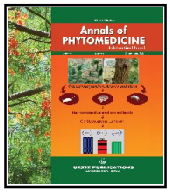
Annals of Phytomedicine 11(1): 1-6, 2022

DOI: http://dx.doi.org/10.54085/ap.2022.11.1.1

Annals of Phytomedicine: An International Journal

http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885



Invited Commentary : Open Access

Vegetables as nutraceuticals and future plant drugs

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Article Info

Article history : Received 21 April 2022, Revised 11 June 2022, Accepted 12 June 2022, Published Online 30 June 2022

Abstract

In view of consumer's preference for plant based medicinal food, vegetables are paid much attention. Vegetables have potential to meet the nutritional requirements fixed by WHO in the form of minerals, vitamins, antioxidants, nutrients, and phytosterols including dietary fiber for human health. Vegetables due to the innate possession of bioactive medicinal compounds like polyphenols, lycopene, indoles, glucosinolates, carotenoids, anthocyanins, and phytoestrogens are finding a great place in the plate of the consumer. These bioactive compounds present in vegetables offer various benefits like prevention of cancer and cardiovascular disease. Various vegetable crops such as onion and garlic (allicin, allyl propyl disulfide and dially disulfide), brinjal (chlorogenic acid and nasunin), tomato, watermelon and carrot (lycopene), beans (flavonoids), crucifers (sulforaphane) and cucurbits (cucurbitacin), moringa (glucasinolates and isothiocyanates) are rich with medicinal properties and are used as folk medicine by several countries at present and are considered as future plant drugs.

1. Introduction

WHO/FAO recommends consumption of 400 g of edible fruit and vegetables per day to prevent and alleviate micronutrient deficiencies (WHO, 2013). Several countries are facing the threat of under consumption of vegetables leading to energy imbalance and difficulty in maintaining a healthy human body weight.

In 1989, DeFelice coined the term 'nutraceutical' from the words, nutrition and pharmaceutical. Nutraceutical is 'a food that provides medical or health benefits by preventing or treating a disease. In view of low calories, bioactive compounds like phytochemicals, vitamins and minerals offer the medicinal values and hence, the fruits and vegetables are regarded as nutraceutical or protective foods. Carotenoids, phenolic compounds, phytosterols, phytostanols, tocotrienols, organo-sulfur compounds (allium compounds and glucosinolates), non-digestible carbohydrates (dietary fiber) and prebiotics are the phytochemicals present in vegetables. Phytochemicals act as antioxidants, enzyme stimulators and antibacterial compounds, *etc*. Cabbage, cauliflower, *Allium* sp., tomato, carrot, cucurbits, basella, bhendi, lettuce, moringa, winged bean, sweet potato and yams, *etc*., are the rich sources of bioactive compounds (Poobalan *et al*., 2019).

2. Coloured vegetables for richness of nutraceuticals

All the coloured vegetables such as green, orange and yellow are rich sources of calcium, beta-carotene, iron, magnesium, vitamin B-complex, potassium, vitamin A, vitamin C, and vitamin K including insoluble dietary fibers such as cellulose, mucilage, hemicellulose, gums, pectin, *etc.* (Crisosto, 2003). In the recent past, cultivated area under these coloured vegetables is increased and accordingly, consumption volume of respective vegetables has taken up a big leap.

Vegetables are primarily consumed in the form of fruits, roots, tubers, shoots and flowers and are regarded as sources of bioactive compounds. These include carotenoids, anthocyanins, capsinoids, glucosinolates, isoflavones, lipoic acids, nasunin, charantia, betalins, beta-carotene, carbohydrates, phenolics, and fatty acids (Vanlalneici *et al*., 2019; Poobalan *et al*., 2019). These are used to treat several ailments such as cancer, hypertension, malaria, diabetes, helminthes, liver problems, indigestion, inflammation and haemorrhoids (Behera *et al*., 2007; Astadi *et al*., 2009; Tanaka *et al*., 2017). Some of the bioacive compounds are described below in brief.

2.1 Charantia

Bitter gourd tops the cucurbits with higher nutritive value. The charantia present in bitter gourd activates the inactive insulin present in the human blood and also acts as antiulcer, antitumor, antileukemic, anti-inflammatory, antimicrobial and antidiabetic (Behera *et al*., 2007).

2.2 Capsaicinoids

Capsaicinoids are produced exclusively in the placenta of chilli fruits. Capsaicinoids (capsaicin and dihyrocapsaicin) acts against rheumatoid arthritis, neuralgias, osteoarthritis, and diabetic neuropathy (Tanaka *et al*., 2017).

