COMPARATIVE ANALYSES ON ANTIOXIDATIVE PROPERTIES OF LOCALLY FOUND LEAFY AND ROOT VEGETABLES - A REVIEW

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Abstract: Dietary plant antioxidants have been considered beneficial to human health. Antioxidants can eliminate free radicals and prevent many health related disease. Vegetables are rich in phytochemicals. This review paper highlights the pharmacological properties of Ipomoea sp., Colocasia sp., Beta sp., Daucus sp., B. oleracea var. capitata, B. oleracea var. italic, S. oleracea and their medicinal values. This vegetables are beneficial in the prevention of chronic diseases through its antioxidant, anti-inflammatory, antimicrobial activities. The phytochemicals such as flavonoids, terpenoids, cyanidin, peonidin, carotenoids, polyphenols, β-cryptoxanthin, lycopene, and zeaxanthin etc. are present in high amount in these vegetables. These vegetables are economically affordable. This paper reviews on the scientific approach and pharmacological activity of these vegetables.

Keywords: Anti-carcinogenic, Anti-inflammatory, Anti-diabetic, Anti-microbial properties, Phytochemicals, Colocasia sp.

INTRODUCTION
Free radicals are reactive oxygen molecules produced by the oxidation reduction process. Free radicals damage the cell and formed various diseases such as tumors, diabetes, cardiovascular disease, joint inflammation etc. [1]. Antioxidant means, “Against oxidation.” Antioxidant is a substance that prevents oxidation and helps to remove free radicals and protect the body against toxic effect of free radicals [2]. Antioxidants are two groups. These are enzymatic antioxidants and non-enzymatic antioxidants.

Suloxide dismutase, catalase, glutathione peroxidase are enzymatic antioxidants and vitamin C (ascorbic acid), vitamin E (tocopherol), carotenoids, flavonoids are non-enzymatic antioxidants [3,4].

Vegetables are the good source of antioxidants. Green leafy vegetables and yellow orange vegetables are rich in carotenoids and flavonoids.

Mullar investigated that 22 species of vegetables like spinach, broccoli, carrot were very rich in carotenoids (over 10mg/100gm edible portion) [5].

Red beet root (Beta vulgaris rubra) leaves and roots are rich in phenolic compounds. Red beet root contains betalains which is nitrogen containing water soluble pigments derived from betalamic acid. Red beet roots are used for a long time for their beneficial health effects, mainly protection of kidney, liver, gut and immune systems from toxic compounds [6].

Red Cabbage (Brassica oleracea var. capitata f. rubra) and purple sweet potato (Ipomoea batatas(L.) Lam) Contain red or purple colour due to the presence of anthocyanins pigment. Anthocyanins possess antioxidant, anti-inflammatory, antimicrobial and anti-carcinogenesis properties.

Different colour of the vegetables depends on the different PH of the soil. Reddish leaves cabbage grow in acidic soil, purple or red leaves grow in neutral soil and greenish yellow coloured leaves grow in alkaline soil [7, 8]. Colocasia (Colocasia esculenta) contain high amount of phytochemicals that are used as the base of modern drugs that cure various diseases. Colocasia have many medicinal importance due to presence of chemical components like alkaloids, glycosides, resins, volatile oils, gums, tannins etc. Colocasia esculenta is rich in easily digestible carbohydrates, micronutrients and vitamins (A, B complex, C) and contain antinutrient factors such as oxalate, phytate etc. [9].

AIMS AND OBJECTIVES
- The aim of this review is to find out the various antioxidative properties of vegetables like cabbage, spinach, broccoli, carrot, sweet potato, colocasia, beet-root etc.
- To gain knowledge about medicinal importance of these vegetables.
- To express the health benefits of these vegetables.

