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Review of Antioxidants in Fresh and Processed Fruits and Vegetables: Their Benefits in Human Nutrition

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Abstract: There has been a growing interest in the beneficial health effects of edible fruits and vegetables. Fruit and vegetables are the major source of vitamins, minerals, fibers and antioxidants. Studies have shown that increased consumption of fresh fruits and vegetables is associated with a lower incidence of disease, particularly of various degenerative diseases such as cancer, neurological, cardiovascular and immune and brain dysfunction diseases.Their protective mechanisms are thought to be attributed to the presence of natural antioxidants as flavonoids, ployphenols, tocopherols, carotenoids, anthocyanins, isothiocyanates and allyl sulfides which help to scavenge free radicals and reactive oxidants in the body. The purpose of this article is to review the antioxidants found in different fruits and vegetables and their benefits in human nutrition.

Key words: Antioxidants · Flavonoids · Phenolic Compounds · Phytochemials · Polyphenols

INTRODUCTION

Nutrition is an organic process of nourishing or being nourished; the process that allows organisms to assimilate the food and use it for growth, work and maintenance. The substance that provides nourishment or nutrition is called as nutrient. There are six main classes of nutrients, which the body needs namely; proteins, carbohydrates, fats, vitamins, minerals and water.

Food which comes directly or indirectly from plants provides energy and nourishment. The food enriched with the protecting factors which is called 'protective food' will certainly be a better choice over medicine [1]. Fruits and vegetables enjoy the status of protective foods and this fact is established by the recent findings on linkage between the pattern of diet and some diseases, in which fruits and vegetables have received more attention on their benefits in human diet than any other food group.

Fruits and vegetables make up a major portion of the diets of humans in many parts of the world and play a significant role in human nutrition, especially as sources of phytonutraceuticals as vitamins C, A, B, E, minerals and dietary fiber [2].

Antioxidants are present in all plant organs and include ascorbic acid, carotenoids, vitamin E and phenolic compounds, among others [3, 4, 5]. Interest in the role of antioxidants (bioactive compounds) in human health has prompted research in the fields of horticulture and food science to assess fruit and vegetable antioxidants [6, 7]. Bioactive compounds are extra nutritional constituents that typically occur in small quantities in foods as indicated in Table 1. They are being intensively studied to evaluate their effects on health. The majority of the antioxidant capacity of a fruit or vegetable may be from compounds such as flavonoids, flavones, anthocyanins, catechins and isocatechins rather than from vitamins C, E or β-carotene [8, 9]. Many of these phytochemicals may help to protect cells against the oxidative damage caused by free radicals [10]. Fruit and vegetable antioxidants play an important role in reducing the risk of degenerative diseases, such as cardiovascular, various cancers and neurological diseases [6, 11].

Antioxidants: Antioxidants are naturally occurring or synthetic substances in food that prevent or delay oxidative damage of lipids, proteins and nucleic acids caused by reactive oxygen species (ROS) as well as free radicals [12-14]. The most well-known antioxidant constituents of fruits and vegetables, which may play the roles of prevention and protection, are vitamins C and E, carotenoids, minerals and phenolic compounds [5].

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Table 1: Various bioactive food components sources and biological functions

S/ No	Bioactive compounds	Fruits/vegetables	Functions
1	Glucosinolates, isothiocynates	Broccoloi, cabbage, cauliflower, Brussels sprouts	Induction of detoxifying enzyme system, antimicrobial, immunomodular, anticancer
2	Diallyl sulfides	Garlic, onion	Antimicobial, immunomodular, anticancer
3	Tocopherols	Avocado, vegetable oil	Antioxidant, immunomodular
4	Isoflavonoids and polyphenols	Grapes, fresh fruits and Vegetables	Antioxidants, lipid lowering, immunomodular, anticancer
5	Lutein	Green and yellow leafy Vegetables	Reducing age related macular degeneration
6	Carotenoids	Carrot, green leafy vegetables, orange, papaya, sweet potato, squash	Antioxidant, immunomodulators
7	Lycopene	Tomatoes	Antiproliferate, anticancer

Source: [7]

Radicals are chemical species with one or more unpaired electrons and free radicals which have moved out (highly unstable) of the immediate molecular environment of their generation [7, 15]. They reside primarily in the mitochondria of cells. When free radicals are released from the mitochondria in numbers sufficient to devastate the protective biochemical systems of the body, they become a threat to some cellular structures such as lipids, proteins, carbohydrates and nucleic acids in cell membranes.

