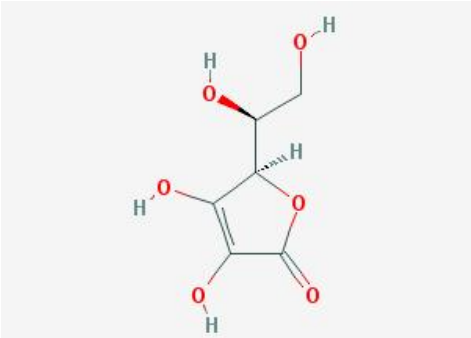


Isoflavones



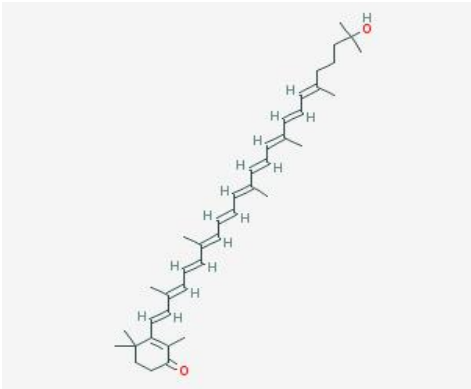
Pelargonidin 3-glucoside

Ascorbic acid



It is widely in fresh fruits and vegetables. Orange, papaya, lemon, watermelons and cherries are some of examples for fruits and broccoli, Tomato, peppers and cabbage are some of examples for vegetables. It is a liable molecule and may be lost from foods during cooking and processing. Eg: The non-peeled Guava fruit has higher total phenol and ascorbic acid contents compared to the peeled fruit. (Lim et al., 2006)

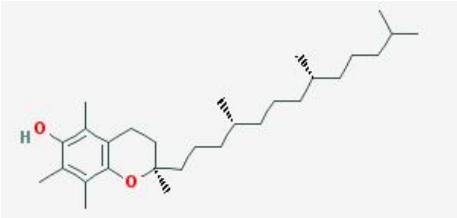
Carotenoids



1'-OH-4-Keto-gamma-carotene/ (Carotenoid K)

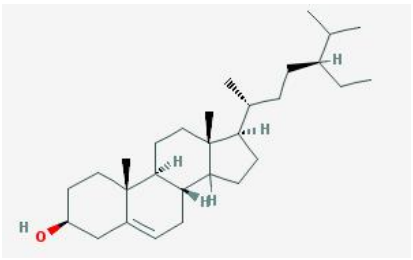
The principal sources are fruits and vegetables and play an important role in diet because it consists of vitamin A activity. Other than that carotenoids are important for antioxidant activity, immune system activity and intercellular communication. According to the several studies, it has been proved that carotenoids lower the incidents of cancers, cardio vascular diseases, age related macular degenerations and cataract formation. Eg: Pumpkin also contain high amount of antioxidants which are varied with the maturity stage. (Sonu et al., 2013)

Vitamin E



Vitamin E consists of Tocopherols and tocotrienols together. It is a well known main dietary fat soluble vitamin and insoluble in water. Both tochopherols and tocotrienols have same aromatic chromanol head although they differ in their hydrocarbon tail. Eg; Avocado consist of vitamin E. (Mark et al., 2013)

Phytosterols



Those are triterpenes and very important structural components of plants. Most phytosterols has 28 or 29 carbons with carbon-carbon double bonds and structurally similar to cholesterol like animal sterols. Phytosterols and phytostanols inhibit intestinal absorption of cholesterol and reduce the risk of coronary heart disease. Eg: Avocado consists of Phytosterols. (Mark et al., 2013).

Fruits have very agreeable taste and those are juicy with high water and sugar content and consist of vitamin, minerals and fibers.

Fruits show considerable variations in composition and structure because fruits contain a wide variety of different compounds. Normally each fruit is composed of living tissues and hence they are metabolically active. So the composition is constantly varied.