FINDINGS OF THIS STUDY
Sweet potato, colocasia, beet-root, carrot, cabbage, broccoli, spinach vegetables are represent an important part of the human diet worldwide are consumed by people all over the world. These vegetables contain phytochemicals and rich source of antioxidants. The bioactive compounds of these vegetables help to prevent many diseases. Summary of the phytochemical properties and medicinal importance of these vegetables are described through the following tables.
<table>
<thead>
<tr>
<th>Vegetables name</th>
<th>Scientific name</th>
<th>Nomenclature</th>
<th>Phytochemical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet potato</td>
<td><em>Ipomoea batatas</em> (L.) Lam</td>
<td>Kingdom: Plantae, Division: Magnoliophyta, Class: Magnoliopsida, Order: Solanales, Family: Convolvulaceae, Genus: <em>Ipomoea</em>, Species: <em>I. batatas</em></td>
<td>The major phytochemicals that are present in sweet potato are flavonoids, terpenoids, tannins, saponins, glycosides, alkaloids, steroids and phenolic acids.[10] Some phytochemicals are responsible for the colour variation of sweet potato such as orange varieties are rich in Beta carotene and anthocyanins are responsible for the red, purple and blue pigments. Peonidin and cyanidin are example of anthocyanin present in purple sweet potato.[11] Phenolic acids such as chlorogenic, isochlorogenic, caffeic, cinnamic acid hydroxycinammic are present in sweet potato.[12] High performance liquid 19 individual phenolic compounds such as 3, 5-di-o-cafeoylequnic acid, astragalin and cyanidin were the predominant phenolic acid.[13] A 100g tuber provides 14187 IU of vitamin A and 8509µg of β-carotene.[11] Anthocyaniniperlargonid 3-glucoside, cyaniding 3-glucoside, cyaniding 3-rhamnoside, alkaloids, ascorbic acid, saponins, terpenes, anthraquinones Flavonids.[12] A study reported that pour colocasia based cropping system find out that the high concentration of phenolics 0.966+0.009mg gallic acid equivalent/100mg fresh weight and anthocyanin 4.29+0.04mg/100mg fresh weight.[13] Hydroxycinnamic acid derivatives (Caffeoylghecaric acid, D-Glucaric acid, glucosylsinapic acid, caffeic acid, p-coumaric acid, dihydro caffeoylquinic acid). Flavonoids (c-glycosylflavone, o-glycosyl-c-glycosylflavone, luteolin, apigenin, orientin, isoorientin).[14, 15] Beetroot rich in glycine, betaine, saponins, polyphenols and flavonoids.[16] Betalain is a nitrogen pigment, which contributes antioxidant property of red beetroot.[17] Betalains are two types, these are betacyanins and Betaxanthins. The range of betacyanins in reddish purple pigment beetroot is 0.44 to 0.60g/kg and the range of betaxanthins in yellow pigment beetroot is 0.32 to 0.42g/kg.[18] Triterpenes, sesquiterpenoids, coumarins, flavonoids(tiliroside,</td>
</tr>
<tr>
<td>Vegetable</td>
<td>Scientific Name</td>
<td>Kingdom: Plantae</td>
<td>Division: Magnoliophyta</td>
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<tr>
<td>-----------</td>
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</tr>
</tbody>
</table>
| Carrot    | Daucus Carota          |                  |                         |                     |                |                 |              | astragaline, rhamnocitrin, rhamnetin, kaempferol |[19]  
|           |                        |                  |                         |                     |                |                 |              | Carrots are rich sources of carotene, phenolic compounds such as flavonoids, tannins, lignans, stilbenoids, curcuminoins |[20]  
|           |                        |                  |                         |                     |                |                 |              | Two types of carotenoids present in carrot, carotene and xanthophylls. The major carotenoids in carrot roots are β-carotene(75%), α-carotene(23%), lutein(1.9%) and β-cryptoxanthin, lycopene, and zeaxanthin. |[21]  
|           |                        |                  |                         |                     |                |                 |              | Carrot contain terpenoids and p-cymene, limonene, β-myrcene, sabine, terpinolene, γ-terpinene, β-caryophylene, β-bisabolene, γ-bisabolene, α-humulene, and α-pinene that provide aroma to the root. |[22]  
| Cabbage   | Brassica oleracea var. capitata |                  |                         |                     |                |                 |              | Cyanidin 3-sophoroside-5-glucoside, cyanidin 3-sophoroside-5-glucoside acylated, sinapic acid, ferulic acid, p-coumaric, malonic acid, glucoraphanin, sinigrin, glucoiberin. |[23, 24]  
|           |                        |                  |                         |                     |                |                 |              | Main phytochemical components of cabbage are alkaloids, glycosides, steroids, flavonoids (flavonols, anthocyanins). Flavonols are quercetin and kaempferol. |[25, 26]  
|           |                        |                  |                         |                     |                |                 |              | The phytochemicals of broccoli are glucosinolates (glucoraphanin, glucobrassicin, neoglucobrassin), tocopherols and carotenoids (lutein, zeaxanthin, β-carotene), dithiolthiones, s-methyl cysteine sulfoxide, isothiocyanates and indole-3-carbinol. |[27, 28]  
|           |                        |                  |                         |                     |                |                 |              | The flavonols of broccoli are quercetin-3-O-sophorotrioside-7-O-glucoside, quercetin-3-O-sophorotrioside-7-O-glucoside, kaempferol-3-O-sophorotrioside-7-O-glucoside, 3-p-coumaroylquinic acid, sinapic acid, kaempferol 3-O-sophoroside. |[29, 30]  
| Broccoli  | Brassica oleracea var. italica |                  |                         |                     |                |                 |              | The extracts of spinach oleracea contain phenolic compounds (ortho-coumaric acid, para-coumaric acid, ferulic acid), various flavonoids isolated from this plan are apigenin, glucuronide, flavone, jaceidin, kaempferol, myricetin, quercetin, patuletin, methoxyflavone, spinacetin and carotenoids are lutein, β-carotene, violaxanthin , neoxanthin, tannins, saponins, anthraquinines. |[31, 32]  
| Spinach   | Spinacia oleracea      |                  |                         |                     |                |                 |              | The phytochemicals of broccoli are glucosinolates (glucoraphanin, glucobrassicin, neoglucobrassin), tocopherols and carotenoids (lutein, zeaxanthin, β-carotene), dithiolthiones, s-methyl cysteine sulfoxide, isothiocyanates and indole-3-carbinol. |[27, 28]  
| Spinach   | Spinacia oleracea      |                  |                         |                     |                |                 |              | The extracts of spinach oleracea contain phenolic compounds (ortho-coumaric acid, para-coumaric acid, ferulic acid), various flavonoids isolated from this plan are apigenin, glucuronide, flavone, jaceidin, kaempferol, myricetin, quercetin, patuletin, methoxyflavone, spinacetin and carotenoids are lutein, β-carotene, violaxanthin , neoxanthin, tannins, saponins, anthraquinines. |[31, 32]  