Free radicals and oxidants can trigger lipid peroxidation, as well as the oxidation of proteins and Deoxyribonucleic acid (DNA), causing extensive damage to body cells. Compromised cellular structure alters cellular function and may lead to the initiation of the disease process. In severe oxidative stress, cell death may occur. Antioxidants react with the free radicals before they are able to react with other molecules, thus providing protection from oxidation reactions. Free radicals are formed during the body's normal metabolic processes and environmental phenomena such as ultra violet light, cigarette smoke, pollution, alcohol, stress and automobile exhaust [15, 16].

There are several endogenous sources of oxidants in the body: reduction of molecular oxygen in mitochondria during cellular respiration takes place in sequential steps, yielding the radical by-products super oxide anion (O_2^-), hydroxyl radical (OH) and hydrogen peroxide (H_2O_2); degradation of fatty acids and other molecules [8].

Epidemiological studies and intervention trials on prevention of cancer and cardiovascular disease in people taking antioxidant supplements are suggestive that dietary intake of antioxidants can help scavenge free radicals and oxidants by inhibiting or quenching free radicals and ROS and protect the body against oxidative damage [7, 15, 17]. Many fresh fruits and vegetables have been found to contain natural antioxidants, mainly phenolic compounds (ferulic acid and catechins), vitamin C, vitamin E and β-carotene and intake of these nutrients has an inverse relationship with degenerative disease risk [9, 11]. Phenolic compounds are secondary metabolites, which have been associated with flavour and colour. Fruits and vegetables are gaining considerable attention because of their potent antioxidant and health promoting properties.

Vitamin C is one of the most popular and least toxic antioxidant components of foods and has been most widely used as a dietary supplement to prevent oxidative stress mediated diseases [18]. However, the contribution of vitamin C to the antioxidant activity of fruits and vegetables is generally about 10% [12]. Antioxidant capacity of fruit and vegetables is dependent not only on vitamin C content but also on phenolic compounds.

Polyphenols are the most numerous and widely distributed group of bioactive molecules [7]. They are a diverse group of plant substances that contain one or more benzene rings and varying number of hydroxyl (OH), carbonyl (CO) and carboxylic acid (COOH) groups. These commonly exist with one or more attached sugar residues (conjugated). The most common class of polyphenols is flavonoids and carotenoids [19].

As antioxidants, polyphenols, carotenoids, tocopherols and allyl sulfides quench free radicals and ROS. The primary actions of antioxidants include the regulation of the redox potential within a cell and reduction of potential initiators of carcinogenesis [19]. The redox potential refers to the balance of the reducing and oxidizing reactions that occur within the cell. A primary mechanism for immune-modulation is the multiple antioxidant capability of ployphenols, tocopherols, carotenoids, isothiocyanates and allyl sulfides. Together these compounds are able to reduce the deleterious effects of ROSand free radicals, which cause premature death of immune cells.

Phytochemicals: There are approximately 5000 known plant phenolics and model studies have demonstrated that many of them have antioxidant activity [20].

Phytochemicals such as flavonoids and other phenolics may contribute to the protective effects. Many of these phenolic phytochemicals have antioxidant capacity and may protect cells against the oxidative damage caused by free radicals [15]. Oxidative stress can cause oxidative damage to large biomolecules such as proteins, DNA and lipids, resulting in an increased risk of cancer and cardiovascular disease. Their main functions are acting as deterrents of potential predators or antimicrobials, protecting against UV-radiation and contributing to the pigmentation of fruits and flowers. Phenolic compounds canalso contribute to the astringency and bitter taste of some products [21]. Mohammed [17] studied the role of natural antioxidants mainly phenolic compounds, which may have more antioxidant activity than vitamins C, E, β-carotene and lycopene.

