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# Potentialities of antioxidants in fruit crops

■ **A. ASWINI, LILA MATHEW[1] AND K. AJITHKUMAR[1]**

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**Members of the Research Forum**

**Associated Authors:**
[1]Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara, THRISSUR (KERALA) INDIA
Email : lilamathew@yahoo.com; ajithkumar.k@kau.in

**Author for correspondence** :
**A. ASWINI**
Department of Pomology and Floriculture, College of Agriculture, Kerala Agricultural University, Vellayani, THIRUVANANTHAPURAM (KERALA) INDIA
Email : aswini.ajith@gmail.com

The doctrine 'Let food be thy medicine' espoused by Hippocrates nearly 2500 years ago is receiving interest by the researchers now a days. Recently, the focus has been shifted to the achievement of a balanced diet, and maximization of both life expectancy and quality, by identifying food ingredients that improve the capacity to resist disease and enhance health (Agte and Tarwadi, 2012).There has been a rapid increase in the oxidative stress and associated disorders such as prevalence of diabetes, cataract and cardiovascular diseases, due to the rapid changes in diet and lifestyle. The natural strategies such as increased intake of antioxidant rich food could be a valuable tool in coping up with the stress.Fruits form an integral part of our daily balanced diet ensuring abundant supply of antioxidants which prevents the risk of many chronic diseases (FAO, 2004). Important antioxidants in fruits include polyphenols, ascorbic acid, β carotene and vitamin E (Mitra *et al*., 2014). Antioxidants are the compound that are capable of quenching or stabilizing free radicals and plays an important role in the body defense system.

**Reactive oxygen species (ROS) :**

ROS represents a broad category of molecules that indicate the collection of radical and non radical oxygen derivatives.Non radicals have no unpaired electron and are generation from free radical species. There intermediates may participate in reactions that give rise to free radicals that damage organic substrate.In addition, there is another class of free radicals that are nitrogen derived called reactive nitrogen species (RNS). They are nitrogen derived molecules and are considered a subclass of ROS.

**Sources of ROS production :**

A number of sources of ROS were recognized in physiological and pathological conditions. Some of the widely accepted sources of ROS are classified in to exogenous and endogenous sources.Exogenous sources include; electromagnetic radiation, cosmic radiation, car exhaust, UV light, cigarette smoke, ozone and low wave length electromagnetic radiation.Endogenous sources include; electron leakage during metabolic processes, NADPH oxidase (leukocytes and macrophages),

xanthine / xanthine oxidase aracidonic acid pathway, auto oxidation of catecholes and flavonoids and chemicals, atmosphere and environment (bleomycins, paraquat, mineral dust and smog) (Kaur and Singh, 2011).

**Free radicals in human diseases :**

These free radicals have been implicated in the pathogenesis of many human diseases including neurodegenerative disorder like Alzheimer's disease, Parkinson's disease, multiple sclerosis, amyotrophic lateral sclerosis, memory loss and depression. cardiovascular disease, pulmonary disorders, diseases associated with premature infants, autoimmune disease, renal disorders, gastrointestinal diseases, tumors and cancer, eye diseases and ageing process (Sen *et al.*, 2009).

**Antioxidants :**

"Antioxidants" are substances that prevent harmful molecules (free radicals) from damaging the body's DNA and act as protective agents for the more complex and functional parts of a nutritional complex. It includes specific vitamins, minerals and enzymes that protect cells against damage from oxidation. The four antioxidants, many experts consider to be the most important ones are vitamin A (beta-carotene), vitamin C (ascorbic acid), vitamin E (tocopherol) and the polyphenols. One of the best sources of antioxidant is different fruits. Some components of fruits are strong antioxidants and function to modify the metabolic activation and detoxification / disposition of carcinogens or even influence process that alters the course of the tumour cell (Mitra *et al.*, 2014).

**Antioxidants defense and its importance in prevention of diseases :**

To encounter the harmful effect of ROS, antioxidant defense mechanism operates to detoxify or scavenge these ROS. A variety of antioxidant mechanism has been evolved to combat the potential threat of damage to vital biological structures from the aforementioned sources. An antioxidant can be considered as a molecule that, when present at low concentrations compared with those of an oxidizable substrate, significantly inhibits oxidation of that substrate. This antioxidant affect can be achieved in two different ways as;

*Preventative antioxidants :*

Preventive antioxidant proteins exist to sequester free transitional metal ions such iron and copper include the iron-binding protein transferring and copper-binding proteins cerruloplasmin and albumin. These antioxidants preventing their interaction with $H_2O_2$ and $O_2$, which would facilitate the production of the produce highly reactive hydroxyl radical(OH). Intracellular environment contains enzymes such as superoxide dismutase (SOD), catalase (CAT), glutathione reductase (GR), glutathione peroxidase (GPx), glutathione-S-transferase (GST) and low molecular weight antioxidant glutathione (GSH) that catalyze the breakdown of oxidants generated by cellular metabolism.