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**Carrot** — Daucus Carota  
**Kingdom:** Plantae  
**Division:** Magnoliophyta  
**Class:** Magnoliopsida  
**Order:** Apiales  
**Family:** Apiaceae  
**Genus:** Daucus  
**Species:** D. carota  

Carrots are rich sources of carotene, phenolic compounds such as flavonoids, tannins, lignans, stilbenoids, curcuminoins. Two types of carotenoids present in carrot, carotene and xanthophylls. The major carotenoids in carrot roots are β-carotene(75%), α-carotene(23%), lutein(1.9%) and β-cryptoxanthin, lycopene, and zeaxanthin. Carrot contain terpenoids and p-cymene, limonene, β-myrcene, sabine, terpinolene, γ-terpinene, β-caryophylene, β-bisabolene, γ-bisabolene, α-humulene, and α-pinene that provide aroma to the root.

**Cabbage** — Brassica oleracea var. capitata  
**Kingdom:** Plantae  
**Division:** Magnoliophyta  
**Class:** Magnoliopsida  
**Order:** Brassicales  
**Family:** Brassicaceae  
**Genus:** Brassica  
**Species:** B. oleracea  

Cyanidin 3-sophoroside-5-glucoside, cyanidin 3-sophoroside-5-glucoside acylated, sinapic acid, ferulic acid, p-coumaric, malonic acid, glucoraphanin, sinigrin, glucoiberin. Main phytochemical components of cabbage are alkaloids, glycosides, steroids, flavonoids (flavonols, anthocyanins). Flavonols are quercetin and kaempferol.