According toStewart *et al.* [22] flavonoids and their derivatives (flavanols, flavonols, isoflavones, flavan-3-ols and anthocyanins) are the largest and most important group of plant phenolics and have shown various biological effects including inhibition of low-density lipoprotein oxidation and increased antimicrobial and anticarcinogenic capacities. They are known to possess remarkably high antioxidant activity. A recent review of current literature suggests that fruits and vegetables in combination have synergistic effects on antioxidant activities leading to greater reduction in risk of chronic diseases [12, 23].

Therefore, antioxidants, which can neutralize free radicals, may be of central importance in the prevention of carcinogenicity, cardiovascular and neurodegenerative changes associated with aging. To prevent or slow the oxidative damage induced by free radicals, therefore, sufficient amounts of phenols as antioxidants need to be consumed in foods.

Antioxidants in Fresh and Processed Fruits: Fruits are good source of antioxidants, including carotenoids, ascorbic acid, tocopherols, flavonoids and phenolic acids such as hydroxycinnamates [7, 9, 24]. More recently, the antioxidant functions of flavonoids and other phenolic compounds have received increased attention. Phenolics are generally reactive acidic substances that rapidly form hydrogen bonds with other molecules [25]. Phenolic compounds rarely occur in a free state within the cell; rather they are commonly conjugated with other molecules. Their compositions in fruits vary depending on the species investigated, harvest time, fruit maturity stage, geographical origin, methods employed, etc. Generally, antioxidants in fruits and their products reported in many studies vary widely and are partly due to the use of different oxidation systems and methods to analyze antioxidant compounds [24].

Antioxidants composition (anthocyanins, flavanols, flavonols, hydroxycinnamates, carotenoids, vitamin C and vitamin E) of selected commonly consumed fruits is presented in Table 2. Large amount of anthocyanins (up to 4840 mg/kg) are found in the strongly coloured fruits. The amount of falvanols is generally low with large amount found in blueberry, red wine grapes and peaches and fresh strawberry. Apart from a few exceptions such as blueberry, strawberry and red grapes, fruits are generally also low in flavonols and high in phenolic acid such as hydroxycinnamates. The vitamin C content of fresh fruits is generally high while that of provitaminA (carotenoids) and vitamin E is low. Processing of fruits in to juices and jams resulted in lower amounts of antioxidant compounds (Table 3). For example losses of anthocyanins in juices and in canned fruits. Peeling and juicing result in substantial losses of antioxidant, provitamin A (carotenoids), often surpassing those associated with heat treatment.

Antioxidants in Fresh and Processed Vegetables: Vegetable contains a unique combination of phytonutraceuticals (vitamins, minerals, dietary fiber and phytochemicals) and a great diversity of vegetables should be eaten to ensure that diet includes a combination of phytonutraceuticals to get all the health benefits [19]. The antioxidant present in commonly consumed vegetables include ascorbic acid, tocopherols, carotenoids and phenolic compounds such as flavonols and phenolic acids (Table 4). In comparison to fruits, vegetables generally contain much lower amounts of antioxidants compounds. A large amount of vitamin C is found in sweet red pepper (1850 mg/kg) and significant amounts in Brussels sprouts (up to 900 mg/kg) and broccoli (750-830 mg/kg) while the amount of vitamin E is generally below 10 mg/kg, except tomato ketchup (23mg/kg) and sweet pepper (22 mg/kg).

Carotenoids contribute to antioxidant activity, with beta-carotene (1-644 mg/kg) and lutein (up to 203 mg/kg in spinach) present in all vegetables and lycopene dominating in tomatoes (0.2 -623 mg/kg) and tomato products (Table 4). As a result of processing involving heat treatment carotenoids undergo which may decrease their antioxidants activity. On the other hand thermal processing is reported to increase carotenoids concentration, perhaps owing to greater extractability, enzymatic degradation, losses of moisture and soluble solids.