*Sacrificial antioxidant (Chain breaking) :*

They are powerful electron donors and react preferentially with free radicals before more important target molecules are damaged. In doing so, the antioxidant is sacrificed (oxidized) and must be regenerated or replaced (Kaur and Singh, 2011).

**Antioxidants in fruits :**

*Polyphenols :*

Polyphenols are the most abundant antioxidants in the diet. Their total dietary intake could be as high as 1 g/day, which is much higher than that of all other classes of phytochemicals and known dietary antioxidants. For perspective, this is 10 times higher than the intake of vitamin C and 100 times higher than the intakes of vitamin E and carotenoids (1, 2). Their main dietary sources are fruits and plant-derived beverages such as fruit juices. Current evidence strongly supports the contribution of polyphenols in the prevention of cardiovascular diseases, cancers, osteoporosis, neurodegenerative diseases and diabetes mellitus.

*Vitamin C :*

Vitamin C is biochemically known as ascorbic acid and it is a highly potent antioxidant. Even in very low concentrations it protects the indispensable molecules in the body such as proteins, lipids, carbohydrates and nucleic acid from the damages of reactive oxygen species. It has got the potent to regenerate other antioxidants like vitamin E. Barbados cherry (1400mg/100g), aonla (600-700mg/100g) and guava (300mg/100g) are the richest sources of vitamin C (Agte and Tarwadi, 2012). Current evidence strongly supports the contribution of ascorbic acid in Collagen formation, Inorganic iron absorption, Immune system enhancement

and Scurvy prevention

*carotene :*

β carotene found in fruits is the member of carotenoid family which has got a dual role in the body. It acts as the precursor of vitamin A and also as a powerful antioxidant. Mango (2200µg/100g) and Papaya (232.3µg/100g) are the richest sources of β carotene (Agte and Tarwadi, 2012). Current evidence strongly supports the contribution of β carotene in vision, reproduction and immune function.

*Vitamin E :*

Vitamin E is found in large quantities in our body. α and β tocopherols are the only forms that are recognized to meet human requirements. Olive *(Olea europaea)* is the fruit rich in vitamin E (1.65 mg/100g) (Agte and Tarwadi, 2012).

| **Tropical fruit crops** | | |
|---|---|---|
| Mango | *Mangiferaindica* | Anacardiaceae |
| Banana | *Musa* spp. | Musaceae |
| Papaya | *Carica papaya* | Caricaceae |
| Guava | *Psidium guajava* | Myrtaceae |
| Pineapple | *Ananas comosus* | Bromeliaceae |

**Mango :**

Mango (*Mangifera indica* L.) is one of the most important commercial crops worldwide in terms of production, marketing and consumption. It is important tropical fruits worldwide in terms of production and consumer acceptance (FAO, 2005).

| Antioxidants | Health benefits |
|---|---|
| Ascorbic acid | Anticarcinogenic, |
| Carotenoids | Antiatherogenic, |
| Phenolic compounds – Flavonol, Xanthone, | Antitumor, Antiviral, |
| Gallotannins and Benzophenone derivatives | Anti-inflammatory |
| Mangiferin | |

(Kumar *et al*., 2012)

Total phenolic content was different among the four varieties *viz*., Haden, Tommy Atkins, Palmer and Uba were studied and higher phenolic content was recorded in variety Uba mango pulp. The palmer cultivar showed an intermediary value and Haden and Tommy Atkins presented lower values. The analysed mango cultivars contain expressive total phenolic concentrations that may contribute to increase antioxidant intake in human diet, since the intake of polyphenolic compounds in the diet was estimated to range between 0.15 and 1.0 g/day. Varieties Tommy Atkins, Palmer and Haden showed no difference in β-carotene contents, but were significantly lower than varieties Uba. The total ascorbic acid content obtained for Haden, Tommy Atkins and Palmer mangoes was lower than those described for the variety Uba. In summary, the investigation of four mango varieties has demonstrated that the secondary metabolites content varies with the variety. Although the Uba variety has a commercial value limited to Brazil, it proved to be particularly promising as a source of bioactive antioxidants.