**Broccoli** — Brassica oleracea var. italica  
**Kingdom:** Plantae  
**Division:** Magnoliophyta  
**Class:** Magnoliopsida  
**Order:** Brassicales  
**Family:** Brassicaceae  
**Genus:** Brassica  
**Species:** B. oleracea  

The phytochemicals of broccoli are glucosinolates (glucoraphanin, glucobrassicin, neoglucobrassin), tocopherols and carotenoids (lutein, zeaxanthin, β-carotene), dithiolthiones, s-methyl cysteine sulfoxide, isothiocyanates and indole-3-carbinol.

**Spinach** — Spinacia oleracea  
**Kingdom:** Plantae  
**Division:** Magnoliophyta  
**Class:** Magnoliopsida  
**Order:** Caryophyllales  
**Family:** Amaranthaceae  
**Genus:** Spinacia  
**Species:** S. oleracea  

The extracts of spinach oleracea contain phenolic compounds (ortho-coumaric acid, para-coumaric acid, ferulic acid), various flavonoids isolated from this plan are apigenin, glucuronide, flavone, jaceidin, kaempferol, myricetin, quercetin, patuletin, methoxyflavone, spinacetin and carotenoids are lutein, β-carotene, violaxanthin, neoxanthin, tannins, saponins, anthraquinines.
### Table 2. Health benefits of the vegetables