Table 2: Bioactive compounds in selected fruits (mg/kg fresh weight)

Fruit	Anthocyanins	Flava nols	Flavo Nols	Hydroxyci nnamates	β-Carotenoids	Vitamin C	Vitamin E
Apple (juice)	4-5	0-15	17-70	263-308	0.4	40	2
Blueberry (fresh)	3970-4840	63-70	115-139	226-315	------	------	----
Grape							
Table red	72.5-765	1-160	13-25	5-19	0.3	50	7
Wine red	0.6-385	0-500	10-55	4-13	trace	0	0
Table white	0	0	10-13.5	5.5	0.3	50	7
Wine white	0	0-106	------	1-34	trace	0	0
Orange (juice)	-----	-----	0-5	136-163	0-5	510	4
Peach(fresh)	0-17.8	24.5-700	0-11.9	54-148	0.9	80	10
Peach(canned)	0	trace	Trace	11-29	1.0	20	20
Strawberry							
(fresh)	202-790	9-184	7-174	14-69	0.1	420-600	6
Strawberry (Jam)	4-22	------	11.4	------	0.04	80-236	1.0

Source: [24]

Table 3: Bioactive compounds in different fruits juices

Juice	Vitamin C (mg/ 100gm)	Vitamin B9 (Folic acid) (µg/100 gm)	Vitamin E (mg/ 100 gm)	Carotenoids β-carotene (µg/100g)
Orange	23 – 50	30		
Grapefruit	29 – 38	10.2	0.2	4-6
Grape	trace	3	trace	15
Pineapple	9-11	10	0.03	10-20
Mango	13	NA*	0.3	87

Source: [16]; *NA, Data not available

Table 4: Bioactive compounds in selected vegetables and their products (mg/kg fresh weight)

Vegetable	Flavonols (quercetin)	Hydroxyci nnamates	Carotenoids (β-carotene)	Vitamine C	Vitamine E
Broccoli (fresh)	15-65	62-148	4-27	750-830	7
-boiled	------	------	------	640	7
Brussels sprouts (fresh)	0-6	-----	4.3	900	4
Carrots (fresh)	------	-----	11-70	60	4
-boiled	------	------	101	42	4
Onions (fresh)	340-420	------	0.1	75	0.4
-fried	220-370	------	0.2	57	8
Potato (fresh)	------	140	0.1	100	1
-boiled	------	------	------	100	1
Spinach (fresh)	trace	------	8-240	600	12
Tomato (fresh)	2-14	------	0.2-623*	140	7
-juice	13	-----	------	140	7
-ketchup	------	------	99*	80	23
Sweet pepper (fresh)	------	------	1.2-33	1850	22

Table 5: Antioxidant activity, total phenolics and flavonoids content of selected fruits and vegetables.

S/No	Fruit/ vegetable	Antioxidant Activity (%)	Total Phenolics (mg/kg fresh weight)	Flavonoids (mg /kg)**
1	*Apple	14.7-40.2	541-1333	308-823
2	*Grapes	16.6 -37.6	548-2025	452-1069
3	*Quince	51-68	2823-4306	1198-2115
4	*Pear	11.5-16.7	326-473	321-381
5	Pomegranate	62.7	2408	459
6	Potato	14.2	553	153
7	Onion	12.5	536	170
8	Red radish	29.4	1056	179
9	Red cabbage	40.8	2166	842
	Antioxidants			
	BHA (50 mg/l)	92.4		
	BHT (50 mg/l)	90.7		
	α-Tocopherol (50 mg/l)	90.9		

Source: [27]

* For different varieties, ** results are expressed as mg of (+) catechin per kg of fresh material

Flavonols levels in processes vegetables are lower than in fresh products due to the fact that boiling or cooking reduced the contents of flavonols. All vegetables contain phenolic acids such as hydroxycinnamates where either caffeic acid, ferulic acid, sinapic acid or coumaric acid has been conjugated with quinic acid and/or esterified with sugars [26]. Phenolic compounds such as flavonols and hydroxycinnamic acids in the cruciferous vegetables may be responsible for the antioxidant activity rather than the main bioactive compounds in crucifers, namely glucosinolates. Among commercial juices tested, tomato juice has a higher oxygen radical absorbance capacity than orange juice and apple juice [8].