Seven varieties of mango fruits (Alphonso, Banginapalli, Raspuri, Neelam, Imampasand, Rumani, Totapuri and Sindhura) were obtained from the local mango fruit market of Tirupati (India) and were evaluated for the antioxidant activity by FRAP assay.The Banganapalli mango exhibited the highest antioxidant potential among the different mango varieties based on the FRAP assay. The reducing power obtained was in the range of 0.6 – 3 mM ascorbic acid equivalents in all the varieties. Alphonso and Rumani mangoes also exhibited the highest antioxidant potential followed by Neelam, Sindura, Imampasand, and Totapuri.

**Banana :**

*Musa* spp., comprising banana and plantain are among the world's leading fruit crops and in terms of economic value, it is the number five agricultural crop in world trade.

| Antioxidants | Health benefits |
|---|---|
| Vitamin C | Anti-inflammatory, Reduces |
| Vitamin E | Hypolipidemia, Hypoglycemia, Heart |
| β carotene | diseases and Ageing |
| Polyphenols, Flavonoids | |
| Gallocatechin, Dopamine | |

(Vijayakumar *et al.*, 2008)

The banana varieties Monthan, Karpooravalli, Nendran, Kadali, Poovan, Rasthali, Robusta and Redbanana were evaluated for the antioxidant activity. It is inferred that Rasthali extract showed higher phenol content compared to other varieties, which could be related to its antioxidant potential.Many flavonoids are found to be strong antioxidants capable of effectively scavenging the reactive oxygen species because of their phenolic hydroxyl groups. In this study, Poovan extract

exhibited higher flavonoid content which might be correlated with its anti-lipid peroxidation activity.Kadali showed higher activity in the range of 4.89 mM/g in comparison to other varieties of banana, whereas the extract of Nendran showed least activity.

| Papaya | |
|---|---|
| Antioxidants | Health benefits |
| Carotenoid | Atherosclerosis |
| Vitamins C | Reduce constipation |
| Flavonoids | Immune booster |
| | Anti-inflammatory |
| | Papain – dyspepsia |
| | Bacteriostatic properties |

(Khor and Wong, 2014)

Sunrise Solo had a higher total phenolic content than Red Lady which accounted for its antioxidant property. The free radical scavenging potential of different concentrations was tested by the DPPH method. All cultivars had scavenging effects against DPPH radicals, ranging from 52.1-63.4 ml/g DPPH. The hierarchy for free radical scavenging activity with respect to $IC_{50}$ values was Sunrise Solo > Red Lady. Sunrise Solo had an $IC_{50}$ value of 52.1 ml. of juice, while Red Lady had $IC_{50}$ values of 63.4ml of juice. The lower $IC_{50}$ values are associated with higher free radical scavenging activity.

## Guava :

The total phenolic content, ascorbic acid content, and antioxidant activity of seeded and seedless guava are compared. Both varieties of guava fruit contain relatively high quantity of antioxidants. Whereas antioxidant activity is found higher in seedless guava compared to seeded guava.

| Guava | |
|---|---|
| Antioxidants | Health benefits |
| Ascorbic acid | Reduces risk of Hypertensive, |
| β carotene | Hypercholesterolemia, Arthritis, |
| Vitamin B - Thiamine ($B_1$), | Arteriosclerosis, Cancer, Heart |
| Riboflavin ($B_2$), Niacin and | disease, Inflammation, Brain |
| Pantothenic acid | dysfunction |
| Carotenoids – Lutein, | |
| Zeaxanthine, Lycopene | |

(Yan *et al.*, 2006)

## Pineapple:

Antioxidant capacities and total phenolic contents of 62 fruits were evaluated. Of these while comparing the antioxidant capacity of tropical fruit crops guava is said to have highest antioxidant activity followed by pineapple. Whereas banana, papaya and mango is said to have similar antioxidant capacities.

| Pineapple | |
|---|---|
| Antioxidants | Health benefits |
| Vitamin C - 18.88 (mg/100 g ) | Anti-inflammatory, lowers risk |
| β-carotene - 3.35 (µg/100 g ) | of Cardiovascular disease and |
| Total phenolics - 26.2 (mg /100g ) | Cancer |
| FRAP - 118.18 ( µmol/100g FW) | |

(Kongsuwan *et al.*, 2009)