<table>
<thead>
<tr>
<th>Biological properties</th>
<th>Species name</th>
<th>Findings</th>
<th>Reference no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioxidant activity</td>
<td><em>Ipomoea batatas</em> (L.) Lam</td>
<td>Recent research has shown the skin of sweet potato contain different concentration of anthocyanin which have antioxidant properties. Total phenolic content has been found in highest amount in the stem end of the roots of the sweet potato. The total antioxidant strength of raw sweet potato measured the oxygen radical absorbance capacity is 902µmol Trolox Equivalent/100g. One study shows that the antioxidant activity of purple fleshed sweet potato is higher than the white fleshed sweet potato.</td>
<td>[33]</td>
</tr>
<tr>
<td></td>
<td><em>Colocasia esculenta</em> (L.)</td>
<td>C. esculenta contain high amount of phenolic acid which have antioxidant properties. Many phytochemicals found in this root vegetables to reduce oxidative stress. The H-ORAC (Hydroxyl Radical Antioxidant Capacity), ABTS (2,2'-Azino-bis[3-ethylbenzoline-6-sulfonic acid] diammonium salt), FRAP(ferric reducing antioxidant power) and DPPH (2,2'-diphenyl-1-picrylhydrazyl radical assay) methods are used to evaluate the TAC of colocasia extracts.</td>
<td>[10]</td>
</tr>
<tr>
<td></td>
<td><em>Beta vulgaris</em></td>
<td>Red Beet is a good source of natural antioxidant. Beetroot contain high amount of Betalain that have free radicals scavenging activity. <em>B. vulgaris</em> contain phenolics compound such as rutin, epicatechin and caffeic acid which are also known as excellent antioxidants. The presence of high concentration of antioxidants carotenoids mainly β-carotene have antioxidants properties which can remove the free radicals. Total phenolics in peel is 78.3mg GAE/100g determined by the Folin-ciocalteu assay.</td>
<td>[35]</td>
</tr>
<tr>
<td></td>
<td><em>Daucus carota</em></td>
<td>The total antioxidant capacity of cabbage extracts is 0.025 mmol Trolox /g determined by the Trolox equivalent antioxidant activity assay. Anthocyanins which are present in highly amount in red cabbage to diminish platelet activation by antioxidative activity.</td>
<td>[39]</td>
</tr>
<tr>
<td></td>
<td><em>Brassica oleracea var.</em></td>
<td>Antioxidant activity determined by FRAP (Ferric Reducing Antioxidant Power) from broccoli extracts is 2.06 to 3.56 µ mol Trolox/g.</td>
<td>[41]</td>
</tr>
<tr>
<td><strong>Brassica oleracea var. italic</strong>a</td>
<td>Broccoli sprouts rich in phytochemicals such as flavonoids, phenolic acid which have antioxidant properties.</td>
<td>[42]</td>
<td></td>
</tr>
<tr>
<td>Spinacia oleracea</td>
<td>Spinach oleracea plan leaves extract contain phytochemicals mainly tannin flavonoid, tereponoid with highly antioxidant properties.</td>
<td>[43]</td>
<td></td>
</tr>
<tr>
<td><strong>Spinacia oleracea</strong></td>
<td></td>
<td>[44]</td>
<td></td>
</tr>
<tr>
<td><strong>Anti-cancer</strong></td>
<td><em>Ipomoea batatas</em> (L.) Lam</td>
<td>Different parts of sweet potato extracts inhibits cell proliferation and induces apoptosis in prostate cancer cells. A recent study reported that purple fleshed sweet potato extract have inhibitory effect on the growth of MCF-7 (breast cancer) and SNU-1 (gastric cancer) cancer cell.</td>
<td>[45] [46]</td>
</tr>
<tr>
<td></td>
<td>Colocasia esculenta (L.)</td>
<td>Root and tuber phytochemicals have demonstrated anticancer effects in several types of carcinoma cell lines.</td>
<td>[13]</td>
</tr>
<tr>
<td></td>
<td>Daucus carota</td>
<td>A studies shown that the consumption of carrots can reduce the risk of lung cancer, breast cancer and colon cancer because carrots are rich in poly-acetylene antioxidant, falcarkinol, which destroy cancer cell in the tumors.</td>
<td>[47]</td>
</tr>
<tr>
<td></td>
<td><em>Brassica oleracea var. capitata</em></td>
<td>Broccoli sprouts are a rich source of isothiocyanates that are known as cancer chemopreventive agents by suppressing tumor growth.</td>
<td>[48]</td>
</tr>
<tr>
<td></td>
<td><em>Brassica oleracea var. italic</em>a</td>
<td>Spinach extract contain various carotenoids and lipophilic active compounds such as neoxanthin, lutein, zeaxanthin and chlorophylls which have anti-cancer effects against ovarian, lung, breast, colon cancer. Glycoglycerolipids which are present in spinach to inhibit cancer cell growth.</td>
<td>[49] [50]</td>
</tr>
<tr>
<td><strong>Anti-diabetic</strong></td>
<td><em>Ipomoea batatas</em> (L.) Lam</td>
<td>A human studies shown different forms of sweet potato have maintaining blood sugar levels and lowering insulin resistance. “Caiapo” is a dietary supplement and a crude extract of white skinned sweet potato which has been consumed for a long time in Japan as a remedy for diabetes. Methanol extract of <em>C.esculenta</em> leaves have anti-diabetic activity and decrease the blood glucose level.</td>
<td>[8,51] [52]</td>
</tr>
<tr>
<td></td>
<td>Colocasia esculenta (L.)</td>
<td>According to a study, 10% Beetroot contained 9808.0mg GAE/100ml ofpolyphenols and 8334.0mg QE/100ml of flavonoids. Administration of beetroot juice for six weeks led to significantly</td>
<td>[19]</td>
</tr>
</tbody>
</table>
Brassica oleracea var. capitata

Reduced blood glucose levels from 76.1mg/dl to 49.8mg/dl.

Red cabbage have protective effect on destruction of pancreatic β cell and inhibit the formation of glycated hemoglobin. [26]

Brassica oleracea var. italica

Broccoli sprouts are known to improve insulin resistance in type-2 diabetic patients. Broccoli contain sulforaphane which is supplementary treatment in type-2 diabetes. [53]

Anti-inflammatory activity

Ipomoea batatas (L.)Lam

Purple sweet potato extract inhibit the inflammatory brain diseases by suppressing lipopolysacharide (LPS) induce inflammatory responses. [54, 55]

Spinacia oleracea

Ethanolic and aqueous extracts of spinach leaves express a dose level of 1100mg/kg have shown anti-inflammatory activity compare to standard drug, Indomethacin,(20mg/kg) in rat. [56]

Brassica oleracea var. capitata

The methanolic extract of red cabbage shown anti-inflammatory activity by reducing formaldehyde induced paw oedema in rats [57]