The nutritional value of fruit depends on the composition of it. Water, Proteins, carbohydrates, fats, minerals and vitamins are the most important components in fruits. Most of these components are essential nutrients required by body and some of them are not essential nutrients. The amount of nutrients of fruits required by body is depended on the Age, mass, sex, health and physical activity. Some of these nutrients are also required in very minute quantities.

List of fruits and vegetables

English name	Scientific name	Sinhala name	Tamil name
Beet root	*Beta vulgaris crassa*	Beet root	Beet root
Yellow sweet clover	*Melilotusofficinalis*	-	-
Guava	*Psidiumguajava*	Pera	Koyya
Pumpkin	*Cucurbita*	Wattakka	Poosani
Avocado	*Perseaamericana*	Alipera	Anaikoyya
Pears	*Pyrus*	Pears	Pears
Peach	*Prunuspersica*	Peach	Peach
Plums	*Prunusdomestica*	Wiyali midi	Munthirihai
Passion fruit	*Passifloraedulis*	Passion fruit	Passion fruit
Berries	-	Berry	Berry
Strawberries	*Fragariaananassa*	Strawberries	Strawberries
Tomato	*Lycopersiconlycopersicum*	Thakkali	Thakkali
Mango	*Mangiferaindica*	Amba	Maampalam
Pineapple	*Ananascomosus*	Annasi	Annasi
Payaya	*Carica papaya*	Papol	Pappasi
Mangusteen	*Garciniamangostana*	Mangus	Mangusteen
Star fruit	*Averrhoacarambola*	Kamaranka	Natchathirapalam
Banana	*Musa*	Kesel	Valai
Bean	*Phaseolus vulgaris*	Bonchi	Avarai
Bell pepper	*Capsicum*	Bell pepper	Manimilahari
Acerola fruit	*Malpighiaemarginata*	-	-
Cucumber	*Cucumissativus*	-	Vellari
Water melon	*Citrulluslanatus*	Komadu	Vathahai
Sweet potato	*Ipomoea batatas*	Bathala	Vatralai
Brinjal	*Solanummelongena*	Wmbatu	Kaththari
Water spinach	*Ipomoea aquatica*	Kankun	Keerai
Broccoli	*Brassica oleracea var. italica*	Broccoli	Broccoli
Cabbage	*Brassica oleracea var. capitata*	Gova	Gova
Raddish	*Raphanussativus*	Rabu	Mullangi
Onion	*Allium sativum L.*	lokuluunu	Ulli

Temperate climate fruits

These species grow in areas characterized by a temperate climate, that is, where temperatures are never extremely cold. Considering the nutritional value of these fruits,

According to the previous researches, the total phenolic contents and total flavoniod contents in peel and pulp parts of pears have tested varied over 601.50-619.25, 333.90- 355.80 mg GAE/100g and 543.50-561.30, 270.50-290.50 mg CE/100g, respectively. Reducing power, in terms of absorbance values, of peel and pulp extract (at 12.5 mg/mL concentration) have ranged between 0.56-0.58 and 0.30-0.32, respectively. DPPH radical scavenging activity and inhibition of linoleic acid peroxidation varied from 49.71-49.94% and 60.32-60.60% in peel and 27.89-28.29% and 34.15-34.45% in pulp. (Maleeha et al.,2013)

Nineteen peach [*Prunus persica* (L.) Batsch] genotypes and 45 plum (*Prunussalicina*Erhr. and hybrids) genotypes with different flesh and skin color have analyzed for their antioxidant content and activity. Anthocyanin content, phenolic content, and antioxidant activity have higher in red-flesh than in light-colored flesh peaches. Carotenoid content has higher in yellow-flesh peaches than in light-colored ones. Red-flesh plums generally have higher anthocyanin and phenolic contents than the other plums but not necessarily greater antioxidant capacity. The total phenolic content has the most consistent and highest correlation with antioxidant activity, indicating that it is more important in determining the antioxidant activity of peaches and plums than are the anthocyanin or carotenoid contents. (Marcia et al, 2007)