2.3 Carotenoids

Carotenoids are fat-soluble plant pigments. They imparts the color to tomatoes and carrots. The widely investigated carotenoids are lycopenes, β-carotene, zeaxanthin and lutein (Krinsky *et al*., 2005).

2.4 Isoflavones

Isoflavones belongs to the phenols subgroup. Broad beans are very rich in isoflavones and also found in beans and other legumes as well. These isoflavones effectively blocks tumor promoting enzymes .

2.5 Glucosinolates (GSL)

Glucosinolates are sulfur and nitrogen-containing secondary metabolites (Woodward *et al*., 2005) and are found in the crops of Brassicaceae family. When vegetables containing them are broken,

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glucosinolates convert to isothiocynates (contain sulfur) and indoles (contain no sulfur) and are involved in blocking enzymes, thereby arrests tumourous growth in various human beings (Baskar *et al*., 2012).

2.6 Anthocyanins

Anthocyanins are water-soluble pigments. Anthocyanins display antioxidative, radical-scavenging activity (Astadi *et al*., 2009), anti-diabetic and act as chemoprotective agents.

2.7 Nasunins

These are the first isolated anthocyanins from brinjal, which inhibits the hydroxyl radical generation (Nisha *et al*., 2009). These are present in the skin of brinjal, purple radish, red varieties of turnip, and cabbage. Nasunins have the high antioxidant activity.

2.8 Betalins

Betalins are the phytochemicals present in beet. The betalin is naturally absorbed by the body. It has antiviral, antiradial scavenging activity and antimicrobial activity (Strack *et al*., 2003).

2.9 Lipoic acid

Spinach and broccoli have the highest concentrations of alpha-lipoic acid in the chloroplasts and also present in peas and brussels sprout (Drake *et al*., 2012).

3. Nutraceutical richness of under-exploited vegetables

Tuber crop, *Dioscorea bulbifera* L. is used in the treatment of diarrhoea, *D. esculenta* (Lour.) Burkill for treating ulcers, kidney stones; Taro for appendicitis and Yam (*Dioscorea dumetorum* (Kunth) Pax to relieve cancer, inflammation, diabetes, heart disease, gonorrhea, dysentery and haemorrhages. All the above tuber crops through roots and tubers provide carbohydrates, crude fibre, minerals, phenolics crude fat and protein (Salehi *et al*., 2019).

The vegetable legume crops were used as dual-purpose plants to provide nutritional elements and medicinal use. Among the legumes such as grass pea and broad bean are used in the treatment of cardiovascular diseases, cancer, and diabetes in addition to being sources of nutritional compounds (Fasoyiro *et al*., 2006). Cannabis (roselle) with its phytomedicines like manganese, copper, molybdenum and ascorbic acid for curing inflammation, fruits of *Solanum torvum* with fats, minerals, proteins, carbohydrates, crude fibre and vitamin C for curbing bacterial diseases while, *Solanum torvum* fruits with vitamins A and C, carbohydrates and phenolics for curing diabetes and cassava to clean wounds are used as sole shrubs (Nyadanu and Lowor, 2015).

Among the cucurbits, bottle gourd and pumpkin fruits provide not only nutritional compounds but also medicinal values. Their seeds and fruits provide fibre, vitamins, carbohydrates and minerals and are useful to treat cancer, helminthes, liver diseases and bowel movements. Bitter gourd is good for diabetic persons to reduce glucose level (Agata and Beata, 2020). Okra (*Abelmoschus esculentus* (L.) Moench originated from Asia is rich in phyto medicines.

4. Vegetable crops with their phytonutrients

Some vegetable crops with their phytonutrients are dealt in detail as below and in Table 1.

4.1 *Allium cepa* (Onion)

Phytomedicines such as sulfides of onion gives protection against tumor growth of stomach and colon cancer, while anti-inflammatory properties are due to their vitamin C and quercetin. Fructo-oligosaccharide acts as stimulants of healthy bacteria and suppresses the potentially harmful bacteria in the colon (Chiej, 2004). As per the reports of Sampath Kumar *et al*. (2010), GPCS-gamma-L-glutamyl-trans-S-1-propenyl-Lcysteine sulfoxide inhibits the osteoclasts.

4.2 *Allium sativum* (L.): Garlic

Allicin has antibacterial and antifungal activity. Quercetin, diallylsulphide and allin blocks cancer causing agents such as nitrosamine and aflatoxins (Sampath Kumar *et al*., 2010).