## Subtropical fruit crops :

The phenol content of the citrus fruits varies from 232.5 to 66.5 mg/g of the fruit. Sweet oranges are reported to have highest phenolic content followed by mandarins and lemon. Grape fruit and sour oranges are said to have moderate phenolic content, whereas Satsuma madarins has the least phenolic content. Evaluating the flavonoid content of citrus groups, Satsuma mandarins are said to have highest flavonoid content (6.4 mg/g), followed by sour orange and lemon. Sweet orange and Mandarins are having moderate flavonoid content. Grape fruit is said to have the least flavonoid content (0.3 mg/g). Madarins are reported to have the highest antioxidant activity with least $IC_{50}$ value 2.8 followed by sweet orange. Lemon and grape fruit is having moderate antioxidant activity. Satsuma mandarins and sour oranges are reported to have least antioxidant activity with the highest $IC_{50}$ value of 3.9.

| Subtropical fruit crops | | |
|---|---|---|
| Citrus | *Citrus* spp. | Rutaceae |
| Grapes | *Vitisvinifera* | Vitaceae |
| Mangosteen | *Garcinia mangostana* | Clusiaceae |
| Litchi | *Litchi chinensis* | Sapindaceae |
| Rambutan | *Nepheliuml appaceum* | Sapindaceae |

| Citrus | |
|---|---|
| Antioxidants | Health benefits |
| Ascorbic acid | Reduces risk of coronary |
| Flavonoids | heart disease, Anti- |
| Phenolic compounds – Flavanones, | carcinogenic and Anti- |
| Flavones, Flavonols | inflammatory |

(Turner and Burri, 2013)

Antioxidant capacities and total phenolic contents of 62 fruits were evaluated. Of these while comparing the antioxidant capacity of sub-tropical fruit crops citrus

| Grapes | |
|---|---|
| Antioxidants | Health benefits |
| Vitamin E<br>Polyphenols<br>Proanthocyanidins | Anti-inflammatory, anti-arthritic, anti-allergic effect and improvement in vision. Prevents constipation, kidney and liver diseases, Venous and capillary disorders, Heart diseases and skin ageing |

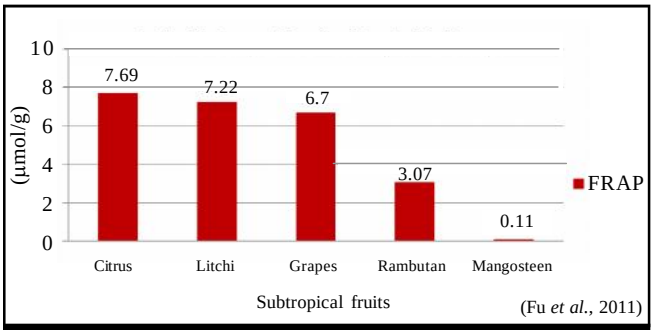
(Lange, 2007)

| Mango steen | |
|---|---|
| Antioxidants | Health benefits |
| Xanthones<br>Mangostanin<br>α-mangostin | Antibacterial, anti-inflammatory, anti-plasmodial, detoxify carcinogen, reduces, diarrhoea, inflammationand ulcers |

(Chin *et al.*, 2007)

| Litchi and Rambutan | |
|---|---|
| Litchi | Rambutan |
| Gallic acid<br>Chlorogenic acid<br>Epicatechin<br>Caffeic acid<br>Catechin<br>Rutin | Ellagic acid<br>Corilagin<br>Geranin |

(Zhang *et al.*, 2013)




(Fu *et al.*, 2011)

**Fig. 1 : Antioxidant capacities of subtropical fruits crops**

fruits are said to have highest antioxidant activity (7.69 µ mol/ g) followed by litchi, grapes and rambutan. Mangosteen is having the least antioxidant activity (0.11 µmol/ g) (Fig. 1).

Blackberry is reported to have the highest anthocyanin content (134.6 mg/g), followed by raspberry (49.1mg/g) and Red currant (35.1 mg/g). Strawberry is having the least anthocyanin content (0.2 mg/ g).Assessing the ascorbic acid content Red currant is having the highest ascorbic acid content (37.7 mg/g), followed by raspberry (32.4 mg/g) and blackberry (14.3 mg/g). Strawberry is having the least ascorbic acid content (0.59 mg/g).Blackberry is reported to have the highest phenolic content content (2349 mg/g), followed by raspberry (1280 mg/g) and Red currant (657 mg/g). Strawberry is having the least phenolic content (55 mg/ g).Blackberry is reported to have the highest antioxidant activity (146.6 µ mol/g), followed by raspberry (86.5 µ mol/g) and Red currant (63.3 µ mol/g). Strawberry is having the least antioxidant activity (11.7 µ mol/ g).Antioxidant activity in different temperate fruits ranged between 2.09 to 10.11 µ mol/ g. Blackberry is having the highest antioxidant activity followed by apple whereas peach is having the least antioxidant activity of 2.09 µ mol/ g.