Considering the three cultivars of plums (*Prunus domestica*): 'WegierkaZwykła', 'Bluefre' and 'Elena', the higher antioxidant activity (μM Trolox/g d.m.) has assayed in plums of relatively new cultivars, 'Bluefre' and 'Elena', in comparison to the traditional cultivar 'WegierkaZwykła'. (Dorota et al, 2008)

Passion fruit is also rich in anti-oxidants. After chosen several extraction conditions have contributed to the high TPC and antioxidant activity of passion fruit peel. But the levels of antioxidant activity obtained from the passion fruit peel were also lower compared to BHA and α-tocopherol. (Yuh et al, 2014)

Phenolic compounds (phenolic acids, flavonoids, such as anthocyanins and flavonols, and tannins) and ascorbic acid are the bioactive compounds in berries. These compounds, either individually or combined, are responsible for various health benefits of berries.(Sona et al, 2015) Strawberries are the good source of antioxidants and could be used to prevent deleterious effects induced by free radicals. According to previous results it may be significant for industry concerning food quality and disease prevention. (Panico et al, 2009)

Tree tomato is good sources of provitamin A, vitamin C, B6, E and iron. The different parts of *C. betacea* fruit mainly placenta, endocarp and epicarp are potential functional food ingredient and their incorporation into human diets might provide protection and help to reduce oxidative damage in different vital organs. (Palash et al, 2012)

Tropical and subtropical fruits

Tropical and subtropical fruits include members of the Anacardiaceae family, which comprises about 59 genera and 400 species. Such species are generally found in tropical areas and in high temperature zones throughout the world.

Some researches have done to evaluate the antioxidant activity of Mango (*Mangifera indica*) kernel due to the presence of high amount of phytochemicals and antioxidant activity. (Arogba et al., 2012) Though theIC50 value is varied among the species of same genus, commonly the IC50 value of Mango have shown better correlation with the reference samples such as Quercetin than the reference Vitamin C and have shown relatively higher radical scavenging effect than the reference samples. (Arogba et al., 2012)Thus, in plants polyphenol concentrations also vary.

The present studies have shown that a local fruit such as guava has a high quantity of antioxidant such as phenols and ascorbic acid. Guava also has high primary antioxidant potential when compared to other local fruits and an imported fruit. (Lim et al., 2006)
In Pineapple Gallic acid (31.76 mg/100 g dry extracts), catechin (58.51 mg/100 g), epicatechin (50.00 mg/100 g), and ferulic acid (19.50 mg/100 g) present as main polyphenolics and have high antioxidant activity. (Ti et al., 2014)

Papaya (*Carica papaya* L. cv. Eksotika) is one of the most commonly consumed tropical fruits by humans. It has the highest antioxidant activity and has the highest capacity to scavenge free radicals. (Zuhair et al., 2013)

The pericarp extraction of Mangusteen has exhibited higher antioxidant capacities than those of pulp and seed extracts, with a Trolox equivalent antioxidant capacity (TEAC) value of 122.00 μM·g–1 and ferrous sulphate equivalent antioxidant capacity (FEAC) value of 18.99 mM·g–1. (Yin et al., 2013)

According to the previous researches; *Averrhoa carambola* plant contains flavonoids, alkaloids, saponins and tannins. These active constituents alone or in combination may be responsible for the observed antioxidant activity and the results of anti-oxidant activity revealed that, the ethanolic extract shows good IC50 values.(Sindhu et al.,2013) As well as some researches have done to Phytochemical screening of alkaloids, flavonoids, terpenoids, steroids, tannins and saponins by using *Averrhoa carambola* and *Averrhoa bilimbi*.

Banana serves as a natural store of various health beneficial phytochemicals, they exist significant differences in the phytochemical composition, antioxidant properties among different varieties of banana. (Deepa et al., 2015)

Similar to fruits, there are various vegetables available with high antioxidant activity.