4.3 *Brassica oleracea* var. *capitata* (L.): Cabbage and *Brassica oleracea* var. *italica* (L.): Sprouting broccoli

Glucosinolates, isothiocyanates and sulforaphane are blocking enzymes for tumorous growth in liver, gastrointestinal and lungs, whereas sulforaphane of broccoli is anti-inflammatory, antimicrobial and indole-3-carbinol of broccoli and cabbage are anticancerous (Baskar *et al*., 2012).

4.4 Legumes

Fibre of peas is used for gastrointestinal function and health, while cluster bean with low serum cholesterol levels and is used in antidiabetic treatment and prevention of cancerous and cardiovascular diseases. Velvet bean with L-dopa to treat Parkinson's disease, whereas, winged bean protein (>30%) acts as antimicrobial agent in traditional medicines. The phytoestrogens of legumes in general has potential as antioxidants to scavenge free radicals and lowers blood cholesterol, whereas saponins are useful as anticarcinogenic agents, as per the reported investigation results of Siddhuraju (2006).

4.5 *Amaranthus tricolour* (L.): Amaranthus

The root of amaranthus is used in the treatment of menorrhagia; while whole plant derived products are useful for treating stones in the urinary tract. Juicy drink of raw green leaves useful in treating teeth decay.

4.6 *Moringa oliefera* (Lam.): Moringa

Different plant parts of Moringa containing polypehols and *in vitro* antioxidant and the methanol extract of the leaves of *M. oliefera* contained organic acid, rutin, quercetin, glucoside and kaempferol and rhamno glucoside, whereas in the root and stem barks, several procyanidins were detected. Moringa contains more than 90 nutrients and 46 types of antioxidants and is very effective to overcome various physiological disorders The high antioxidant/ radical scavenging effects observed, may have impact on the cancer. Consumption of moringa leaves is claimed to cure about 300 ailments in human beings (Atawodi *et al*., 2010).

The drumstick leaf extracts (ethanol or hot water extracts) could kill 70-86% of the abnormal cells among primary cells harvested from 10 patients with acute lymphoblastic lukemia (ALL) and 15 with acute myeloid leukemia (AML) and culture of lepatocarcinoma cells (75% death). This concludes that *M. oliefera* may have potential for use as source of natural treatment for cancer (Khalafalla *et al*., 2010).

4.7 *Momordica charantia* (L.): Bitter gourd

The phytochemicals such as charatin (sitosteryl glucoside and stigma steryl glucoside) is attributed with hypoglycemic activity could treat diabetes and jaundice. The glycoalkaloid, vicine present in the seeds is also of hypoglycemically active (Behera *et al*., 2007).

Table 1: Vegetable crops with their phytonutrients

Vegetable crop	Plant part used	Phytomedicine	In the treatment of	References
Tomato	Fruit	Lycopene, vitamin C, vitamin K, anthocyanin	Blood clotting, hypertension and urinary tract infections	Sesso *et al*., 2004
		Caffeic and chlorogenic acid, and flavonoids (Nasunin, Nasusin)	Skin protection, stomach and rectal cancers	Stahl *et al*., 2001
Brinjal	Fruit	Anthocyanins	Prevents from cardiovascular disfunction and protective effect on pancreatic cells	Kumar *et al*., 2017
		Chlorogenic acid	Potential antioxidant, antimutagenic, antimicrobial and anti-low-density lipoproteins	Guimaraes *et al*., 2000
		Carotenoids, lycopene, lutein, and β-carotene	Antioxidant and antimutagenic	Miean *et al*., 2001
Chilli	Fruit	Capsaicin	Antibacterial, anticarcinogenic, analgesic and antidiabetic properties	Zimmer *et al*., 2012
		Beta carotene, lutein, zeaxanthin, cryptoxanthin and vitamin C	Antioxidant and antimutagenic	
		Lycopene in red peppers	Prostate cancer as well as cancer of the bladder, cervix and pancreas	Howard *et al*., 2000
Potato	Tuber	Starch	Against colon cancer and enhances glucose tolerance	Chakraborty *et al*., 2010
		Patatin	Removes free radicals	
		Kukoamines	Blood pressure lowering compounds	
		Chlorogenic acid	Antiscorbutic, emollient, antidote, aperient, diuretic, galactagogue and antispasmodic stimulant	
Bottle gourd	Seed	Lagenin	Jaundice, diabetes, ulcer, piles and skin diseases heart problems, urinary problems and diabetes	Prajapathi *et al*., 2010
Pumpkin	Fruit	Cucurbitane and hexane cucurbitane; glycosides and other triterpenoids; Anti -ulcer type cucurbitane	Prostatic hyperplasia, increases appetite, cures leprosy and purifies the blood	Ge *et al*., 2006
Cucumber	Leaves and seed	Glycosides	Antiulcer properties	Dhimman *et a*l., 2012
Ash gourd	Seed	Hispin	Antifungal activity	Ng and Prakash, 2002
Chow-chow	Fruit	-	Antihypersensitive and antioxidant effects, used in treatment of inflation and circulatory system disorders	Dhimman *et al*., 2012