Antioxidant Activity in Fruits and Vegetables: Study on the antioxidant activity of selected fruits and vegetables grown in Turkey [27] showed that fruits and vegetables exhibited varying degrees of antioxidant capacity (Table 5). The average antioxidant activities of pomegranate, quince, grape, apple and pear have been found to be 62.7%, 59.5%, 27.6%, 27 % and 14.0%, respectively. For comparative purposes, 50 mg/l of BHA (butylated hydroxyl anisole), BHT (butylated hydroxyl toluene) and α-tocopherol were also used and the antioxidant activities were determined as 92.4, 90.7 and 90.9, respectively.

They further indicated that the different antioxidant activities of the fruits can be ascribed to their total phenolic concentrations. Quince (up to 4306 mg/kg) had much higher total phenolics than any of the other fruits studied, approximately 9, 3 and 3 times higher than those of pear, apple and grape. Antioxidant activity and total phenolics in fruits showed a high correlation, implying that the phenolic compounds were major contributors to the observed antioxidant activity. On the other hand, pomegranate (2408 mg/kg) contained a lower level of total phenolics than did quince, but its antioxidant activity was higher. Since pomegranate is known to be a good source of anthocyanins [28], it can be suggested that these compounds accounted for its antioxidant activity. Anthocyanins, a glycosilated form of anthocyanidins, are a group of flavonoids mostly responsible for the color of fruits from red through purple to blue.The main anthocyanins reported as being present in pomegranate are cyanidin glycosides [28] and the most abundant anthocyanins in fruits [20]. Because of their O-dihydroxy structure, cyanidin glycosides have a high antioxidant capacity. Therefore, the higher antioxidant activity of pomegranate can be attributed to its cyanidin glycosides content.

Among the vegetables, red radish had the highest antioxidant activity (29.4%), followed by potato (14.2%) and onion (12.5%). Red cabbage possessed the highest antioxidant activity, as well as the highest total phenolic concentration.Karadenuz *et al.* [27], concluded that total phenolics are the major contributor to the antioxidant activity of fruits and vegetables. The flavonoid content of fruits correlated closely with their antioxidant activity.

Effect of Processing on Antioxidants: Processing involves changes in structural integrity of the plant material and this produces can be beneficial or detrimental effect to the total content of health-promoting phytochemicals. When the benefit and detriment effects counterbalance each other, no change in the antioxidant activity occurs [7, 24]. The antioxidant activity is diminished owing to inactivation of antioxidant compounds caused by oxidation, by polyphenoloxidase enzymes and others or leaching into the cooking water. Both negative changes have a greater impact on the water-soluble antioxidants (vitamin C, flavonoids and phenolic acids) than on the lipid-soluble antioxidants (carotenoids and tocopherols).

Fruit juice' extracted from Ecballium elaterium L. have potential activity as source of natural antioxidant [29]. Research on the antioxidant and antibacterial effects of polyphenols and flavonoids content of *Ecballium elaterium* 'Fruit juice' showed to possess strong anti-oxidant activity. The antioxidant activity of *E. elaterium*" fruit juice" ranged from 37% at 100µl to 89% at 500 µl and each 100 µl of fruit juice equivalent to 30 µg/ml of vitamin C. The anti-bacterial activity of Ecballium elaterium 'fruit juice' may be due to its free radical-scavenging and antioxidant activity, resulting from the presence of some phenolic compounds in the fruit juice of plant [29].

Enset (Ensete ventricosum [Welw]) plant native to Ethiopia, it is often called false banana. The plant nutritional values and its major food processed products are Kocho, Amicho and Bulla along with medicinal values encompasses antimicrobial, antinematodal diseases of humans, expel of placenta and healing bone fracture [30].

The effect of processing on the level and bioavailability of antioxidants depends on the treatment intensity, as well as on the component considered [31]. In some cases, processing could lead to higher availability of antioxidants, due to an increase in the ease of extractability. For instance, with carrot and spinach carotenoids vapor cooking increases assimilation,

probably due to a disruption of carotenoid-protein complexes. Similarly, the bioavailability of lycopene increases in heat-treated tomato [21].