**Table 1 : Temperate fruit crops**

| | | |
|---|---|---|
| Apple | *Malus domestica* | Rosaceae |
| Peach | *Prunus persica* | Rosacea |
| Blackberry | *Rubus fruticosus* | Rosaceae |
| Raspberry | *Rubus idaeus* | Rosaceae |
| Blueberry | *Vaccinium* spp. | Ericaceae |
| Strawberry | *Frageria x ananassa* | Rosaceae |

| Apple | |
|---|---|
| Antioxidant | Health benefits |
| Procyanidins<br>Catechin<br>Epicatechin<br>Chlorogenic acid<br>Phloridzin | Reduces<br>Asthma<br>Bronchial hypersensitivity<br>Lower risk for diabetes<br>Cardiovascular disease |

(Sesso *et al*., 2003)

| Peach | |
|---|---|
| Antioxidants | Health Benefits |
| Carotenoids<br>Anthocyanins<br>Phenolic compounds | Cancer prevention<br>Cardiovascular health |

(Casals *et al*., 2005)

| Berries | |
|---|---|
| Antioxidants | Health benefits |
| Proanthocyanidins<br>Ellagic acid<br>Chlorogenic acid<br>p-coumaric acid<br>Hyperoside<br>Quercetin-3-0-glucoside<br>Isoorientin<br>Isovitexin<br>Orientin<br>Vitexin | Reduces risk of cancer, heart disease and age-related loss of cognitive function |

(Dastmalchi *et al.*, 2011)

Assessing the antioxidant activity of arid and semi-arid fruit crops ranged from 58.8 µ mol/ g to 0.049 µ mol/ g. Aonla is reported to have the highest antioxidant activity followed by pomegranate. Sour sop and bael is having the similar antioxidant activity. Jamun and Barbados cherry is having moderate activity whereas star fruit and wood apple is having the lowest antioxidant activity. Of the mentioned arid and semi arid fruit crops Kokam is reported to have the least antioxidant activity of 0.049 µ mol/ g.

**Table 2 : Arid and semi-arid fruit crops**

| | | |
|---|---|---|
| Aonla | *Emblica officinalis* | Euphorbiaceae |
| Pomegranate | *Punica granatum* | Punicaceae |
| Jamun | *Syzygium cumini* | Myrtaceae |
| Barbados cherry | *Malpighia punicifolia* | Malpighiaceae |
| Sour sop | *Annona muricata* | Annonaceae |
| Starfruit | *Averrhoa carambola* | Oxalidaceae |
| Wood apple | *Feronia limonia* | Rutaceae |
| Longan | *Dimocarpus longan* | Sapindaceae |
| Kokam | *Garcinia indica* | Clusiaceae |
| Bael | *Aegle marmelos* | Rutaceae |
| Malabar tamarind | *Garcinia gummi-gutta* | Clusiaceae |

Antioxidant activity of underutilized fruit crops varied from 40 µ mol/ g to 1.24 µ mol/ g. Plum is having the highest antioxidant activity followed by custard apple, ber, phalsa, kiwifruit, durian, pear, sapota, passion fruit, avocado and jackfruit. Dragon fruit is having the least antioxidant activity comparing these fruit crops.

In meta-analysis (Table 4) it is found that there are discrepancies between the overall results of case-control and cohort studies regarding the effect of fruit on cancer risk. Prospective studies provide weaker evidence than case-control studies of the association of fruit consumption with reduced cancer risk. Case-control and cohort studies are in agreement with respect to the protective effect of fruit on the risk of lung and bladder cancers. The 2 types of studies also concur in not finding