Warm temperate climate vegetables

In African yam bean (*Sphenostylisstenocarpa*) the seed has high antioxidant capacity and an appreciable amount of phenolic extracts.(Victor et al., 2012).In Tomato, one of the four varieties, which is locally known as round tomato or potato tomato, proved to be the most powerful in antioxidant activity (EC50 values≤1.63 mg/ml), phenolic compounds (phenolics 31.23 mg ClAE/g extract, flavonols 6.36 mg QE/g extract and anthocyanins 3.45 mg ME/g extract) and carotenoids (β-carotene 0.51 mg/100 g and lycopene 9.49 mg/100 g), while the so-called yellow tomato variety have shown interesting nutritional composition, including higher fructose (3.42 g/100 g), glucose (3.18 g/100 g), α-linolenic acid (15.53%) and total tocopherols (1.44 mg/100 g) levels. (Pinela et al., 2012)

The results of the present studies have revealed differences in the content of bioactive compounds and antioxidant activity among the grafted varieties of bell pepper. Fascinato/Robusto has shown the highest concentrations of lycopenes and total phenols as well as the greatest antioxidant activity of all/cultivar/rootstock combinations evaluated. Meanwhile, Sweet/Robusto has shown the highest content in vitamin C and Orangela Terrano in β-carotenes. (Celia et al., 2015)

Acerola is a fruit with a high content of phytochemicals with proven antioxidant activities according to the previous researches as well as Acerola fruit presents high in vitro antioxidant activity. (Blessy et al., 2012) Upon preliminary phytochemical screening, the aqueous extract of *Cucumissativus* fruit has found to contain glycosides, steroids, carbohydrates, saponins, and tannins. (Kumar et al., 2010) Watermelon has shown a very high scavenging activity for DPPH and hydrogen peroxide and the activities were comparable with the known standard antioxidant, BHT. (Adewale et al., 2015) Dietary fiber, total phenolics content, and total antioxidant capacity of sweet potato have significantly high. (Hua et al., 2015)

The present studies have demonstrated that all aqueous extracts of brinjal exhibit potent antioxidant activity and apparently, the antioxidant properties of all five types (purple with no lines (S1), light purple with lines (S2), dark purple with lines (S3), pink coloured (S4) and purple with green lines (S5)) of brinjal positively correlate with their polyphenolic content. (Somawathi et al., 2014)

Cold climate vegetables

In water spinach (*Ipomoea aquatic* Forsk) phytochemicals may have a significant effect on antioxidant and anticancer activities and the antioxidant activity was directly related to the total amount of phenolics and flavonoids found in the water spinach extracts. (Dong et al., 2005) Lamb's lettuce, compared to broccoli, contains simultaneously a large amount of total polyphenols as well as high antioxidant activity. (Parente et al., 2013)Beetroot is also a good source of antioxidant, according to the previous researches. (Mariya et al., 2016) As well as Cabbage also contain high antioxidant activity. But the total antioxidant capacity of the sauerkraut extract (0.031 mmolTrolox/g) has stronger than that of white

cabbage (0.025 mmolTrolox/g) according to the previous researches. (Ewa at al., 2005) Raddish also contain different classes of biologically active phytochemicals. (Maria et al., 2015)

Allium extracts have possessed variable but interesting antioxidant properties and those were significantly correlated to total phenolics content which was high in red, purple onions and garlic. (Noureddine et al, 2005)

Asparagus also contain high amount of antioxidant activity. (Ting et al., 2007)

Conclusion

Antioxidants are the essential source that we have to take with our fruits. Though some foods have more nutrients, Fruits and vegetables are the best source of antioxidants. The antioxidant activity can be depending on several factors such as maturity stage, climate, species...etc. Therefore, there is a high potential for the use of fruits and vegetables as a health promoting and disease preventing source.

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