The positive effects of processing include transformation of antioxidants into more active compounds, such as the deglycosylation of onion, as well as an increase in the antioxidant activity owing to inhibition of enzymes [7, 24]. In addition, an increases surface area, such as cutting and chopping and heat treatments that breaks down the protein and carbohydrates matrix that bind carotenoids and tocopherols. Peeling and juicing results in substantial losses of carotenoids, anthocyanins, hydroxycinnamates and flavanols as the fruit skins and vegetable peels are very rich in these antioxidant compounds.

CONCLUSIONS

The role of fruits and vegetables and their nutritional importance in human health are briefly presented in this review. All fruits and vegetables may offer protection to humans against chronic diseases. They contain various phytochemicals with different bioactivities, such as antioxidants with possible health effect. Antioxidants have been used as protection of autoxidation and important protective agents for human health. They protect key cell components from damage by neutralizing the free radicals.The physiological role of some of these antioxidants, flavonoids, phenolics, tocopherolsand ascorbic acid and their composition in commonly consumed fruits and vegetables is well established. Thus, the general advice to increase fruit and vegetable consumption in both fresh and processed foods remain valid.

REFERENCES

1. Goyal, R.K., 2000. Nutritive value of fruits, vegetables and their products. In:Verma, L.R. and Joshi, V.K. (ed), Postharvest technology of fruits and vegetables.Vol. I. Indus Publishing Company, pp: 337-389.
2. Craig, W. and L. Beck, 1999. Phytochemicals: Health protective effects, Canadian J. Dietetic Practice and Res., 60(2): 78-84.
3. Larson, R.A., 1988. The antioxidants of higher plants. Phytochemistry, 27: 969-972.
4. Sezeto, Y.T., B. Tomlinson and I.F. Benzier, 2002. Total antioxidant and ascorbic acid content of fresh fruits and vegetables: implication for dietary planning and food preservation. Br. J. Nutr., 87: 55-59.
5. Rupasinghe, V.H. and P. Clegg, 2007. Total antioxidant capacity, total phenolic content, mineral elements and histamine concentrations in wine of different fruit sources. J. Food Comp. Anal., 20: 133-137.
6. Kalt, W., C.F. Forney, A. Martin and R.L. Prior, 1999. Antioxidant capacity, vitamin C, phenolics and anthocyanins after fresh storage of small fruits. J. Agric. Food Chem., 47: 4638-4644.
7. Paul, M., 2007. Effects of food processing on bioactive compounds.Gene-Tech- Books, New Delhi, pp: 260.
8. Wang, H., G. Gao and R.L. Prior, 1996. Total antioxidant capacity of fruits. J. Agric. Food Chem., 44: 701-705. http://www.TanTze.
9. Ellong, E.N., C. Billard, S. Adenet and K. Rochefort, 2015. Polyphenols, carotenoids, vitamin C content in tropical fruits and vegetables and impact of processing methods. Food and Nutr. Sci., 6: 299-313.
10. Wada, L. and B. Ou, 2002. Antioxidant activity and phenolic content of Oregon cranberries. J. Agric. Food Chem., 50: 3495-3500.
11. Dillard, C.J. and J.B. German, 2000. Phytochemicals: nutraceuticals and human health. J. The Sci. Food Agric., 80: 1744-1756.
12. Oviasogie, P.O., D. Okoro and C.L. Ndiokwere, 2009. Determination of total phenolic amount of some edible fruits and vegetables. African J. Biotec., 8: 2819-2820.
13. Bayili, R.G., Fatoumata Abdoul-Latif, O.H. Kone, Mamounata Diao, I.H. Bassole and M.H. Dicko, 2011. Phenolic compounds and antioxidant activities in some fruits and vegetables from Burkina Faso. African J. Biot., 10(62): 13543-13547. Available online at http://www.academicjournals.org/AJB DOI: 10.5897/AJB10. Academic Journals.
14. Akbarirad, H., A. Gohari Ardabili, S.M. Kazemeini and A. Mousavi Khaneghah, 2016. An overview on some of important sources of natural antioxidants. International Food Res. J., 23(3): 928-933.
15. Chun, K.O., D.O. Kim, N. Smith, D. Schroeder, J.T. Han and C.Y. Lee, 2005. Daily consumption of phenolics and total antioxidant capacity from fruit and vegetables in the American diet, J. Sci. Food Agric., 85: 1715-1724.