Based on the recent study, medicinal vegetables, around 24 vegetables from 12 families of cultivated or wild are useful in Ayurvedic treatment for curing of diseases. Various ailments such as urinary disorders, diabetes, dyspepsia, gastritis, constipation, rheumatism, and dysentery are mostly useful. The vegetables are also available in natural habitat, which are cheap and excellent source of nutrients (Anil *et al*., 2021). Roohafza is a famous refreshing formulation having global acceptance, which includes seeds of several medicinal plants including certain vegetables like *Spinacia oleracea*, *Daucus carota* and *Mentha arvensis*. The drink enhances the energy system of the body with potency of immune modulatory, antiviral, and antiallergic against respiratory ailments (Ahmad *et al*., 2021). Certain compounds of *Allium* spp., Brassicaceae, Umbelliferae and Compositae members require detailed information about pharmacologically valuable compounds in vegetables . They are reported to be with dietetic food and anti-carcinogenic substances, due to which they have equivalence with vegetable crops.

In 2021, 13 traditional vegetables of 10 families were with folk medicines having major contribution of Fabaceae and Solanaceae. *Hibiscus* spp. and *Corchorus* spp., along with *Asystasia gangetica* are used for musculoskeletal, gastrointestinal and malaria as well. Diseases treated were in the range of gastrointestinal to reproductive through musculoskeletal abnormalities (Rebecca *et al*., 2021). Coccinia stem, fruit, leaf, flower and root parts are used as medicine for curing many diseases like psoriasis, skin infection, body-heat, burning-eyes, dry skin, inability to pass urine, diabetes, diarrhoea, scabies, sores on the tongue, swelling, jaundice and leprosy (Vidhyalakshmi, 2020).

5. Improvement of nutraceutical vegetables

In view of the associated benefits of nutraceuticals vegetables, identification, improvement and exploitation should be facilitated. The inheritance of bioactive compounds present in vegetable crops are complex in nature and controlled by genetic and environmental factors. Traditional breeding and molecular biology are highly useful for developing nutraceutical vegetable varieties for fresh market. Golden tomatoes with 6-8 times rich in beta-carotene are developed by World Vegetable Centre. Beta-carotene rich cauliflowers are engineered with transfer of 'Or' genes. The transgenic potato enriched with carotenoids are developed by applications of genetic engineering (Li *et al*., 2012). Transgenic broccoli was produced for accumulation of sulphoraphane through introgression of two transgenes, QTL1 and QTL2 of *Brassica villosa* (Mithen *et al*., 2003). In future, molecular biology techniques will have vast application for identification and development of nutraceutical vegetable varieties.

6. Conclusion

Various phytonutrients with antioxidant property of vegetable crops make them referred to as future medicines. Ranging from elimination of free radicals *via* high antioxidant properties, blood pressure regulation through potassium, improved bowel transit, lowering of cholesterol levels, stabilizing blood glucose concentrations with dietary fibre are the applications of phyto medicines of vegetables; due to phytochemicals and minerals, fiber matrix is maintained in human gut. Thus, increasing vegetables in the diet may reduce the intake of saturated fats, trans fats, and foods with higher caloric density, all of which may be related to a healthier overall diet. Because each vegetable contains a unique combination of phyto-nutraceuticals (vitamins, minerals, dietary fiber and phytochemicals), a great diversity of vegetables should be eaten to ensure that individual's diet includes a combination of phyto-nutraceuticals and to get all the health benefits. The availability of a large diversity of vegetables year round, allied to increase in mean per capita income in recent years and knowledge of vegetable health benefits, have enable consumers to include a variety of health promoting phytonutraceuticals in human diet.