**Table 3 : Antioxidants and health benefits of arid and semi-arid fruit crops**

| Crops | Antioxidants | Phenolic content (mg/100g) | Health benefits |
|---|---|---|---|
| Aonla | Vitamin C, Ellagic acid, Gallic acid, Tannins | 290 | Reduces risk of Cancer and Heart diseases, Anti-inflammatory, Anti-mutagenic (Madhuri *et al.*, 2011) |
| Pomegranate | Ellagic acid, Punicalagin | 270 | Reduces risk Cancer and Heart diseases (Rania *et al*., 2008) |
| Jamun | Vitamin C and Anthocyanin | 215 | Anti-Diabetes (Benherlal and Arumughan, 2007) |
| Barbados cherry | Vitamin C and Anthocyanin | 114.56 | Reduces risk of Cancer, Heart diseases, Anti-inflammatory Anti-mutagenic(Araujo *et al*., 2014) |
| Bael | Carotenoids, Phenolics, Alkaloids, Coumarins, Flavonoids, Terpenoids | 87.34 | Against Arthritis (Suvimol and Pranee,2008) |
| Longan | Corilagin, Gallic acid, Ellagic acid | 80.32 | Reduces risk Heart diseases, Anti-inflammatory, Anti-mutagenic (Rangkadilok *et al.*, 2007) |
| Kokam | Garcinol, Benzophenones, Isogarcinol, anthochymol, Isoxanthochymol, Hydroxy citric acid | - | Reduces risk Cancer, Cardiovascular diseases Neural disorders, Diabete (Naveen and Krishnakumar, 2013) |
| Malabar tamarind | Garcinol, XanthochymolGuttiferone Hydroxy citric acid | - | Heart diseases Anti-inflammatory Anti-mutagenic (Naveen and Krishnakumar, 2013) |
| Sour sop | VitaminC, VitaminB1, Vitamin B2 | 22.04 | Anti-inflammatory, Anti-diabetic and Anticancer (Souza *et al.*, 2012) |
| Starfruit | Flavonoids, Ascorbic acid | 8.95 | Reduces risk of Heart diseases Anti-inflammatory and Anti-mutagenic(Lim and Lee, 2013) |
| Wood apple | Phenolics, Flavonoids, Anthocynin | 7.55 | Hypoglycemic activity, Antitumor, Antimicrobial Hepatoprotective activity (Sonawane and Arya, 2013) |

**Table 4 : Epidemiologic evidence of the protective effect of fruits on cancer risk**

| Type of cancer | Fruit (100g/day) |
|---|---|
| Mouth and pharynx | ↓ |
| Larynx | ↓ |
| Oesophagus | ↓ |
| Breast | NS |
| Lung | ↓ |
| Bladder | ↓ |
| Stomach | ↓ |
| Rectum | ↓ |
| Significant protective effect | NS |
| | ( Non-Significant protective effect ) |

(Riboli and Norat, 2003)

a significant protection of fruit on breast cancer. The meta-analyses of case-control studies find a significant risk reduction associated with fruit for cancers of the lung, bladder, stomach, colorectum, mouth and pharynx, larynx, and esophagus, while only the protective effect of fruit on lung and bladder cancer comes out as statistically significant in the meta-analyses of cohort studies.

## Conclusion :

Free radicals have been implicated in the etiology of large number of major diseases. They can adversely alter many crucial biological molecules leading to loss of form and function. Such undesirable changes in the body can lead to diseased conditions. Antioxidants can protect against the damage induced by free radicals acting at various levels. Dietary and other components of plants form major sources of antioxidants. The relation between free radicals, antioxidants and functioning of various organs and organ systems is highly complex and the discovery of 'redoxsignalling' is a milestone in this crucial relationship. Recent research centreson various strategies to protect crucial tissues and organs against oxidative damage induced by free radicals. Many novel approaches are made and significant findings have come to light in the last few years. The traditional Indian diet, spices and medicinal plants are rich sources of natural antioxidants. Higher intake of foods with functional attributes including high level of antioxidants in functional foods is one strategy that is gaining importance in advanced countries and is making its appearance in our country. Co-ordinated research involving biomedical scientists, nutritionists and physicians can make significant difference to human health in the coming decades. Research on free radicals and antioxidants involving these is one such effort in the right direction.

Fruits are considered to be one of the best sources of nutritional values and health benefits. The rich natural source of essential vitamins, amino acids, minerals and dietary fibre and its established nutritional values and health benefits, reinforces the recommendation to increase the intake of fruits rather than any specific supplement. Nutrition and medical science continues to identify and study new phytochemicals in fruits for their benefits in human health protection. Tropical and subtropical fruits contain a broad range of phytochemicals, which are reported to protect against several chronic diseases *viz.*, cardiovascular diseases and cancer.

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