Anti-microbial activity

Ipomoea batatas (L.)Lam

Adsul et al reported that acetone and ethanol extract of sweet potato leaves and root showed antimicrobial activity against Salmonella typhimurium and Pseudomonas aeruginosa. [58]

Daucus carota

The essential oil obtained from aerial parts of the carrot showed inhibitory action against the enteropathogen Campylobacter jejuni. Phenylpropanoids such as methylisoeugenol and elemicin essential oil have antimicrobial effect against Campylobacter. [59, 60]

Spinacia oleracea

Spinach extract can be used as a natural antibiotic and preservative in food industries and pharmaceuticals. [33, 62]

DISCUSSION

Colorful vegetables can offer a range of antioxidants. Antioxidants can protect against the cell damage that free radicals cause, known as oxidative stress. Activities and processes that can lead to oxidative stress include the followings:

- mitochondrial activity
- excessive exercise
- tissue trauma, due to inflammation and injury
- ischemia and reperfusion damage
- consumption of certain foods, especially refined and processed foods, trans fats, artificial sweeteners, and certain dyes and additives
• smoking
• environmental pollution
• radiation
• exposure to chemicals, such as pesticides and drugs, including chemotherapy
• industrial solvent

Such activities and exposures can result in cell damage. This, in turn, may lead to
• an excessive release of free iron or copper ions
• an activation of phagocytes, a type of white blood cell with a role in fighting infection
• an increase in enzymes that generate free radicals
• a disruption of electron transport chains

The damage caused by oxidative stress has been linked to cancer, atherosclerosis, and vision loss. It is thought that the free radicals cause changes in the cells that lead to these and possibly other conditions. An intake of antioxidants is believed to reduce these risks. According to one study Trusted Source, “Antioxidants act as radical scavenger, hydrogen donor, electron donor, peroxide decomposer, singlet oxygen quencher, enzyme inhibitor, synergist, and metal-chelating agents. However, there is a lack of evidence that a higher intake of specific antioxidants can reduce the risk of disease. In most cases, results have tended to show no benefit, or a detrimental effect, or they have been conflicting. There are thought to be hundreds and possibly thousands of substances that can act as antioxidants. Each has its own role and can interact with others to help the body work effectively. “Antioxidant” is not really the name of a substance, but rather it describes what a range of substances can do.

Flavonoids, flavones, catechins, polyphenols, and phytoestrogens are all types of antioxidants and phytonutrients, and they are all found in plant-based foods. Each antioxidant serves a different function and is not interchangeable with another. The best sources of antioxidants are plant-based foods, especially fruits and vegetables. Foods that are particularly high in antioxidants are often referred to as a “superfood” or “functional food. D. carota contain Phenylpropanoids such as methylisoeugenol and elemicin essential oil have antimicrobial effect against Campylobacter. I. batatas leaves and root showed antimicrobial activity against Salmonella typhimurium and Pseudomonas aeruginosa. S. oleracea is rich source of antioxidant, antimicrobial properties due to the presence of quercetin, myricetin, kaempferol and polyphenols, paracoumaric, ferulic acid have anti bacterial activity. I batatas contain high concentration of anthocyanin and B. vulgaris contain high amount of betalain phenolics compound (rutin, epicatechin and caffeic acid) which have antioxidant properties. S. oleracea neoantherin, lutein, zeaxanthin and chlorophyll which have anti-cancer effects against ovarian, lung, breast, colon cancer.

CONCLUSION

This review paper highlights all the benefits of these root and leafy vegetables (I. batatas, C. esculenta, B. vulgaris, D. carota, B. oleracea var. capitata, B. oleracea var. italica, S. oleracea) and their phytochemical properties. These vegetables are locally available or eco-friendly and have high nutritive and medicinal values. The phytochemical properties of these vegetables help to prevent health related disease like diabetes, cancer, other degenerative disease. These vegetables are selected for this review work because these are rich in antioxidant and flavonoids; glycosides, phenolic acids etc. and these are economically affordable.

ACKNOWLEDGEMENT

We acknowledge our college authority to carry on this review work without any interruption in this pandemic condition.

REFERENCES