Timely dissemination of investigation results pave a greater path for practical utilization of the information. Post COVID scenario demands enhanced use of the folk medicines and herbal medicines including nutraceutical vegetables. The **"Annals of Phytomedicine: An International Journal"** is seems to be a dedicated and centric platform with publication of the advanced research on phytomedicines with critical analysis. All the comprehensive research on phytomedicines of vegetable crops should be accessible to the needy and people to harvest their natural curing benefits. This also requires wider dissemination and regular updating of advancements in this field. The **'Annals of Phytomedicine: An International Journal'** acts as an excellent vehicle to deliver the information on nutraceutical vegetables timely and in simple, straight forwarded way for the benefits of researchers, farmers and scholars.

Conflict of interest

The author declares no conflicts of interest relevant to this article.

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Biography

Dr. B. Neeraja Prabhakar, Senior Professor and Vice Chancellor of Sri Konda Laxman Telangana State Horticultural University (SKLTSHU), Mulugu, Siddipet District. She has served for about 28 years in Research, Teaching and Administration. During her tenure, she has guided 9 PG/ Ph.D students as Chairman, 19 students as member of advisory committee. She has published about 89 research papers in peer-reviewed National and International Journals. She has contributed in authoring four chapters in two books, five extension booklets, four bulletins, 130 popular articles and also presented 25 research papers and Key note address in National and International Conferences, Seminars and Symposia including other countries like Srilanka and Malaysia.

Her significant contributions in publication of famous book on "Vegetable Cultivation in Telugu" which is considered as bible for vegetable crops cultivation, has gained popularity in the farming community of Telangana.

She gained vast experience in the field of vegetable crops during 1997-98 and proposed Ridge gourd hybrids HYRGH-5HB (Pusa Nasdar X LA-12) with 2.093 % Standard Heterosis and 45.2% Heterosis and HYRGH-4HB (Pusa Nasdar X LA-17) with 33.1% Standard Heterosis and 67.4% Heterosis for releasing in zone -VII (2009) at National Level under AICRP on Vegetables.

In Teaching, she was involved in preparation of TELAgE Recorded Video Lectures for development of e-course HORT 181 Title: Principles of Horticulture and Production Technology of fruit crops in 10 fruit crops under program of TELAgE under Niche Area of Excellence (NAE) at NAARM Studio during 2016-18, developed Polytechnic Manual and Detailed lecture notes for the courses DA 281, DA181 and prepared AGRO-302 Practical Manual.

She has attended many Personality Development Programmes such as Siddhi Samadhi Yoga (SSY), Advanced Meditation Course (AMC) in 1998, Diwakar Institute of Leadership Training (DILT)-Personality Development Programme (1999), ART OF LIVING (2001), The Landmark Forum (Landmark Education) in 2007, Advanced Course (Landmark Education) in 2009, SELP-Self Expression and Leadership Programme (Landmark Education) in 2010.

She has acted as a member in 1st State Level Steering Committee (SLSC) Meeting of the National Bee Keeping and Honey Mission, Department of Horticulture, Government of Telangana and also acted as a member in Cabinet Sub-Committee meeting on existing status of Agriculture under the Chairmanship of Hon'ble Minister of Agriculture, Government of Telangana.

- She has completed P.G. Diploma in Personnel Management from Annamalai University.
- She is recipient of CSIR Senior Research Fellowship and secured highest OGPA for pursuing Ph.D, ANGRAU, Rajendranagar.
- She has received "State level Best Scientist Award" from Honourable Chief Minister of Andhra Pradesh, Dr.Y.S.Rajasekhar Reddy for her relentless services to farming community on 17-1-2007.
- She has received "University Meritorious Teacher Award" from Dr. M.S. Swaminathan on 41st Convocation of ANGRAU on 30-12-2010.
- She has also received "Badam Saroja Jayanthi Puraskaram" and felicitated by Dr. C. Narayana Reddy and Sri. T.G. Venkatesh (Minister) on 12-5-2011.
- Also received "State Best Teacher Award" from Govt. of Telangana on 5-9-2019.
- She has been awarded as " Queen of the Nation 2022" on the eve of International Women's Day by Viswaguru World Records Team, Hyderabad on 12-3- 2022.
- She has received "Best organization for Women Empowerment Award" by IIWA 2022 (International Inspirational Women's Award) organized by GISR Foundation in 30-4-2022.
- She has received "CHAI Honorary Fellow Award 2022" from Confederation of Horticulture Association of India (CHAI) New Delhi on 28-5-2022.