16. Lecerf, J.M., 2006. Antioxidants in juices and processed fruits and vegetables, Functional claims of article 13, Department of nutrition, Pasteur Institute, Lille, France, http://www.aijn.info/.
17. Mohammed, A.A., 2002. Antioxidant activity of commonly consumed vegetables in Yemen, J. Nutr., 8: 179-189.
18. Gardner, P.T., T. White, P.D. Duthie and G. Duthie, 2002. The relative contributions of vitamin C, carotenoids and phenolics to the antioxidant potential of fruit juices. Food Chem., 68: 471-474.
19. Dias, J.S., 2012. Nutritional quality and health benefits of vegetables: a review. Food and Nutr. Sci., 3: 1354-1374 http://dx.doi.org/10.4236/fns.2012. 310179. (http://www.SciRP.org/journal/fns).
20. Robards, K., P.D. Prenzler, G. Tucker, P. Swatsitang and W. Glover, 1999. Phenolic compounds and their role in oxidative processes in fruits. Food Chem., 66: 401-436.
21. Vicente, A.R., G.A. Manganaris, G.O. Sozzi and C.H. Crisosto, 2009. Nutritional Quality of Fruits and Vegetables. Postharvest Handling: A Systems Approach. Second edition Elsevier Inc. Academic Press.
22. Stewart, A.J., S. Bozonnet, W. Mullen, G.I. Jenkins, M.E. Lean and A.Crozier, 2000. Occurrence of flavonols in tomatoes and tomato based products. J. Agric. Food Chem., 48: 2663-2669.
23. Yu, B., 1994. Cellular defences against damage from reactive oxygen species. Physiol. Rev., 76: 139-162.
24. Heinonen, I.M. and A.S. Meyer, 2002. Antioxidants in fruits, berries and vegetables. In Wim Jongen (ed), Fruit and vegetable processing: Improving quality. CRC press, Boca Raton, Florida, USA, pp: 23-51.
25. Kays, S.J., 1991. Postharvest physiology of perishable plant products, Van Nostrand Reinhold, New York, USA, pp: 532.
26. Clifford, M.N., 2000. Chlorogenic acids and other cinnamates-nature, occurrence, dietary burdon, absorption and metabolism, J. Sci. Food Agric., 80: 1033-1075.
27. Karadenuz, F., H.S. Burdurlu, N. Koca and Y. Soyer, 2005. Antioxidant activity of selected fruits and vegetables grown in Turkey, J. Agric., 29: 297-303.
28. Du, C.T., P.L. Wang and F.J. Francis, 1975. Anthocyanins of pomegranate (*Punica granatum L*). J. Food Sci., 40: 417-418.
29. Saleh, M.M., H.A. Saleh, S.M., Osma, A.A. Marei, A.N. Muftah, H.A. Idress, O.A. Ilham and F.E. Maraia, 2013. Antibacterial screening and antioxidant and free radical scavenging activity of *Ecballium elaterium.* African J. Basic & Appl. Sci., 5(6): 276-283. DOI: 10.5829/idosi.ajbas.1150.
30. Azene Tesfaye and Abebe Girma, 2017. Phytochemistry, pharmacology and nutraceutical potential of Enset (*Ensete ventricosum).* African J. Basic & Appl. Sci., 9(3): 112-117. DOI: 10.5829/idosi.ajbas.
31. Bernhardt, S. and E. Schlich, 2006. Impact of different cooking methods on food quality: Retention of lipophilic vitamins in fresh and frozen vegetables. J. Food Eng., 77: 327-333.